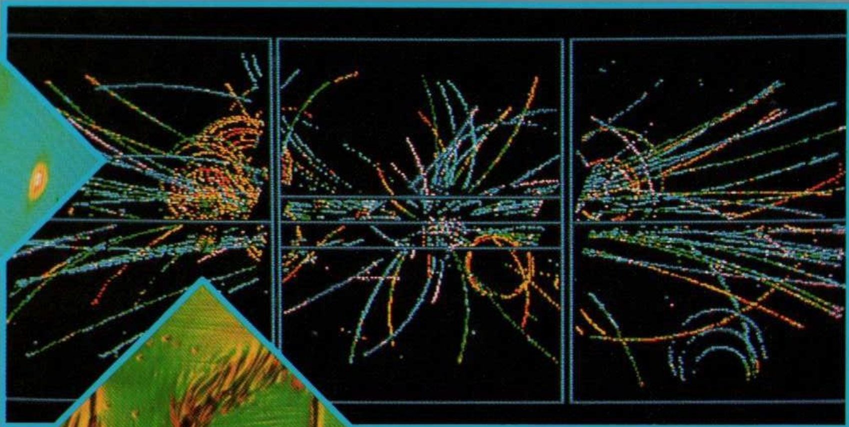
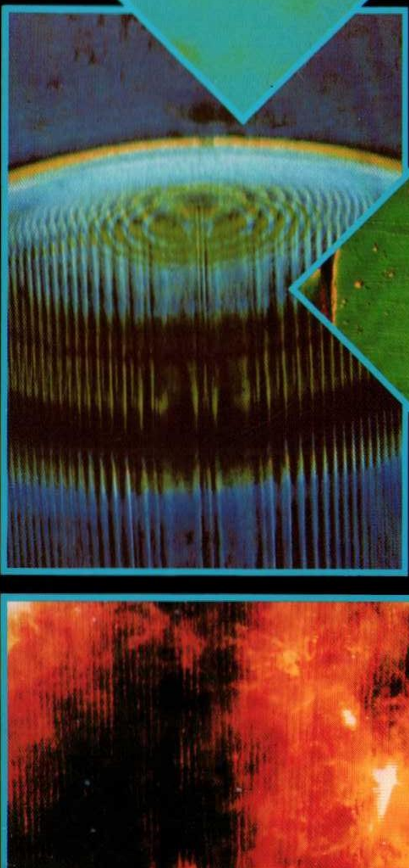
SERC 1965-1985

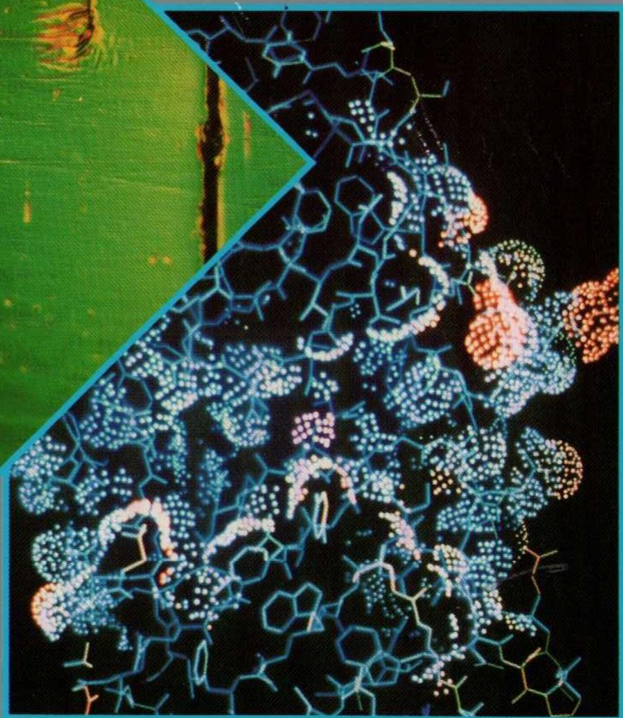
BULLETIN

SCIENCE & ENGINEERING RESEARCH COUNCIL

APRIL 1985







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20th Anniversary SPECIAL ISSUE

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Front cover:

SOME INTERESTING RESULTS (left to right from top):

An X-ray pattern from a diamond crystal.

High energy proton-antiproton collisions. (Photo: CERN).

Refractive index distribution in an optical fibre. (Photo: Southampton University).

Surface cracks in PVC observed by fractographic techniques. (Photo: ICST).

Computer studies of protein crystallography. (Photo: Birkbeck College).

Infrared measurements near the constellation Orion. (Photo: NASA).

CHAIRMEN 1965-1985

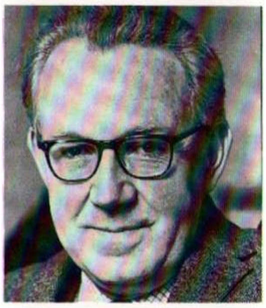
1965-67

Sir Harry Melville, FRS, who came from the Department of Scientific and Industrial Research and later became Chairman of the Advisory Council for Research and Development at the Department of Trade and Industry.

1967-73

The Lord Flowers, FRS, (then Sir Brian Flowers) who came from Manchester University where he was Professor of Theoretical Physics. In 1973 he became Rector of the Imperial College of Science and Technology and, this September, becomes Vice-Chancellor of London University.

1973-77



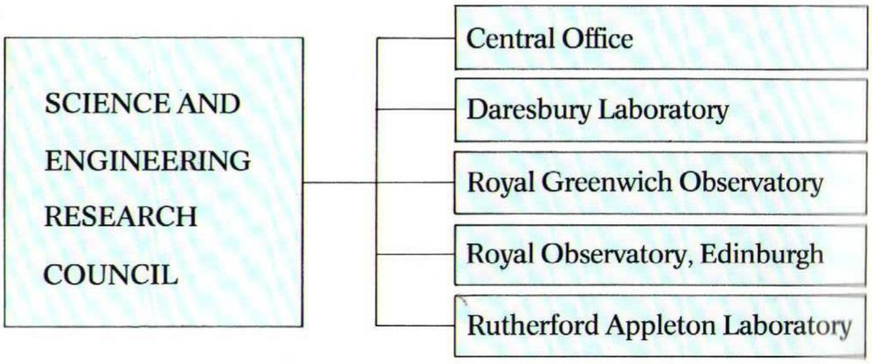
Sir Sam Edwards, FRS, who had been Professor of Theoretical Physics at Manchester University and became the John Humphrey Plummer Professor of Physics at Cambridge University, since 1972.

1977-81

Sir Geoffrey Allen, FRS, from Manchester University who was Professor of Chemical Physics (1965), of Polymer Science (1975) and, at the Imperial College of Science and Technology (1976), Professor of Chemical Technology. At present he is Head of Research at Unilever plc.

1981-85

Sir John Kingman, FRS, who is Professor of Mathematics in the University of Oxford. When he leaves the Council in September 1985, he will take up the position of Vice-Chancellor of Bristol University, succeeding Sir Alec Merrison, FRS, who used to be Director of Daresbury Laboratory, SERC.



INTRODUCTION BY THE CHAIRMAN

The United Kingdom is very fortunate in having a lively and active scientific community, full of ideas for new scientific projects. As a result, the Science and Engineering Research Council is faced with demands which it cannot possibly meet with its limited resources, and has had to take very hard decisions about scientific priorities. Originally the bulk of its resources went into 'big science', ie high energy physics and space science, but the last twenty years have seen a massive transfer into other areas of science, and into engineering.

Sir John Kingman, FRS, Chairman of the Science and Engineering Research Council.

When the Council was set up in 1965, it inherited the responsibilities of the former Department of Scientific and Industrial Research (DSIR) for university research, together with the two Royal Observatories and the Laboratories which are now the Daresbury and the Rutherford Appleton Laboratories. The more applied research establishments of the DSIR came directly under appropriate Ministries, and the clear remit of the (then) Science Research Council was to sustain basic research either for its own scientific interest or for long-term strategic reasons, across a broad range of science and technology limited only by the existence of the more specialised Agricultural, Medical and Natural Environment Research Councils.

Central to the Council's strategy has been the role of the universities as the leaders of basic scientific research, and the Council's own establishments have been seen as part of a team effort, providing central facilities for the use of academic researchers. Similarly, the Council has been the agent of UK involvement in international organisations like the European Organisation for Nuclear Research, the European Space Agency and the Institut Laue-Langevin, which have provided access for our scientists to facilities more advanced than could have been provided nationally.

The Council has pioneered new ways of fostering collaboration between universities (and more recently polytechnics) and industry, in order that the fruits of the basic research it supports should be plucked by British industry. This has gone along with a more 'directed' approach to applied science, but always with the proviso that the very bright idea, or the very talented scientist or engineer, should be supported even if he (or she) does not fall within the policy guidelines.

In the future as in the past, the Council will build on strength to support those aspects of pure and applied science where we can excel. To do this in what will remain an unfriendly financial climate will require ingenuity and imagination, the ability to make difficult choices, and to back those choices with generosity and determination. It is crucial that it should succeed, for the health of the science base (and not just those parts of it for which we can now see application) is an essential condition for our future prosperity.

SCIENCE AND ENGINEERING RESEARCH COUNCIL

This special issue of the Bulletin marks the twentieth anniversary of the Science and Engineering Research Council and we take the opportunity to look back at achievements, assess the work of the Council in the mid 1980s and set forward plans and aspirations for future development.

The articles in this issue come from the Council's two Laboratories and two Royal Observatories and review the fields of Science and Engineering.

The Council was established by Royal Charter on 1 April 1965 as the Science Research Council, under the provisions of the Science and Technology Act. The Act reorganised Government support of civil scientific research under five Research Councils (Agricultural, Medical, Natural Environment, Science and Social Science) that were put under the aegis of the Department of Education and Science but, as autonomous bodies, were free to determine their own scientific policies and research programmes within financial limits laid down by Government. They also acted as advisers to the Department's Council for Scientific Policy.

The responsibility given to the Science (now Science and Engineering) Research Council was to provide and operate equipment and facilities for the common use in research and development in science and technology, of universities, colleges, or other institutions and of persons engaged in research; to make grants for postgraduate instruction; and to disseminate knowledge.

In 1965 the equipment and facilities provided by the Council were housed in the six research establishments:

Daresbury Nuclear Physics Laboratory
Royal Greenwich Observatory
Royal Observatory, Edinburgh
Atlas Computer Laboratory
Radio and Space Research Station
Rutherford High Energy Laboratory

The last three have since united and become the Rutherford Appleton Laboratory.

BUDGETS

A look at the budgets for 1965, 1975 and last year indicate the Council's spending power and gives a broad idea of how the budget was allocated.

Budget	
1965	£28 million
1975	£85 million
1984	£254 million

1965

Allocation by discipline	%
Nuclear Physics	46
Space and Radio Research	16
Chemistry	8
Engineering	6
Other Physics	6
Mathematical and Computing Sciences	5
Biology and Human Sciences	5
Astronomy	5
Central Administration	3

Allocation by sector	
Intramural (Council facilities)	47
University awards and grants	34
International (CERN and ESRO)	18

1975

Allocation under the Council's Boards	%
Science	22
Nuclear Physics (except CERN)	22
European Organisation for Nuclear Research (CERN)	19
Astronomy, Space and Radio	15
Engineering	12
European Space Research Organisation (ESRO)	6
Central Administration	4

Allocation by sector	
Intramural	39
Universities	30
International	31

1984

Allocation under Boards	%
Science	27
Engineering	24
Nuclear Physics	22
Astronomy, Space and Radio	16
Centrally supported activities	7
Central Administration	4

Allocation by sector	
Universities	44
Intramural	35
International	21

TRENDS IN SCIENCE

The twenty years since the Science Research Council was founded cover a substantial part of the history of modern science: more than one-fifth of the time since the electron was discovered and nearly two-fifths of the time since the discovery of the neutron. Among more recent developments, the transistor was invented less than two decades before the Council's formation, and in the same period the pioneer work on nuclear magnetic resonance was carried out. The structure of DNA was elucidated as recently as 1953, and the first laser operated in 1960. Underlying recent advances in almost all contemporary science is, of course, the explosive expansion of the development and use of the digital computer; none of the research activities mentioned in this review could have been carried out without access to modern computing resources.

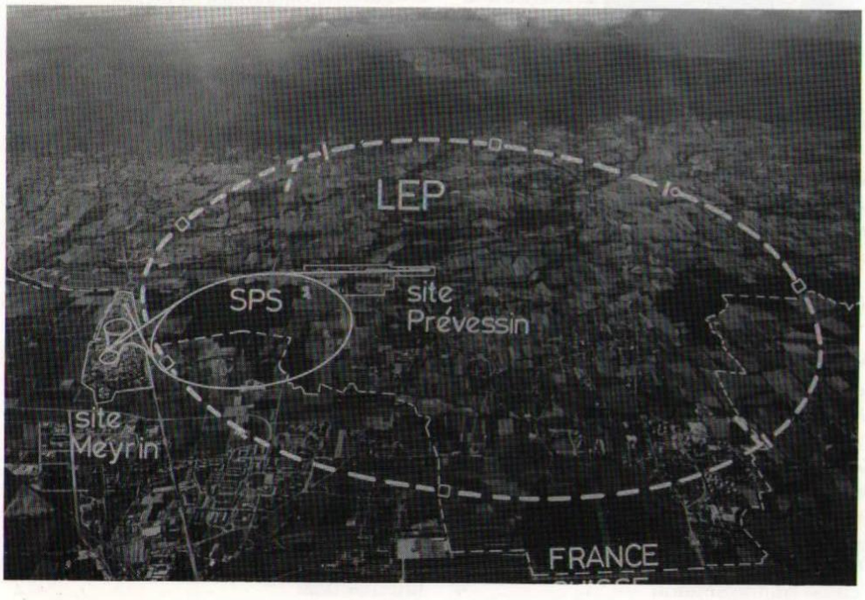
It is, therefore, not surprising that the two decades of the Council's existence have themselves seen dramatic advances, in which UK scientists, most of them in universities and polytechnics and many of them with the Council's support, have played a full part. It is almost invidious to select any for special mention, but no summary, however brief, can exclude the discovery of the W and Z intermediate vector bosons which verifies the 'electroweak' theory unifying two of the four known forces of Nature, which ranks with the earliest discoveries of sub-atomic particles mentioned above; or the evolution of a 'new astronomy' with the discovery of a wide range of hitherto unsuspected objects, from quasars to pulsars, of fundamental importance to our understanding of the origin and evolution of stars and galaxies and indeed of the origin of the Universe itself. Of equal significance to such striking advances has been the widespread application of sophisticated experimental techniques to a wide range of problems in the physical and biological sciences, which has led to a revolution both in the direction of scientific research and in the means by which it is performed.

Twenty years is also a long time in the history of the modern world of higher education. In 1965 the explosive post-war expansion was already in full spate. The 'new' universities were becoming well established and the colleges of advanced technology, which for some time had been encouraged to develop a research function, had become technological universities. In universities alone in 1965-66 there were 170,000 students as compared with 50,000 in the immediate pre-war period. This was in sharp contrast to the present-day situation where the university world is confronted not only with the prospect of a decline in student numbers, but also with a cut in the level of financial resource per student available to them. The polytechnic community has had similar experiences over the past twenty years.

This change in the fortunes of the community which the Science and Engineering Research Council (SERC) serves is, of course, paralleled by the Council's own experiences. We can understand that there never has been enough money for a vigorous scientific community to do all that it would like to do, but nevertheless it is ironic now to look back on the early days of the Council when the rate of growth needed to meet its optimum programmes amounted to over 18% per year, and when it was said that successive annual growth rates of about 9% (at constant prices) were inadequate to carry out its proposed programme which was itself less than what was warranted by scientific and technological considerations. Since then the Council has had to contend with continuing cuts in its funds which makes those days look palmy indeed, to the extent that last year it was said: "The overall condition of the Science Vote, and of the SERC share of it, can be described as 'sloping funding', a steady attrition of the real value of the basic allocation". As a result, the history of the first twenty years of the Council's support of science is one of achievements which, although very real, have been limited by the constraints imposed by an increasingly severe financial climate.

Dr Harry Atkinson, Director of Science

Below: *an aerial view of CERN (the European Organisation for Nuclear Research) where the W and Z particles were discovered, seen from Geneva Airport. The main Laboratory site at Meyrin, Switzerland, is shown left and, centre, the Prévessin site in France. The circles indicate the underground sites of the Super Proton Synchrotron (SPS) and the planned Large Electron-Positron collider (LEP). (Photo: CERN).*

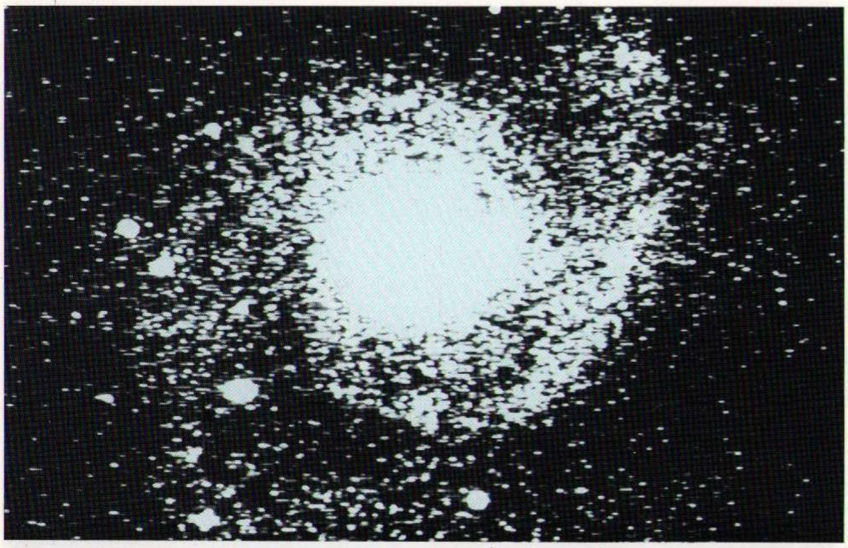


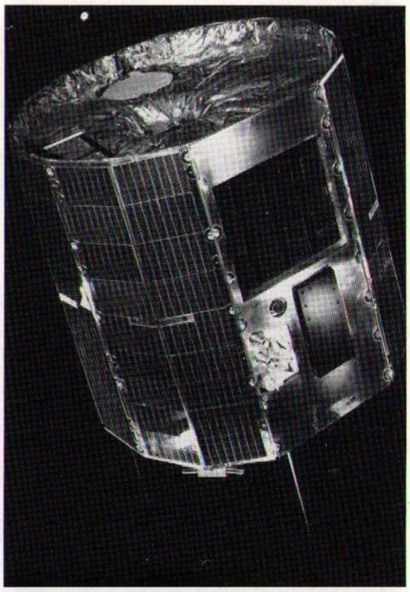
The increasing cost of research

An all-pervading characteristic of scientific progress is that achievements at one level of experimentation frequently show that still greater understanding can be had from working under more extreme conditions that can only be achieved at correspondingly greater expense. One important consequence is an increasing need for resources too complex and too costly to be installed within every institution requiring access to them, and any review of the trends in science since the Council's formation must give prominence to the increase in the support that it has given to large facilities, centralised at the national or international level.

Big sciences

Some facilities on this scale were already established in important fields (the so-called 'big sciences') when the Council was established. This was reflected in the original definition of its responsibilities as "taking over the present responsibilities of the Department of Scientific and Industrial Research (DSIR) for giving research grants to universities and postgraduate training awards . . . and also for the National Institute for Research in Nuclear Science (NIRNS), the Royal Greenwich Observatory, the Royal Observatory Edinburgh, the DSIR Radio and Space Research Station and supervision of the Scientific Space Research programme", and in its responsibility for this country's involvement in the European Organisation for Nuclear Research (CERN) and the European Space Research Organisation (ESRO): international organisations whose existence was already reflecting the high cost of research in these areas, marking the early stages of a development which has subsequently expanded in many directions.





Above: *a computer-enhanced picture of the whirlpool Nebula M51 recorded during 'first light' with the 2.5 metre Isaac Newton Telescope at the new international Observatory on La Palma, February 1984.*

Right: *A model of the Ariel V satellite used to study cosmic X-radiation in the 1960s, which gave UK scientists the highest reputation in this field.*

Particle physics

Thus, in 1965 the UK's interests in particle physics, while already making important use of international facilities, were still closely involved with UK-based resources. NIRNS was operating the 7 thousand million electron volt (GeV) proton accelerator Nimrod at what was then the Rutherford High Energy Laboratory; at Daresbury the 4 GeV electron accelerator NINA was under construction, to be commissioned in 1966, and through its interests at CERN this country participated in the operation and use of a 28 GeV proton accelerator. Today it is accepted that collaboration, whether through international organisations or by *ad hoc* agreements to other countries' national facilities, is the only way in which the UK can take part in research in particle physics. NINA, after a short life by the standards of such major facilities, was closed in 1977, and Nimrod in 1978.

This country's efforts are now concentrated on participation in the proton-antiproton collider at CERN, which has already led to the remarkable discoveries mentioned above, and on the construction of the Large Electron-Positron ring due to begin operation in 1989, also at CERN. UK experimenters are also involved with overseas installations such as PETRA, the electron-positron colliding ring at Hamburg, and hope to participate in experiments using its successor, the electron-proton collider HERA, scheduled for completion in 1989. By making use of international facilities, UK particle physicists have been able to do better work at substantially lower cost than would have been possible with national installations.

Space research and astronomy

Space research presents a similar picture. In parallel with its involvement with ESRO the UK, through SERC, was in the 1960s involved in the operation of the 'UK-Ariel' series of satellites for scientific research; a space programme which culminated in the launch of the Ariel V and Ariel VI satellites, the last independent UK-led space science missions. Ariel V in particular provided the means for studies of cosmic X-radiation which have given the UK the highest standing in this important field. Now the satellite-based programme depends entirely on international collaboration, either through the European Space Agency (which subsumed ESRO) or through access to other countries' space missions. The balance that is desirable between the various methods of collaboration, given the overall limitations of the Council's resources, is at present a matter of careful consideration.

In a brief review of this kind no more than passing mention can be given to developments in ground-based astronomy, now also largely international in its facilities, with the Anglo-Australian Telescope and the Infrared Telescope in Hawaii yielding important results. To follow these in an overall plan for ground-based astronomy, determined some years ago, the optical observatory at La Palma will be inaugurated later this year, to be followed by the Millimetre-wave Telescope now under construction on Hawaii. A significant aspect of these developments is that they will increasingly involve remote operation from the UK, with important implications for the way in which optical astronomy is conducted in the future.

Nuclear structure

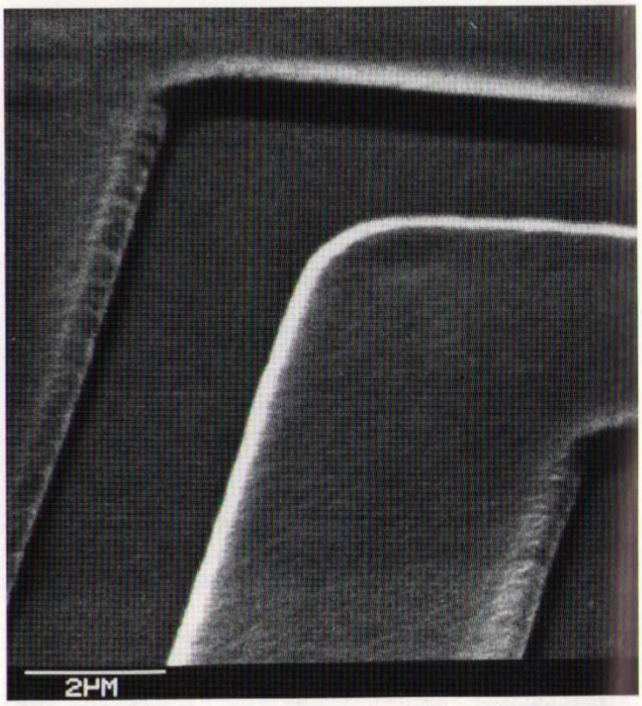
Other important areas of science have shown similar trends: for instance twenty years ago research into nuclear structure was still on a scale which could be encompassed by installations on university sites, and the Council assumed responsibility for five major installations previously funded by DSIR. Now research in this field is concentrated on facilities at two sites. A Van de Graaff generator, now operating at 20 million volts, was commissioned at Daresbury Laboratory in 1982, and is complemented by a folded tandem accelerator at Oxford University.

Small sciences

In parallel with these developments, the so-called 'small sciences' have developed in response to the increasing demands of the experimentalist to a stage at which they require facilities operated at the regional, national and international levels. Prior to the creation of the Council, the Research Grants Committees of DSIR were able to operate effectively in relative isolation from the national and international laboratories which then existed. The requirements of much of physics, and nearly all of chemistry and biology, could then be substantially met through the use of comparatively modest installations sited in individual departments at individual universities.

Electromagnetic sources

The study of the interaction of electromagnetic radiation with matter, which has for long played a part of central importance in the natural sciences, furnishes a striking example of the trend to centralisation. The need for radiation sources of greater intensity and greater versatility than were available from laboratory-based equipment became apparent in the 1960s, and experiments were carried out in the late 1960s making use of the electron accelerator NINA, primarily dedicated to particle physics experiments, as a source of electromagnetic radiation more intense than was accessible in the laboratory. Following the closure of NINA, the first electron accelerator specifically designed for the production of electromagnetic radiation was constructed at Daresbury Laboratory and is now finding important applications in physics, chemistry and biology – the last named being particularly significant as an instance of the development over the past twenty years in the applications of the methods of the physical sciences to biological problems. The next stage in the development of synchrotron radiation sources will be at the international level, and plans are already well ahead for the specification and construction of a European Synchrotron Radiation Facility, which is likely to be built on a Continental site.



Left: *A typical view of synchrotron radiation beam lines linked to experimental workstations. The storage ring is below, and to the left of the picture. The apparatus shown is for research on the properties of metal and semiconductor surfaces.*
Right: *Polymethyl methacrylate (PMMA) photo-resist material that has been dry-etched using ultraviolet radiation at the Council's Central Laser Facility. This technique will have important applications in microcircuit fabrication.*

Neutron beams

An equally telling example of the use of major facilities in the 'small sciences' is to be found in neutron scattering techniques. From its earliest days the Council had access to neutron sources of the Atomic Energy Authority; this association survived until 1984. The need for stronger sources was recognised and in the early 1970s the Council pressed the case for a national high-flux neutron source. In the event, this need was met through international collaboration when the United Kingdom became a partner in the French and German operation of the high-flux neutron source at the Institut Laue-Langevin at Grenoble. The latest chapter in this history is the first production of neutrons last December from the Spallation Neutron Source, whose construction at the Rutherford Appleton Laboratory was approved by the Council in 1976. This is attracting substantial international interest.

Trends towards more complex and costly equipment are not, of course, confined to central facilities, but have had a profound effect on almost all areas of experimental science. The examples quoted below are no more than typical of many more that could be cited to show how the increased sophistication of research in the laboratory matches the developments summarised above.

Lasers

Before the advent of the laser, the duration of the shortest pulse of optical energy having sufficient energy for studies of physical and chemical processes was measured in microseconds. Fifteen years ago the interval had fallen to nanoseconds (10^{-9} seconds), and less than five years later research into lasers and the related non-linear optics was working in time-intervals a thousand times shorter. These are the time-scales involved in molecular motions, which means that we now have at our disposal the means for the direct observation of the dynamics of atomic and molecular processes.

This has opened up new fields of research. Modern applications of chemical kinetics would have been unrecognisable in the subject twenty or thirty years ago – for instance the application of flash photolysis in the picosecond (10^{-12} second) time range to the kinetic study of the reactions involved in photosynthesis. Now technology has advanced to the stage at which the duration of pulses of optical energy is measured in femtoseconds (10^{-15} second) in which time the distance radiation travels is to be measured in thousandths of a millimetre. The potential of developments in this direction is now limited not by technology but by the fundamental principles of Nature: the uncertainty principle means that the spectral bandwidth of such pulses must be large.

Meanwhile the development of lasers for applications across the whole range of the natural sciences and medicine has been explosive. One important frontier of research is the production of lasers operating at successively shorter wavelengths. From the optical wavelengths of 1960, lasers have now, at the research stage, reached the extreme ultraviolet region of about 200 angstroms. Undoubtedly the major prize of the future is the development and use of lasers in the hard X-ray region. The practical problems are formidable, but the rewards would be great for the study of condensed matter, including materials of biological origin, as well as in technical applications involving the processing of microstructures, such as photo-lithography.

Nuclear magnetic resonance

During the Council's lifetime, the technique of nuclear magnetic resonance (NMR) spectrometry has advanced from the stage at which it was finding its earliest applications in chemistry to use as a diagnostic method in clinical medicine. The first commercial NMR spectrometer became available in 1953, and with the availability in the early 1960s of relatively cheap instruments using conventional magnets, which operated at 60 million cycles per second (MHz) for protons, the technique became important for organic and inorganic chemistry. Higher magnetic fields which became available as a result of the development of superconducting magnet technology meant better spectral dispersion and sensitivity, and a major breakthrough occurred in the 1970s when pulsed Fourier transform techniques opened the way to the study of nuclei of low inherent sensitivity or low natural abundance. As a result carbon-13 NMR rapidly became very important, and by 1979 400 MHz instruments were becoming available commercially, which made possible the study of minute amounts of complex material (as, for instance, in natural product chemistry).

NMR was by now finding important applications in biochemistry. Use of a 470 MHz machine demonstrated that enzymes in solution have a structure very similar to that obtained from crystallographic data, and observations of the mobility of individual side chains and sequence of protein molecules are leading to a reappraisal of our concepts of enzyme function. A generation of 500 MHz instruments is now appearing and spectrometers of still higher fields are under construction. Such developments would be impossible without remarkable advances in the technology of superconducting magnet technology: magnetic fields up to 12 Tesla and homogeneous (over a 10 millimetre diameter sphere) to an accuracy of 1 part in 10^9 are now exploited in commercial equipment.

The study of the phosphorus-31 nucleus makes possible the study of metabolites such as phosphocreatine, ATP and NAD, and techniques were developed some five years ago which made possible the recording of high resolution spectra from defined localised regions of living objects. Subsequent developments allowed the study successively of small animals; human limbs, and the human body. The first clinical facility has been installed in a UK hospital and to date some 400 patients have been examined; other installations are now being planned.

routine basis. Dilution refrigerators attain temperatures well below what is needed for nuclear cooling techniques. These make use of cryogenic and superconducting magnet technology to reach temperatures in the microKelvin range. Novel techniques have attained temperatures of 125 microKelvin in liquid ^3He; and dilute ^3He–^4He mixtures, which present particularly intractable problems, have been cooled to temperatures approaching 200 microKelvin. Nuclear spins can be cooled far below these temperatures: the recent discovery of nuclear antiferromagnetism in copper involved nuclear spin temperatures down to the remarkable level of 0.75 nanoKelvin.

The quantum fluids thereby made available for study are a unique state of matter, and the ultra-low temperatures now attainable are opening up new areas, both experimental and theoretical, in the study of quantum physics which are fundamental to the understanding of condensed matter. The future will see further developments of techniques and equipment to make physics in the microKelvin range more generally accessible.

An image of the major blood vessels and areas of high tissue profusion in a healthy human foot taken at Hammersmith Hospital. The subject inhaled a radioactive isotope of oxygen that was recorded by a positron camera.

Ultra-low temperatures

The foundations of low-temperature research were already established well before the Council was created: helium liquefiers were commercially available and much important work had been carried out at liquid helium temperatures and below. The technique of nuclear cooling, which now provides the means for reaching the lowest temperatures yet attained, had been known for about a decade, and superfluid ^4He for nearly forty years. Perhaps the greatest of the subsequent developments in cryotechnology, which have opened up a new area of ultra-low-temperature research, is the dilution refrigerator, whose operation depends on the quantum mechanical differences in the behaviour of the two isotopes of helium.

The dilution refrigerator was first developed in the 1960s, and today commercial refrigerators are capable of continuous operation down to 2 milliKelvin, so that today experiments at temperatures down to 5 milliKelvin can be carried out on a routine basis.

These examples are selected almost arbitrarily, but they have several features in common which are characteristic of many parallel developments. The advances in all these fields have depended on close interaction between the scientist and the technologist, and have frequently led to commercial developments on the part of the instrument manufacturers. In all of them the UK has played, and is playing, a leading role, with university workers supported by SERC prominent in these advances.

All these fields now involve high expenditures. Already in the late 1970s it was necessary to provide high-field NMR machines to selected institutions on condition that they provided a service to other approved users, and an advanced NMR machine can now cost £500,000. The X-ray lasers, if developed, will need power sources of a size whose cost will be comparable with that of some central facilities. They all reflect remarkable achievements and they all pose formidable problems, of organisation as well as of funding, for the bodies responsible for providing them.

Trends in the pattern of research

Underlying these changes in the methods of research over the past twenty years has been a steady erosion of the established division of the natural sciences into their traditional disciplines. Again, any attempt even to catalogue all the developments in this direction within the present compass would be pointless, and only a few examples can be mentioned.

Among the most striking is the influence of pure mathematics on other disciplines. Theoretical physics has, of course, always owed much to pure mathematics, but recent advances are particularly striking in the application of topological and geometric methods to the study of quantum theory, and the powerful input of pure mathematics to what is perhaps the fundamental problem in physics – the establishment of a unifying theory for all the fundamental forces of Nature. Mathematical logic, whose main interdisciplinary interaction until recently was with philosophy, is now seen as central to the long-term development of computer science. Conversely, computing techniques hitherto found application in fields such as statistics, operational research and numerical analysis, but now the availability of fast computer graphics has led to advances in many fields of pure mathematics. Such developments herald an increasing need for computing facilities in pure mathematics.

Recent trends have seen the emergence of astronomy as the means of testing basic theories of physics under extreme physical conditions that cannot be produced in the laboratory, and astrophysical research is to be seen as one segment of the whole of physical science continuous with laboratory-based investigations in, for instance, atomic and plasma physics. Likewise, laboratory experiments can contribute to the understanding of phenomena inaccessible to observation: for instance, the ultra-low-temperature studies mentioned above contribute to the understanding of the interiors of neutron stars. Astrophysics and high-energy particle physics are converging on experimental studies of the four forces of Nature, and the quanta that transmit them, in the search for the unifying theory, sometimes being concerned with the extreme conditions obtaining during the first fractions of a second of the original 'big bang'.

The extensive developments in the biological sciences over the past twenty years have resulted from the advent of recombinant DNA techniques, which have led to a new discipline, biological engineering, and a new and growing industry, biotechnology, and to the extensive introduction of the quantitative methods of the physical sciences to the study of biological systems (the development of

NMR techniques mentioned above provides an instance). Both these innovations have profoundly influenced much of modern biology.

Two examples must suffice to show how a wide range of disciplines is now converging on the study of living systems. First, mathematical biology has now emerged as a coherent discipline in the use of mathematical models in the study of, in particular, developmental biology, population growth and biomechanics; second, the field of neurobiology and cognitive science provides a remarkable example of the convergence of the concept of molecular biology, psychology, physics, engineering, and computer science in the study of the nervous system and the human brain.

These simple illustrations of the changes in recent years of the pattern of research could be amplified and multiplied almost indefinitely, but even in their present oversimplified form serve to show how the pattern of research in the natural sciences has been reshaped within the comparatively short existence of the Council.

The next twenty years

Notwithstanding the financial problems which have beset the scientific community in recent years, UK workers, many of them with the support of the Council, are carrying out distinguished work in many fields, only some of which is mentioned above. Almost all this work is done by university and polytechnic research workers, either directly through research programmes or by making use of major facilities provided by SERC. We can confidently predict that, if the necessary resources are made available, the UK will play a similarly important role over another two decades of no less dramatic change and development.

It is, however, impossible at the present time to conclude any review on an unreservedly hopeful note. Financial restrictions have already meant the UK's withdrawal from important overseas programmes, a lower level of participation in on-going activities overseas and a slower rate of development of UK facilities than had been expected a decade ago. The UK is excluded from certain important areas of research, for instance planetary science, and it is expected that the level of support for certain well-established and fruitful areas of research, such as gas phase kinetics, will need to fall in the future.

Even more widespread in its effect has been the increasing inability of the Council to provide funds for all the research grants graded 'alpha' – once defined as grants deserving funding in all circumstances. That the UK has succeeded in maintaining its international scientific reputation in the face of these difficulties speaks highly for its quality and resilience, but it would be rash to expect those standards to be held indefinitely unless the financial climate in which it must now operate is not substantially improved.

TRENDS IN ENGINEERING

Engineering has been transformed during the last twenty years as the result of developments in science and technology. The most obvious changes have occurred in microelectronics and computing science – the information technology revolution. As a result of these changes, stemming from progress in science, many aspects of everyday life are now radically different. It is largely the responsibility of engineers and engineering, defined in broad terms, to exploit these possibilities for the benefit of mankind.

While information technology represents perhaps the most pervasive influence to date, other important changes have taken place which are affecting or will affect us in the future. The most obvious, for this country, is the development of North Sea oil and gas reserves. The successful response to the engineering challenges posed has enabled the UK to become a net energy exporter for many years ahead and has provided a promising base for industrial exports of technology and equipment. Another broad development, perhaps more closely analogous to information technology, is that of biotechnology which may have an equally important effect in medicine, agriculture and a variety of industrial activities.

A factor affecting engineering developments on a national and international scale, which presents more of a problem than an opportunity, lies in the development of scientific and engineering knowledge itself. This has perhaps acted as a brake on the exploitation of ideas now that we have a better understanding of the hazards as well as the opportunities offered by new engineering projects. The planning processes for facilities such as nuclear power stations, motorways, major chemical plant and tidal barrages illustrate the increasing sophistication of arguments on both sides.

This is the backcloth to developments in the Science and Engineering Research Council's stance on engineering over the period since its formation; changes which it could not ignore. Perhaps the first step was the recognition that engineering research and postgraduate education in universities, while having some aspects in common with those of pure science, also had important distinguishing features. The most important feature was the direct concern with utility, both in respect of the type of postgraduate produced and, in the longer term, of the research generated. It was with this in mind that the Council established the Engineering Board in 1969.

Since then the engineering activities of the Council have grown substantially in real terms. They have also developed an increasing sophistication by becoming more selective in research, by developing mechanisms for promotion of academic–industrial collaboration and by forging new types of postgraduate education and training. Coincident with these developments, a debate has been taking place on the position of engineering in society, notably through the work of the Finniston Committee and the creation of both the Engineering Council and the Fellowship of Engineering. This debate reflects a concern as to whether this country, in comparison with others, is attaching sufficient importance to developing its scientific and, in particular, its engineering skills.

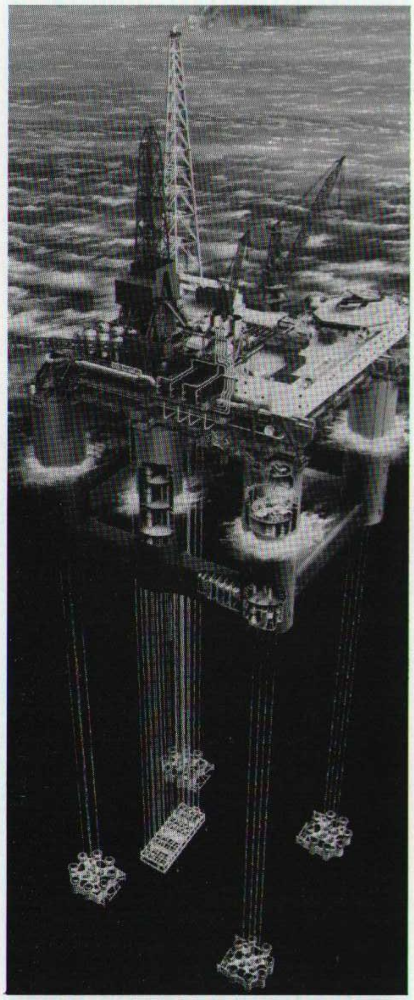
In what follows, some examples are given of specific ways in which the Council and its Engineering Board have responded to the challenges over the past twenty years. Inevitably it is impossible to cover all the ground. Large areas of engineering are omitted, including many developments in fields of importance for the future. Nevertheless the examples do illustrate the nature of the Council's response overall and also some of the difficulties. The most important of these difficulties centres on the inevitable drive towards a greater emphasis on selectivity and industrial relevance. While acknowledging this, Council feels that it remains crucial to support speculative, unsolicited ideas within universities and polytechnics, both to cover the many areas of engineering not included in the directed programme and, indeed, to overturn the conventional wisdom of the day.

Information technology

The broad title of information technology covers the devices which can generate and manipulate electronic signals, the computational techniques and ideas that organise those devices and the communication systems that link devices together.

In the early days of the Council, computing science was an emerging discipline and received a great deal of attention. Perhaps the most notable development was the work at Manchester University on the design and efficient use of computers, which led to extensive collaboration with International Computers Ltd and the design of a new range of computers. Another programme that spawned continuing developments up to the present day was the work at Newcastle University on fault-tolerant and highly reliable systems. A controversial subject was the place of artificial (or machine) intelligence in computing science. A review

Tony Egginton, Director of Engineering



Above: *one of six ground stations for Project Universe, this one at University College London. The system provides an experimental telecommunications link between six sites and the Orbital Test Satellite, giving a high bandwidth transmission of data between computer systems.*

Left: *an artist's impression of the first tension-leg platform, now installed by Conoco (UK) Ltd in the North Sea Hutton oilfield, that the Marine Technology centres in Scottish and London Universities helped to design, develop and construct. (Photo: Conoco).*

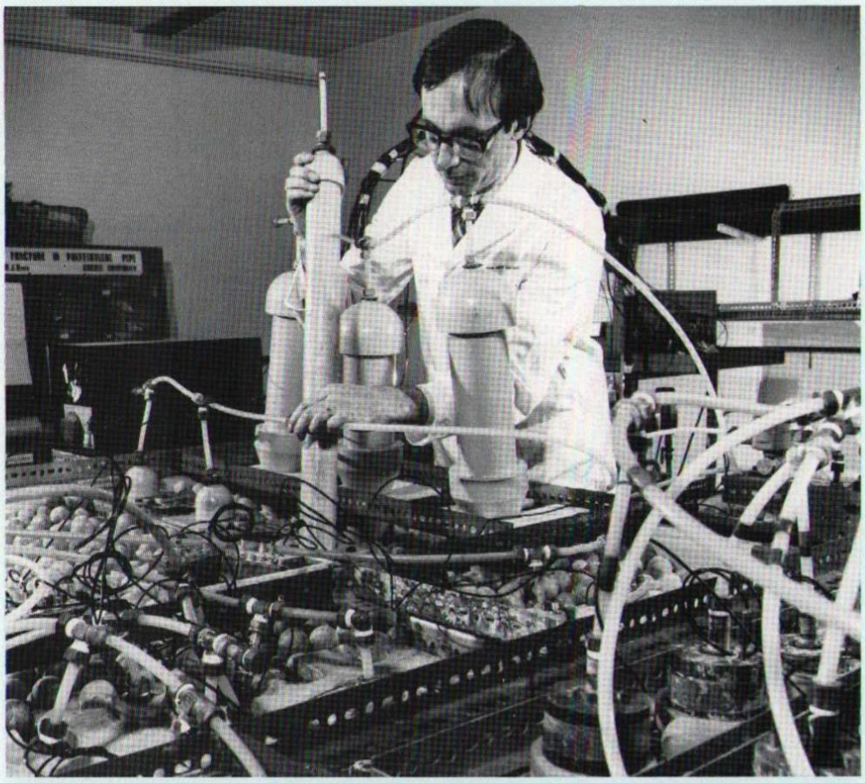
by Sir James Lighthill concluded that there were minimal connections between the fields of artificial intelligence and human intelligence. The debate that succeeded this review had long-lasting effects on the development of artificial intelligence and it is only in recent years, with the introduction of the Alvey programme, that some light has been shone on the research required in this difficult field.

In the late 1970s an important development was the Distributed Computing Systems (DCS) programme which explored computing science problems and opportunities emerging from the possibility of distributed systems. That programme led to the development of Dataflow systems at Manchester University, able to execute many different parts of a programme concurrently at very high computing speeds, and having potentially wider application than alternative parallel computers in not having to rely on a regular structure in hardware and software. A further type of parallel processing architecture investigated within the DCS programme was a Graph Reduction machine by Imperial College of Science and Technology codenamed ALICE. These two machines have established themselves internationally as two of the most promising approaches to parallel processing.

Meanwhile much work had been under way in device research, both electronic and optical. Of particular note was the early work at Southampton University on the development of optical fibres, and the later work at University College London and Glasgow University on integrated optics for signal processing. Also of importance for academic researchers needing sophisticated microelectronic circuits was the creation of a set of microelectronic facilities capable of supplying devices in silicon and other materials. One of these facilities at Sheffield University is also carrying out fundamental research on possible successors to silicon for very large scale integrated (VLSI) circuits, such as gallium arsenide. Finally, there has been a major resurgence of interest in optoelectronics in recent years with the establishment of the Joint Optoelectronics Research Scheme, funded by SERC, the Department of Trade and Industry (DTI) and industry. This collaborative enterprise between academic groups, Government laboratories and industry involves a wide range of scientific and engineering disciplines.

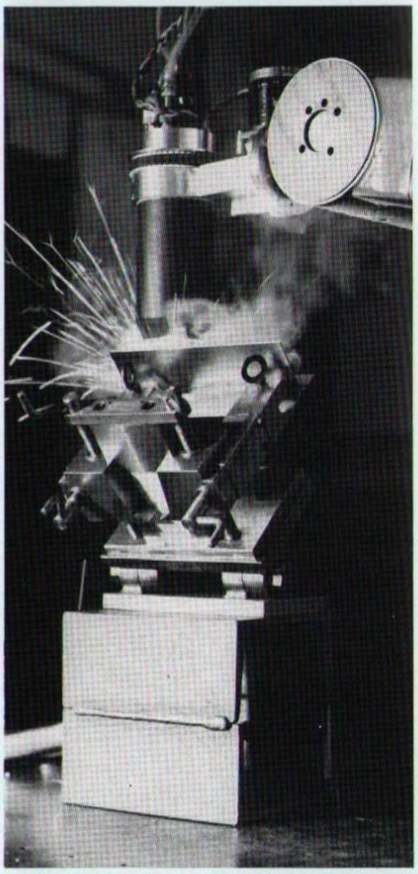
There have been several important developments in communications and networking. It is relevant to mention here one project which studied methods connecting significant numbers of high speed, high reliability local area networks into a wide area system. This was the so-called Project Universe which connected a set of ten Cambridge Rings at seven different sites, some industrial, to one another via a broadcast satellite channel using the Orbital Test Satellite. The project demonstrated the feasibility of closely integrating distributed systems without geographical barriers.

Major parts of the Council's programme are now within the Alvey project, a national programme in advanced information technology funded by SERC, DTI, the Ministry of Defence and industry. Earlier Council studies and research programmes in software engineering, man-machine interface and networking provided a base of policy and organisation from which the Alvey programme could emerge. As a result university and polytechnic research teams are now heavily involved in the VLSI, software engineering, man-machine interface and intelligent knowledge-based programmes which form the overall Alvey project – in most cases in collaboration with industry and Government laboratories. This programme is probably the best developed collaborative research activity in the UK.



Above: *a polymer research project at Brunel University testing thermoplastic polyolefin pipe systems for fatigue and performance variables under pressure and heat.*

Below: *a sensor-guided arc welding system developed at Oxford University. The design of the robot's vision software was influenced by developments in artificial intelligence research. (Photo: Oxford University).*



Manufacturing technology

Manufacturing technology is of crucial significance to UK industry. University work in this field however has been hampered by the difficulty of representing real industrial conditions, an early lack of industrial partners to overcome that difficulty and by the relative unpopularity of the field amongst academic research workers.

As a result, early work in this field concentrated on understanding individual manufacturing processes rather than the system as a whole. An excellent example lies in the process of grinding – which is one of the most common industrial processes for metal removal, yet was so poorly understood. SERC set up a specially promoted programme in grinding to focus research effort onto understanding the processes involved and hence devise ways for improvement. Research by Bristol University into grinding methods and on efficient cooling led to improvements in the metal removal rates by an order of magnitude. This work was subsequently taken up by Rolls Royce Ltd for the manufacture of aero-engine parts, with a saving of over £1 million a year.

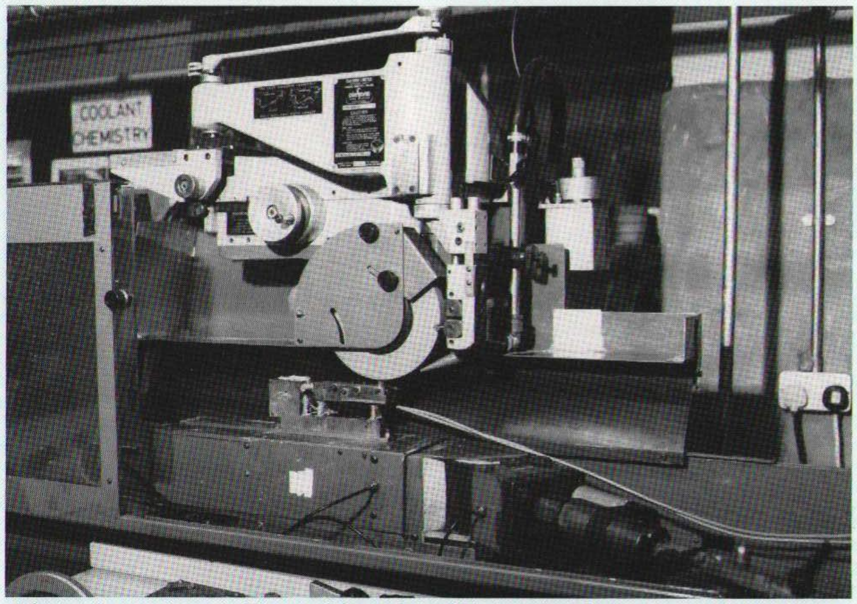
With improvements in microelectronics and communication systems, attention moved to broader aspects of the overall manufacturing process. The report of a Council Panel recommended that there should be a much more positive approach to the problems in the robotics field which were becoming increasingly important in manufacturing systems. As a result, a coordinated programme in robotics was begun in 1980. At first this concentrated on aspects of robotic technology such as sensor systems, the dynamic real-time control requirements imposed by complex systems of this type and the use of robots for industrial tasks, such as joining and assembling. All of this work featured collaboration between individual universities or polytechnics and relevant companies thereby ensuring that real problems were studied as well as aiding the technology transfer process. Many of these projects have led to new products or processes being exploited by partner firms.

A number of related initiatives have been launched in recent years notably in the computer-aided design field, in numerical control problems and in the efficiency of the manufacturing process. These are now all under the one umbrella of the ACME programme (Application of Computers to Manufacturing Engineering) reflecting the growing importance of system integration in this field. In addition to featuring strong industrial links, the ACME programme is guided by a joint SERC–DTI Committee. The interface between this programme and information technology is important and steps have been taken to ensure that this interface is carefully organised.

Materials

The Materials area underpins a wide range of engineering work but also has important interfaces with physics and chemistry. This role of acting as a bridge between engineering and science figured prominently in the late 1960s and early 1970s, when a great deal of attention was paid to the field of polymers. A group of polymer centres at Manchester University, Imperial College of Science and Technology, Liverpool University, Queen Mary College London, Glasgow and Strathclyde Universities were strongly supported during this period. However, the predominant activity was in science rather than in the engineering field in spite of the efforts of the Engineering Board to ensure a rough balance in the activity. This prompted the Council to establish in 1976 a special Directorate in polymer engineering, the first of the Council's initiatives of this type. As a result of that decision, the engineering aspects of polymer processing are now being properly supported alongside the science. Indeed, the Directorate has been so successful that it has recently ceased being the responsibility of SERC alone, and has become a joint responsibility of DTI, SERC and the polymer industry.

In recent years, materials research has suffered from the increasing need for sophisticated instrumentation. In the early years of Council this was anticipated by setting up four high-voltage electron microscopes at Oxford University, Imperial College of Science and Technology, Birmingham University and (jointly with the British Steel Corporation) at Rotherham for use by the materials community. Now, however, the pressure has become intense because of the expanding opportunities for contributions by materials scientists. Interest in novel forms of electronic materials involves materials scientists as well as physicists, chemists and device engineers. Exciting possibilities exist in the recently discovered electroactive polymers.



A fast reciprocating grinding machine at Bristol University. The process is a competitor to the creep feed grinding process on short components and is currently the subject of a research project. (Photo: Bristol University).

been uniformly good, but the principle is accepted as being of increasing importance for the future.

Marine technology

This was a field which university research workers found difficult to penetrate because of the scale and multidisciplinary nature of the work involved. To counter these difficulties, the Council decided in 1977 to establish a Directorate in marine technology to stimulate, guide and coordinate a major research programme in this area.

As a result, there is now a thriving university and polytechnic community in marine technology that attracts substantial funding from SERC, industry and other parts of Government. In particular, there are now six major centres at Cranfield Institute of Technology, London University, Glasgow and Strathclyde Universities, Heriot-Watt University, Newcastle University and a consortium of North Western Universities. It is hoped in the near future to transfer the Directorate out of the Council in the same way as the Polymer Engineering Directorate. At the same time it is hoped to increase industrial funding until it is roughly the same as that provided by SERC.

Most of the research that has been supported so far has been related to oil and gas exploration. There are substantial activities in fields such as the monitoring of structural integrity and defect assessment, the diagnosis of compliant systems, and the automation of sub-sea tasks. Although these topics are highly relevant to the exploitation of North Sea oil and gas, they bear on a wide variety of other marine-related engineering problems and will provide a broad source of expertise for future UK activities offshore.

Education and training

Perhaps the most important aspect of the Council's actions in engineering is the

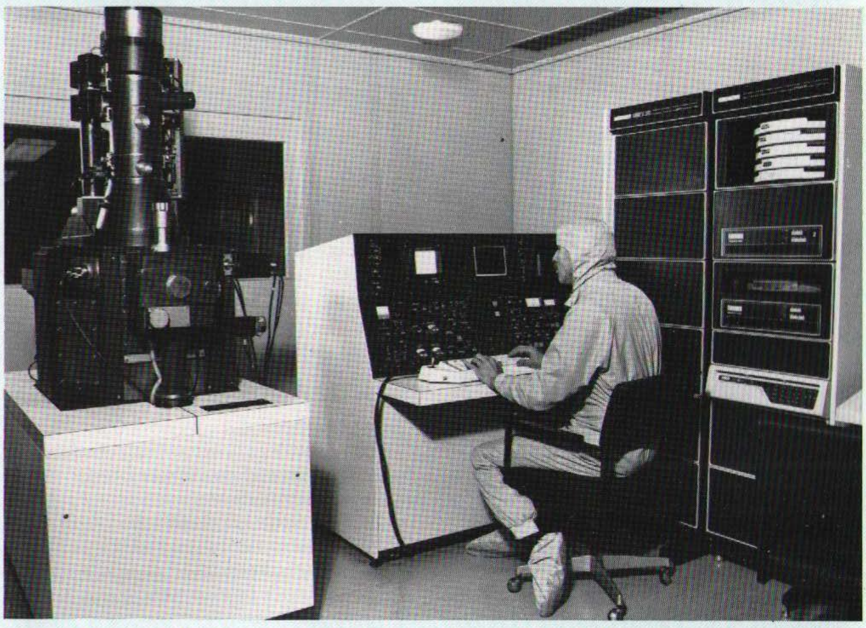
Ceramics, powder metallurgy, biomedical materials and composites are other areas where the advances in knowledge now enable a much more rigorous and scientific approach to the creation of advanced materials and the prescription of their properties.

Instrumentation

A common feature of engineering trends in the first twenty years, as in science, has been the increasing sophistication of research instrumentation. This has led to increased costs associated with research, even though the cost of computing (an important element) has been falling. This, in turn, has generated arguments in favour of shared facilities, as in the case of device fabrication and electron microscopes. In particular, the devices area now has an array of facilities available to the whole community, including silicon processing (at Edinburgh and Southampton Universities) electron beam lithography (at Rutherford Appleton Laboratory) Group III-V semiconductor materials (at Sheffield University) and ion implantation (at Surrey University). The work in electron beam lithography has also contributed to developments in electron beam machines, particularly in association with Cambridge University and Cambridge Instruments Ltd.

The involvement of Rutherford Appleton Laboratory (RAL) in this area stemming from their past experience in microelectronics, computing and electron optics has spread into the whole area of information technology. The Laboratory has provided the coordination function in, amongst other things, the distributed computing systems, software engineering, image processing and robotics programmes as well as the microelectronics facilities. The coordination function has normally been associated with some research work in-house, often in collaboration with university departments and industry. This experience has provided a great deal of momentum for the rapid launch of the Alvey programme.

Another major instrumentation development has been the Interactive Computing Facility (ICF). The rapidly increasing demand for interactive computing in the early 1970s caused the Engineering Board to set up a network of multi-user minicomputers to be shared by the research community. This was organised by RAL and has served the community well over the last seven years. Modern developments in computing are heading towards single-user minicomputers with network connections to program libraries and large databases. A powerful ingredient of ICF was the attempt, through special interest groups, to establish common support software in particular research fields. Achievements in this area have not



Computer controlled electron beam lithography capable of etching line widths as fine as 1 micron, used for printing on to silicon wafers. The operator has to work in a 'clean' room.

output of highly qualified manpower. Although the postgraduate population is small compared with the output of graduates, the postgraduate element does increasingly represent the stream of the future, especially in high technology industry. Thus for decades the PhD has been the norm in the chemical industry, and is becoming increasingly so in information technology. However, recognition of the value of the PhD is still patchy and it was this that generated the interest in industrially-related Cooperative Awards in Science and Engineering projects, where there is joint supervision of a project by an academic supervisor and an industrial supervisor. These now comprise over half of all PhD studentships awarded in engineering and provide a ready way of stimulating partnerships between academic groups and industry.

The position on postgraduate taught courses is more complicated. Masters degrees are essentially meant to deepen a graduate's knowledge in a particular field, with a specific vocation in mind. The Council has begun to stress that the output from such courses should be of proven worth to industry (eg through the recruitment of people with Masters degrees by companies). However, while some of the more sweeping criticisms of Masters' degrees are almost certainly unjustified, there is no doubt that a move towards more modular part-time degrees would increase the number of industrial employees willing to deepen the knowledge relevant to their employment. This had been the pattern in other countries and it seems likely that the UK will have to follow in due course. Recent experiments by the Council in this important area, notably in four MSc courses in integrated circuit design and the Integrated Graduate Development Scheme for organised graduate induction into companies in a particular industrial sector, both suggest ways forward.

Distance learning techniques are becoming more commonly used for education and training purposes and are likely to facilitate a degree of separation between the course providers and the recipients. Recent developments at the Open University, with support from the Council, point the way to opportunities both at postgraduate level and in the field of continuing education.

Another development in the field of education and training concerns information technology (IT) manpower. There has been increasing concern that the UK has insufficient skilled manpower to support IT developments. In 1982 the Department of Education and Science made available resources through SERC for the establishment of conversion courses aimed at producing about 1,000 people each year qualified with the equivalent of a Masters degree in the IT area. The conversion could be, in principle, from any subject – but in practice the majority came from other parts of engineering and science. It is too early to make a judgement on the value of these courses but it represents one way, albeit in very special circumstances, of introducing a rapid change in the generation of trained manpower in a particular field.

One of the Council's schemes that does not fit neatly into any definition, but nevertheless is probably closer to education and training than anything else, is the Teaching Company Scheme. This developed in the mid-1970s out of a concern that manufacturing industry was simply not getting the people or the ideas that it needed if it were to survive. The result was the creation, jointly with DTI, of a scheme in which an academic team participates in a company plan, intended to achieve a substantial and comprehensive change in its techniques and procedures. The 'agents' for these changes are high calibre graduates, employed by the academic institute in consultation with the company. These graduates work full-time in the company on projects which will improve manufacturing practice in the company. The scheme trains able graduates for careers in industry, develops and retrains existing company and academic staff, and gives academic staff that involvement with industry which will benefit their research and enhance the relevance of their teaching. Although the initial focus was in the area of batch manufacturing, other sectors of industry such as chemical and civil engineering are now also involved.

Organisation issues

It is useful to touch briefly on one aspect of Council's operation that has developed substantially in recent years, concerning the question of collaboration and coordination both inside and outside the Council. The development of coordinated programmes of research has featured strongly in recent years. The Directorates represent the most visible form of such programmes, with a Director having delegated powers and authority to organise a major programme of research and postgraduate training. Six Directorates have been created so far in Polymer Engineering, Marine Technology, the Teaching Company Scheme, Biotechnology, Information Technology and the ACME programme. On a smaller scale are the Specially Promoted Programmes which operate in a similar manner.

As for outside relationships, the definition of the Council's role in engineering emerged from the Government's White Paper in 1972 on *The Framework for Government Research and Development.* That role was, as for other parts of SERC, "to sustain standards of research and postgraduate education and training in universities". The negative part of that role was that the Council should not act as a customer for that research which properly lay within the responsibility of industry or other parts of Government. With the passage of time the relationship between the Council and Government departments, such as DTI and the Department of Energy, is becoming increasingly important. The result has been the growth of a variety of collaborative enterprises such as the Alvey programme and the Teaching Company Scheme. In the future, increased collaboration with other European countries is anticipated as EEC programmes, such as ESPRIT in information technology, complement national programmes such as the Alvey programme.

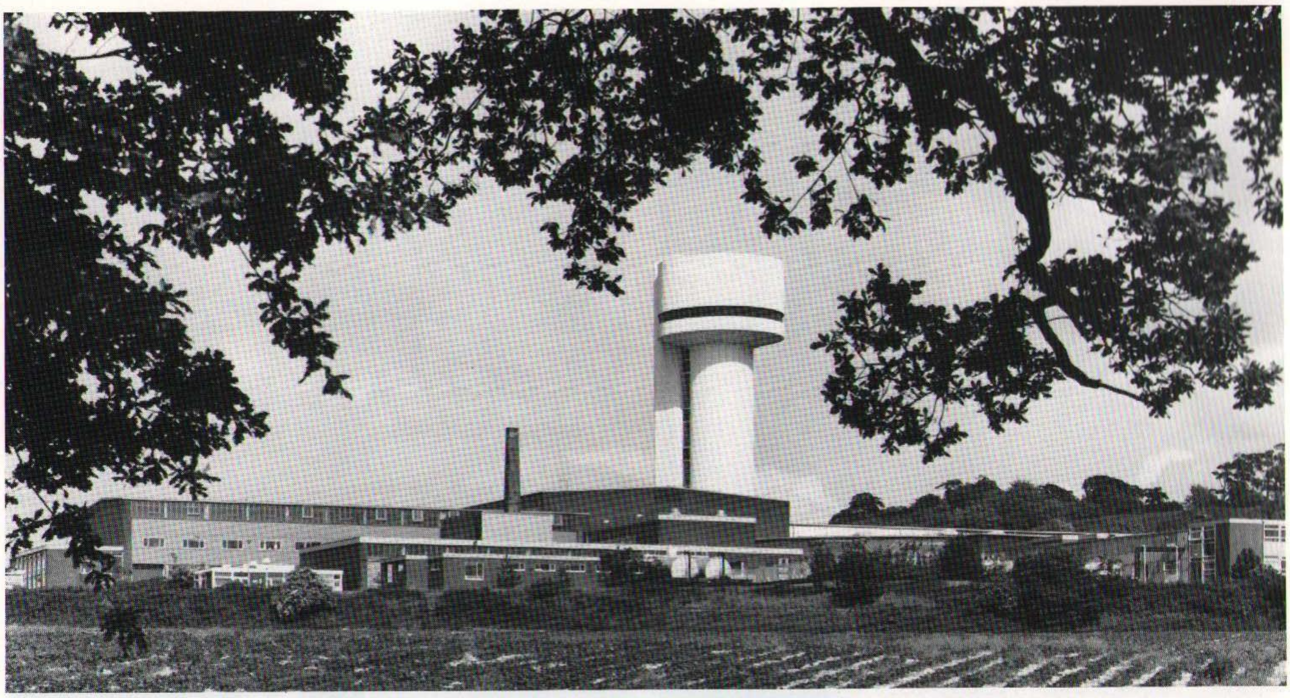
Although SERC has increased its support of engineering substantially in real terms, it still depends on the other part of the 'dual support' system provided by the University Grants Committee. The cuts on universities, particularly in 1981, although intended to protect science and engineering did not achieve that object and there is clear evidence in many fields that the benefits of increased Council spending may not be fully realised unless the universities are able to strengthen their own base. Although the polytechnic sector is organised differently, similar problems apply there.

Specially promoted programmes

Began		Ended
1973	Dies and moulds manufacture	1982
1974	Grinding technology	1982
1977	Instrumentation and measurement	1984
1977	Device fabrication facilities	
1977	Distributed computing systems	1984
1978	Coal technology	1984
1978	Advanced ground transport	1984
1978	Application of numerical control to manufacturing	1984
1979	Energy and materials conservation	1984
1979	Energy in buildings	1984
1980	Combustion engines	
1980	Construction management	
1980	Efficiency of production systems	1984
1980	Robotics	1984
1981	Medical engineering (prev Biomaterials)	
1981	Radio communications systems	
1982	Electroactive polymers	
1982	Particulate technology	
1985	Design of high speed machinery	

The future

Very great strides have been made over the last twenty years to strengthen the engineering research community in universities and polytechnics and to assist them in linking with other parts of the national scene. A future strategy enabling this progress to continue has recently been outlined by the Engineering Board in a study called *Needs of Engineering.* This shows that the advances made have been real and in the national interest, but it would be foolish to pretend that the prospect for the next few years is a happy one. The stresses inside Council caused by financial restrictions operate against the best interest of the country since science and engineering should naturally be in partnership. As to the wider scene, we have outlined the difficulties in academic funding which, if not tackled, will increasingly negate the important contribution the Council has to make in this field.



DARESBURY LABORATORY

Daresbury Laboratory seen from across the Bridgewater canal.

The Minister for Science gave approval to the National Institute for Research in Nuclear Science (NIRNS) for the establishment of an 'electron laboratory' at Daresbury in 1962. By the time the Science Research Council (SRC) was established in 1965, work was well advanced on the construction of an electron synchrotron 'NINA' – the National Institute's Northern Accelerator.

Introducing NINA

Under the Laboratory's first Director, Professor (now Sir) Alec Merrison, FRS, construction of the NINA electron synchrotron with an energy of 4 thousand million electron volts (4 GeV), moved with some speed from first breaking ground in 1964 to achieving acceleration of the first high energy beam in December 1966. The Rt. Hon. Harold Wilson, then Prime Minister, opened the Laboratory in 1967 and from then until 1977 NINA increased in efficiency and performance well adapted to experimental requirements.

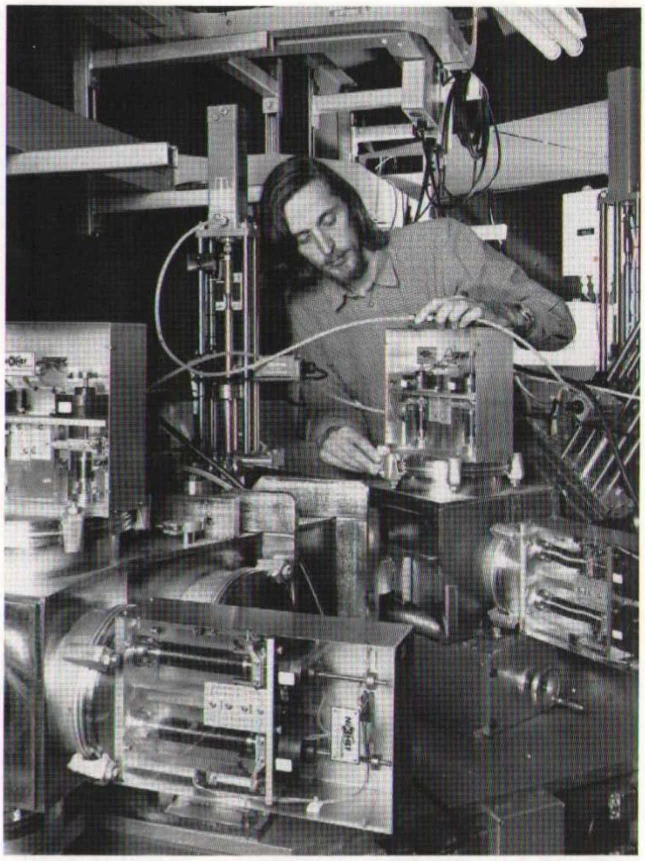
This produced a northern high energy physics community with excellent rapport between external users and Laboratory staff. The quality of data they produced, and its impact on high energy physics, was a considerable scientific achievement. The competitive position of NINA was not aimed at sudden discoveries, but rather at the high quality data needed at that time to unravel the complex spectrum of resonances and their properties – knowledge on which the quark model was built.

By 1970 Professor Alick Ashmore had succeeded Alec Merrison as Director and encouraged a vigorous programme in which many experimental and theoretical avenues were explored. The main impact of NINA physics followed from three developments:

- precision measurement of pion photoproduction using a polarised beam, a polarised target and obtaining recoil polarisation;
- detailed work on electron scattering and electroproduction;
- the use of tagged photons to look at multi-body systems in photoproduction.

Professor Leslie Green, Director of Daresbury Laboratory.

Below: *A laboratory meeting in the 1960s. Left to right: Michael Crowley-Milling, Harold Rothwell, Basil Zacharov, Alec Merrison (Director), Bob Voss, Tony Egginton and Mike Moore.*



Above left: *The Daresbury-Pisa group that worked on pion electroproduction experiments at NINA.*
Left: *Alick Ashmore (Director) showing Sam Edwards (Chairman of SERC) an early experiment on the NINA Synchrotron Radiation Facility in 1973.*
Above: *A beam line on the Synchrotron Radiation Source provided under an agreement with the Netherlands.*

Proof that Daresbury was a scientific force at an international level was first provided by the Glasgow–Sheffield–Daresbury total cross-section measurements in photoproduction together with an experiment carried out by a Daresbury group which measured the cross-sections for pion pair production in the region of the rho meson. The latter provided the first unambiguous proof that the omega meson, which was thought normally to decay into three pions, also decays into two pions.

A Glasgow–Liverpool–Sheffield group gathered extensive data which allowed detailed amplitude analyses to be performed, and yielded precise information on the electromagnetic interaction of the baryon resonances. These results became crucial to the development of understanding not just of electromagnetic interactions but of the whole idea of currents in general and their interactions with hadrons.

A second area of activity was in electroproduction, centred on the Mancaster (Manchester–Lancaster collaboration) series of experiments and that of the PEP group – an international collaboration at Daresbury with Pisa and Frascati. Mancaster's work with pion electroproduction in the resonance region, coupled with work by their counterparts at DESY, provided a remarkable coverage of the whole area of pion electroproduction. PEP experiments were concerned primarily with pion electroproduction near threshold and one of their more interesting results was the determination of the axial vector form factor of the nucleon.

A series of experiments using tagged photons carried out by a Daresbury–Lancaster–Sheffield group set out to clarify the assumptions behind the interpretation of photoproduction and electroproduction of pions and succeeded in a conclusive experiment which, together with their work in multiparticle systems, managed to upset some theoretical applecarts!

When in 1971 the UK Government decided to join the 300 GeV accelerator project at the European Organisation for Nuclear Research (CERN) in Geneva, it became apparent that some of the domestic programme would have to be given up. Like all good facilities, NINA had spawned an intended successor when plans were developed for a 15–20 GeV electron accelerator with injection from NINA. If resources had been available, Daresbury might have grown in a similar way to the DESY Laboratory at Hamburg – but it was not to be. Eventually NINA closed on 1 April 1977 and the UK base for high energy physics transferred to SERC's Rutherford Laboratory.

High energy physics at Manchester, Sheffield and Lancaster Universities all arose from their involvement with Daresbury. In fact the high energy physics community which grew up around NINA is still evident at CERN in the European Muon Collaboration and at DESY in the PETRA experiment. Thus the success of the NINA programme contributed significantly to the potential of current CERN projects, and life at Daresbury took new and interesting directions.

Synchrotron radiation

The history of the emergence of Daresbury as a national centre for synchrotron radiation is really an example of how so-called 'big science' usually has its early beginnings as 'little science'. In 1965 the Atomic and Molecular Physics group at Manchester University was quick to appreciate that NINA was able to produce an intense source of radiation for excitation in the vacuum ultraviolet region. Alec Merrison's response was "If there is good physics in it, I would be enthusiastic". So, after preliminary experiments in 1968, a proposal was put to the Council in 1969 that a national Synchrotron Radiation Facility (SRF) should be set up at Daresbury Laboratory, and this eventually provided two beam lines from NINA together with some ten different experimental facilities for synchrotron radiation users.

During the 1970s many users in a broad range of science were attracted to the SRF. These included groups from Cambridge, Manchester, Oxford and Reading Universities interested in photoionisation and atomic excitation in gases, and also in the optical absorption and reflectance of solids and the information this provided about the electronic structure of solids. Leicester, Ulster, Warwick and Daresbury used a photoelectron spectrometer for studies of the electronic band structure of solids and surface studies. Programmes of work on biological structure and X-ray studies of complex crystal structures were approved and supported not just by SRC but also the Medical Research Council (MRC) and the National Physical Laboratory.

A dedicated source

However, there were difficulties as synchrotron radiation research was parasitic to the mainstream of the Laboratory's work and inevitably NINA (as a source) had shortcomings – notably in intensity, stability and its pulsed nature. Therefore, early in 1974, the Science Board authorised Daresbury to carry out a design study for a dedicated source of synchrotron radiation. This was proposed as a 2 GeV electron storage ring into which accelerated electrons are injected from a linear accelerator and booster synchrotron. The Facility was designed to fit into existing NINA buildings and make use of the experimental halls and other ancillary services. With NINA due to close in 1977, and continuity of the experimental programmes at stake, the proposal was dealt with urgently.

In May 1975 approval was received – and the world's first dedicated Synchrotron Radiation Source (SRS) became a reality. The first beam was obtained in the storage ring in June 1980 and the SRS was formally inaugurated by the Rt. Hon. Mark Carlisle in November of that year.

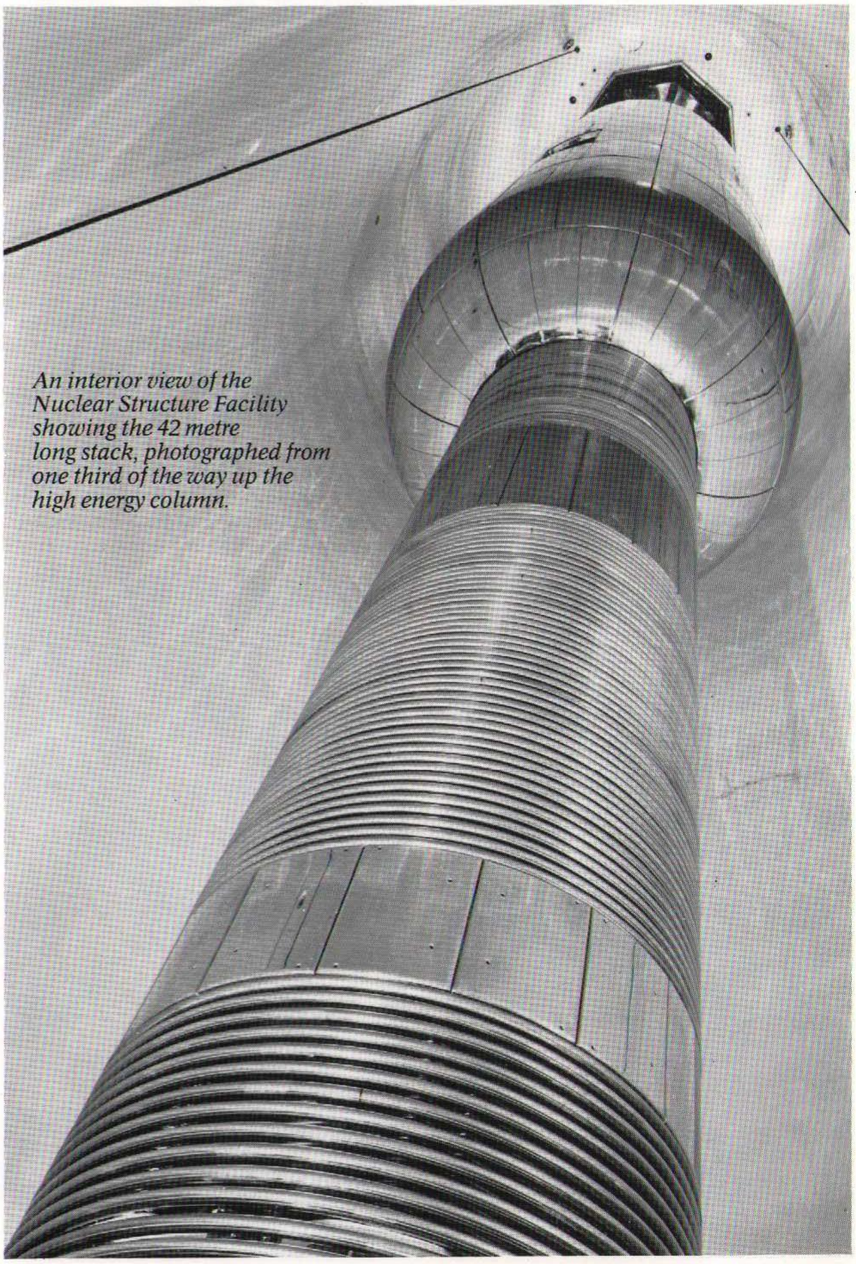
Synchrotron radiation is emitted when high energy electrons are deflected in the fields of the storage ring dipole magnets. It has many unique properties which make it a highly desirable research tool. For example, it is very intense, orders of magnitude brighter than conventional sources in the X-ray range, it is highly polarised and well collimated – with a divergence angle smaller than most laser beams – and has a precise time structure imposed by the acceleration process. The smooth, continuous spectrum, which stretches from X-rays to the infrared in the electromagnetic spectrum, allows for extremely varied research in many branches of science.

By February 1982 first results from the SRS had been reported and ten experimental stations were in operation. Plans for improvement, for example by adding a 'wiggler magnet' to extend the useful output wavelength down to about 0.1 angstrom, were under way and collaborative agreements were set up with organisations both within the UK and internationally to widen and increase the exploitation of the source.

By the end of the third year of exploitation a total of eighteen workstations were in operation, offering facilities for most experiments, which can be operated simultaneously and independently. Collaborative projects had progressed well, including provision of a Biology Support Laboratory – a joint MRC–SERC initiative – and a new beam line established under an agreement with the Netherlands. Since the start of operation in 1981 more than three hundred projects have been undertaken by groups coming from UK universities, MRC, industry and overseas institutes. The user community is drawn from many fields of science: from physics, chemistry and biology to materials science.

Within the last few years work on the SRS has produced a rapid expansion of knowledge of the structures of all kinds of materials such as crystals, liquids, clays and glasses. New research fields have emerged and matured in, for example, the areas of surface science and catalysis, the properties of ionic solids, and the structure and function of large molecules of biological importance.

Plans to improve the SRS continue. Brightness is a concept used in experiments to describe the usefulness of radiation falling onto samples when both beam size and divergence are important. These characteristics are determined by beam line optics and parameters of the source, ie the circulating electron beam. Thus it is important that the electron beam too has small size and divergence. Consequently a project was approved to convert the SRS into a 'high brightness lattice' which is planned for installation in 1986. This will benefit from both SERC and MRC funding, and ensure that the SRS will maintain its position as a leading international facility well into the next decade. In addition there are proposals to develop an element-specific X-ray microscope, to carry out X-ray imaging, and X-ray diffraction from surfaces and interfaces.



An interior view of the Nuclear Structure Facility showing the 42 metre long stack, photographed from one third of the way up the high energy column.

Nuclear structure

At the same time that high energy physics research was in progress on NINA, thought was also being given to the future of UK nuclear structure research. In 1970 the SRC approved a proposal from the Nuclear Physics Board for a design study for a large tandem accelerator at Daresbury. After a planning enquiry, approval to proceed with the construction of a Nuclear Structure Facility (NSF) based on a tandem Van de Graaff was eventually received in 1974.

The NSF at Daresbury is currently the world's largest Van de Graaff. Housed in a 70 metre tower which dominates the Daresbury site, the accelerator consists of a 42 metre long insulating stack supporting a 4.5 metre high terminal at its centre. This centre terminal can be charged up to 20 million volts (MV) by a laddertron charging system. This type of accelerator was chosen because of its ability to produce pencil-thin, very steady beams of ions of precisely defined and easily altered energy. Beams can be produced from any atomic nucleus, even those from very rare isotopes.

Professor Leslie Green succeeded Professor Ashmore as Director of the Laboratory in 1981 and shortly afterwards the experimental programme commenced with an initial terminal voltage of up to 20 MV, deploying several world-class experimental facilities. The total energy suppressed spectrometer array (TESSA) set new standards in instrumentation and the isotope separator, together with its associated dilution refrigerator and laser facility, represents state-of-the-art apparatus for measurements on rare nuclides. The magnetic spectrometer is an instrument of similar calibre for high resolution particle spectroscopy, capable of detecting very small cross-sections in the presence of many competing channels.

The NSF achieved its design potential of 20 MV in April 1983, shortly before the official inauguration by Sir Keith Joseph later that year. By the end of 1984, 84 experiments involving a hundred and fifty scientists from the UK and abroad, and using 39 different ion species at voltages up to 19.6 MV, had been carried out. For example, TESSA was used to investigate cascades of de-excitation gamma rays emitted by a highly-excited, spinning nucleus, revealing fundamental aspects of nuclear structure and behaviour as the normally 'superconducting' state of the nucleus is perturbed by the strong coriolis force.

These early experiments were followed by the first observation of super-deformation in nuclei expected to occur at very high spin as a precursor to fission and long sought after by many groups. Other nuclei such as hafnium 168 and zirconium 84 have been the subject of experiments in which the NSF now leads the world in mapping out the nature and properties of an important group of nuclei.

The isotope separator, associated with the dilution refrigerator and laser equipment, has demonstrated the ability to determine electromagnetic properties of unstable iodine, tellurium and caesium isotopes, and thus represents an important step in the application of the nuclear orientation technique to previously inaccessible regions. The magnetic spectrometer has been used to determine the most accurate mass measurements to date of several light nuclei close to the limits of nuclear stability. This has provided a crucial test of theories based largely on current knowledge of near-stable nuclei.

Towards the end of 1984 acceleration of radioactive tritium and carbon 14 marked the latest new era of research to be opened up on the NSF. The potential of new high-precision measurements of hyperfine structure and isotope shifts are being realised and new aspects of collision phenomena are being revealed with particle–particle coincidence studies. This year the recoil separator will greatly expand possibilities for research in many fields, eg nuclei far from stability. The NSF enters 1985 with a very active community who have unique opportunities for exploring a wide range of nuclear phenomena, thus consolidating its reputation as a world centre in nuclear physics.

A major centre for science

Whilst a brief account such as this concentrates on major projects, it is worth remembering the substantial support a central laboratory provides. This includes theoretical and computational scientists who carry out studies in support of the experimental programmes, electronic and computing expertise to support the sophisticated data processing required by modern science, together with engineering and administrative effort providing the basic organisation of science on this scale.

Over the last twenty years Daresbury has evolved, despite all the difficulties of money and manpower SERC has experienced, into a major centre for science in the UK. Central facilities, as was learned in very early days, require close collaboration between the laboratories who have the facilities and the external community that use them. The international recognition which Daresbury has achieved is a tribute to the high level of understanding and co-operation between the Laboratory and its users. To be mutually responsive to this environment will always be fundamental to the forward progress of UK science, and to the role of SERC and its laboratories.

Below: *Leslie Green (Director) touring the Nuclear Structure Facility with Sir Keith Joseph, Secretary of State for Education and Science, at the inauguration in 1983.*
Right: *Members of an international collaboration between Orsay, Oak Ridge, Manchester, Liverpool and Daresbury preparing for an experiment on the NSF.*

ROYAL GREENWICH OBSERVATORY

Above: *The domes of the equatorial telescopes at the Royal Greenwich Observatory, Herstmonceux.*

The Royal Observatory, founded at Greenwich by Charles II in 1675, is Britain's oldest scientific institution. Together with the Royal Observatory Cape of Good Hope, it was supervised by the Admiralty until 1965, when the administration of both observatories was transferred to the newly-formed Science Research Council, now the Science and Engineering Research Council. Although the last twenty years represent only a small part of the history of the Royal Observatory, they cover a time of significant change.

Astronomical research

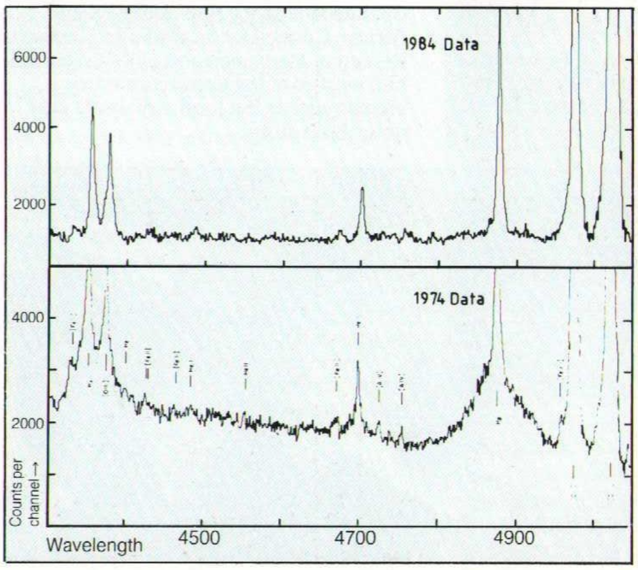
Astronomical research is aimed at determining the past behaviour of the Universe and, using the knowledge gained, attempting to predict what will happen in the future. The research work done at the Royal Observatory over the last twenty years has, in pace with world astronomy, developed from the study of stars, their evolution and composition, to the study of groups of stars and hence to the study of our Galaxy and external galaxies. The latest steps in this progression have been to study active galaxies and their relatives, the most distant objects known, the quasars, and so to determine the properties of the Universe as a whole.

Landmarks in this progression have been the studies of nearby stars which led to the Catalogue of Stars within 25 parsecs of the Sun. The extensive series of papers on the giant globular cluster Omega Centauri led to the extension of abundance studies in single stars to groups of stars. This in turn led to the investigation of abundance variations within external galaxies, which is linked to a study of the evolution of galaxies.

Work on quasars has developed from the discovery using the old Thompson refractor at Herstmonceux that the emitting region in quasars was small, to the recent determination of the mass of the black hole in the centre of the active galaxy NGC 4151. Detailed studies and statistical counts of absorption lines in quasar spectra have led to the recognition that these represent the most distant and therefore the earliest counterparts of galaxies and intergalactic material directly observable, and have allowed determination of cosmical parameters determining the nature and evolution of the Universe.

The number of astronomers at the Royal Observatory has declined markedly over the past twenty years, but the quality of research has remained extremely high and a nucleus of first class astronomers remains who should be fully exploited using the new facilities available to UK astronomy.

Above: *Professor Alec Boksenberg, FRS, Director of the Royal Greenwich Observatory.*



Comparison of spectra of the active galaxy NGC 4151, obtained in 1974, against spectra taken with the image photon counting system in 1984. The change in character of the emission lines is very striking: the very broad Seyfert I type emission clearly visible in 1974 has almost entirely disappeared in 1984.

Herstmonceux Castle

On its removal from Greenwich in 1957 to get away from the heavily polluted air of London, the Royal Greenwich Observatory (RGO) was centred on Herstmonceux Castle. This fifteenth century fortified residence was allowed to fall into ruin in the eighteenth century, but was restored in this century by two wealthy private owners.

The Castle contains a main Library, canteen and most of RGO's meeting rooms which have been formed into a Conference Centre. The Castle houses a valuable set of Archives which cover the period back to 1675 and a small Conservation Laboratory for restoration and maintenance work. There is a Public Exhibition which, together with some of the astronomical telescopes, is open to about 60,000 public visitors a year.

University links
In 1965, when the Science Research Council (SRC) took administrative control of RGO, arrangements were made for cooperation with Sussex University in research and teaching. Members of staff began to give lecture courses at the University for the newly established MSc degree in astronomy. These links have been strengthened with time and the list of graduates who have obtained DPhil degrees while being supervised by Observatory staff contains many distinguished astronomers working world-wide.

Below: *HRH The Princess Anne unveils a bust of the first Astronomer Royal John Flamsteed during the Tercentenary Celebrations in 1975.*

The annual Herstmonceux Conferences started in 1957 by the Astronomer Royal provide an opportunity for astronomers from universities and the establishments together with many research students to discuss a particular astronomical theme. Over the last three years this annual conference has been supplemented by many astronomical workshops and small group meetings held in the Conference Centre.

In 1965 the Director of the Royal Observatory was Sir Richard Woolley, OBE, FRS, the 11th Astronomer Royal and the last director of the Observatory to hold that title ex-officio. As Director he was responsible for both the Royal Greenwich Observatory and the Royal Observatory Cape of Good Hope. He has since been succeeded by Professor E M Burbidge, FRS, in 1972, Dr A Hunter in 1973, Professor F G Smith, FRS, in 1976 and the present Director, Professor A Boksenberg, FRS, in 1981.

South African Astronomical Observatory

The 150th anniversary of the inauguration of the Royal Observatory Cape of Good Hope was celebrated in 1970. In the same year agreement was announced whereby the Royal Observatory would be incorporated into a newly-formed South African Astronomical Observatory (SAAO), to be operated jointly by SRC and the South African Council for Scientific and Industrial Research. Many members of RGO staff who had worked at the Cape returned to Herstmonceux but local staff went to the new observatory.

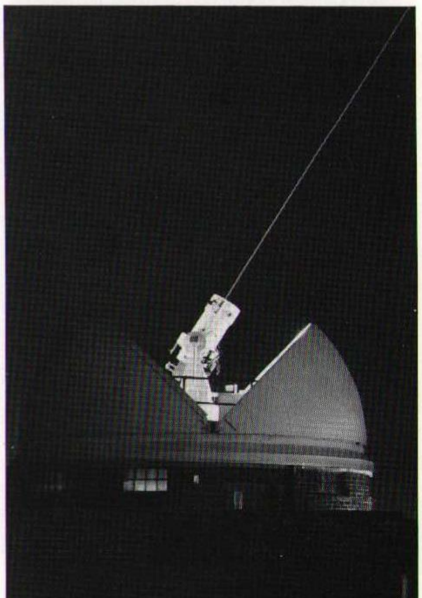
A new observatory outstation at Sutherland in the Karroo was opened in 1972. Several RGO staff were involved with the design and construction of the new Observatory whose first Director, following his retirement from the post of Astronomer Royal, was Sir Richard Woolley. In 1974 the Radcliffe 1.9 metre reflector in Pretoria was acquired from the Radcliffe Trustees and was transferred to Sutherland. RGO has maintained close links with the SAAO and has designed and built several of the major instruments used on the telescopes.

Tercentenary celebrations

The past twenty years have seen some important milestones in the history of the Observatory. One of these was the celebration in 1975 of the tercentenary of the founding of RGO. The historical aspects of this were featured in a number of events organised at Greenwich, while at Herstmonceux emphasis was kept on the current work of the Observatory. Five of the Observatory's telescopes were demonstrated, including the Isaac Newton, and displays were set up showing aspectsof the work of RGO. Nearly 22,000 members of the general public attended a series of open days, as did more than a thousand members of scientific institutions. Two associated international symposia attended by many distinguished guests were held: an historical one at the original Observatory at Greenwich and one on the subject of 'The Galaxy and the Local Group' at Herstmonceux.

Nearly 900 guests attended a garden party at Herstmonceux Castle at which the guest of honour, Her Royal Highness The Princess Anne, unveiled a stone bust of the first Astronomer Royal, John Flamsteed, which together with a specially designed sundial have been placed in the formal gardens to commemorate the occasion.

Below: *The satellite laser ranging telescope at Herstmonceux. The laser beam is clearly seen in this time exposure.*



The Time Service

In 1964 the Greenwich Time Service was based on newly acquired quartz crystal clocks. Portable clocks were used to compare the clocks on either side of the Atlantic, firstly using quartz clocks and then a portable caesium standard. These helped explain discrepancies of about half a millisecond in the timing of artificial satellites. The intermittently run caesium-beam frequency standard at the National Physical Laboratory provided frequency calibration for the formation of an atomic time scale. The first atomic clock was installed at RGO in 1966 and improved methods of comparison have reduced transatlantic uncertainties to less than a microsecond. The Observatory played an important part in defining the stepped atomic timescale (Coordinated Universal Time) that came into world-wide use in 1972.

RGO has continued to supply the traditional 'six pips' to the BBC, as it has done for the last 60 years. 1984 was the centenary of the adoption of the Greenwich meridian, an event that was celebrated with the issue of a special series of stamps and several public events.

Rotation of the Earth

Associated with the determination of Time is the analysis of the Earth's rotation. Because the Earth does not rotate uniformly, the laboratory-defined atomic time scale has to be adjusted, using leap seconds at the start of the year, to accommodate the irregular rotation rate. The determination of the rate and the position of the pole were made, until last year, using the photographic zenith tube at the Observatory. This has now been taken out of operation and has been replaced by the satellite laser ranging telescope (SLR), designed and built in conjunction with Hull University.

SLR incorporates a pulsed laser whose light is fed into a computer controlled telescope. The parallel beam from the telescope is directed towards selected satellites which possess retroreflectors. These reflect back some of the incident laser light to the telescope. By very accurate timing of the intervals between transmission of the initial light pulses containing about 10^{17} photons and the reception of the reflected pulses containing typically one detected photon, the distance to the satellite may be determined. This system is one of the most successful and accurate in the world, giving errors of less than 5 centimetres for individual measurements of the distance to the satellite.

Since 1982 the Hewitt Camera from Aston University has been stationed at Herstmonceux, where the better weather conditions have allowed many more observations of satellites to be obtained than at its previous site at Malvern.

Detector development

In 1964 the principal astronomical detectors in use were the photographic plate for two-dimensional work, such as direct photography and spectrography, and the photomultiplier for photometry. The twenty years since have seen very rapid changes resulting in a new generation of detectors having far higher efficiencies and linear responses. Considerable effort has been spent in exploiting these new devices and making them sufficiently reliable to be incorporated in common-user instruments.

Control of all new instruments is now from an instrumentation computer via built-in microprocessors dedicated to separate functions in the instrument. The extension of this control from a warm room at the distant observatory to remote observing from the UK is the subject of a continuing study. Already one of the American telescopes at Kitt Peak Observatory has been controlled from RGO and very useful data were obtained.

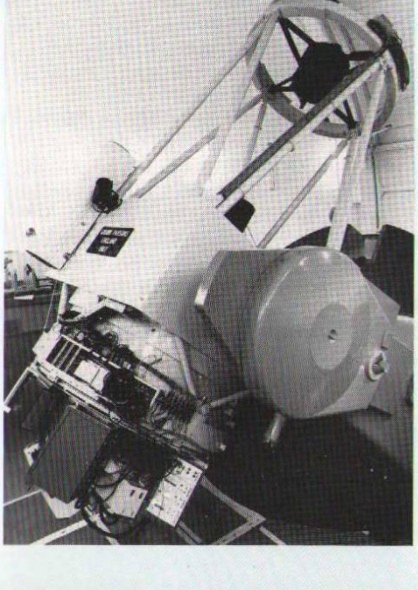
Computers

One of the biggest changes during the last twenty years has been in the field of computing. In 1965 the Observatory installed a new computer which was estimated to be one hundred times more powerful than its predecessor. The core storage of this new machine was significantly less than that of the cheapest home computers now on the market!

In 1974 this computer was replaced by an ICL 1903T central processor with 96K words of central store. With the advent of modern detectors, the explosion in the size of data blocks, the availability of faster machines with larger storage capacity and networks covering the country, the ICL computer has been replaced by two VAX computers. One is dedicated to the Starlink network formed in 1980, while the other is used for more general work at RGO. The work done on mainframe computers has been enlarged by the use of minicomputers, many of which can communicate with the mainframe computer. The use of microprocessors in instrument design, not even contemplated in 1965, is now commonplace.

Isaac Newton Telescope

In December 1967 Her Majesty Queen Elizabeth II visited the Royal Observatory for the inauguration of the Isaac Newton Telescope (INT). This event was the culmination of efforts to bring the UK back to the forefront of optical astronomy by providing access to a world-class telescope.



The 2.5 metre diameter INT was the largest optical telescope in Europe.

While at Herstmonceux, the telescope was used by many astronomers from the universities and the establishments who were able to gain experience of using such a large telescope and of the astronomical problems which could be tackled with it. A notable result from this period is the discovery of HD226868 as the optical component of Cyg X-1 and the determination of the minimum mass for the unseen companion to the visible hot supergiant. This mass determination indicated that Cyg X-1 contained the first known black hole, a theoretically predicted class of object previously undetected.

Instrumental development was also significant; INT was very valuable in the development of the image photon counting system, which has since been successful as a detector on many large telescopes.

Despite choosing probably the best site in the UK for INT, the development of street lights, the relatively poor English weather and atmospheric turbulence, which produces poor 'seeing', all precluded the development of the full potential of INT as a world-class telescope. Its life at Herstmonceux ended in 1979 when it was dismantled for engineering work to enable it to become part of a new international observatory in the Canary Islands.

Left: *The Isaac Newton Telescope now installed on the island of La Palma.*

Above: *HM The Queen with the Astronomer Royal, Sir Richard Woolley, at the inauguration of the telescope in December 1967.*

Northern Hemisphere Observatory

In 1974 came the first formal change in the functions of RGO in its 300 years of existence. The Observatory was to continue carrying out research programmes of its own and collaborating with university astronomers. It was to continue to be responsible for national and international services, such as the provision of navigational almanacs and astronomical ephemerides and the maintenance of the national Time Service, but its primary objective was to become the support of university research. This was to be particularly in the provision and operation of large central facilities for ground-based optical astronomy.

In the same year the Science Research Council approved in principle the construction of a major new Northern Hemisphere Observatory at a good site overseas. RGO, in line with its redefined primary role, was given the responsibility for procuring and operating the new observatory, which would consist of a 4.5 metre diameter telescope, the 2.5 metre Isaac Newton Telescope and a 1 metre telescope.

Observatorio del Roque de los Muchachos

Considerable experience had been gained by Observatory staff in the setting up of new observatories and new telescopes during the establishment of both the South African Astronomical Observatory and the Anglo-Australian Telescope. The resurgence of UK optical astronomy started by the Isaac Newton Telescope at Herstmonceux was considerably strengthened by work with the 3.9 metre Anglo-Australian Telescope in the southern hemisphere, but suffered from the lack of a significant set of telescopes in the northern hemisphere.

Tests had shown that a mountain site on the island of La Palma in the Canary Islands would be excellent for astronomy, and it was there that the Spanish Observatorio del Roque de los Muchachos was set up, following international agreements between Spain, the United Kingdom, Denmark and Sweden. The Irish Republic now shares use of one of the telescopes with British astronomers and a far-reaching partnership between the United Kingdom and the Netherlands has been entered into. The two astronomy communities will share, with Spain, the operation, maintenance and use of the major facilities.

Despite the considerable difficulties in working on a remote mountain site, with access via an unsurfaced mountain road, on an island belonging to a foreign country with the associated problems of differences of language and culture, work has progressed remarkably quickly on the building and commissioning of the UK telescopes. This is due to the long hours and hard work put in by all members of the island team and the short-term workers from RGO.

The UK telescopes so far erected at the new Observatory are the Isaac Newton Telescope (INT), the Jacobus Kapteyn Telescope (JKT) and the Carlsberg Automatic Transit Circle (CATC). INT has been completely refurbished with a new mirror, a computer control system and a new set of instrumentation, which includes a sophisticated conventional spectograph with an image photon counting system and charge coupled device (CCD) as detectors, and a collimatorless faint object spectrograph (FOS) with an integral CCD as detector. The FOS has been designed for maximum throughput to study faint galaxies and quasars.

These instruments, together with the other general user instruments such as the automated prime focus instrument for direct photography, were designed and made at RGO. The JKT is a 1 metre telescope intended for direct photography and astrometry and photometry. Both of these telescopes are now working and excellent progress has been made on the commissioning of the suite of instruments provided for the general user.

The Carlsberg Automatic Transit Circle is a joint project of the Copenhagen University Observatory, the Royal Greenwich Observatory and the Instituto de Marino del San Fernando. The telescope of 18 centimetre aperture rotates about a single, horizontal east-west axis. It thus views stars as they pass the meridian.

Left: *the Carlsberg Automatic Transit Circle.*

Above: *the building for the 4.2 metre William Herschel Telescope during construction in 1984.*

The purpose of the telescope is to measure star positions from transits across the meridian. The observing list of stars is held as a disk file in a minicomputer, and the computer chooses which star is next to be observed, positions the telescope at the right altitude and opens the building roof. The computer reduces the data on-line and closes down the system if the weather is bad. It observes nearly 1000 star positions per night, and in the daytime measures the positions of the Sun, planets and bright stars.

William Herschel Telescope

Another telescope to be installed on La Palma is the 4.2 metre William Herschel Telescope which has been designed and built by N E I Grubb Parsons Ltd of Newcastle. This is the third largest single mirror optical telescope in the world (after the Soviet 6 metre telescope and the Palomar 5 metre telescope) and the fourth largest in total collecting area (after the same two telescopes and the Multi-mirror Telescope in Arizona). Observations on the telescope will be carried out both from a control room in the telescope building and from the UK.

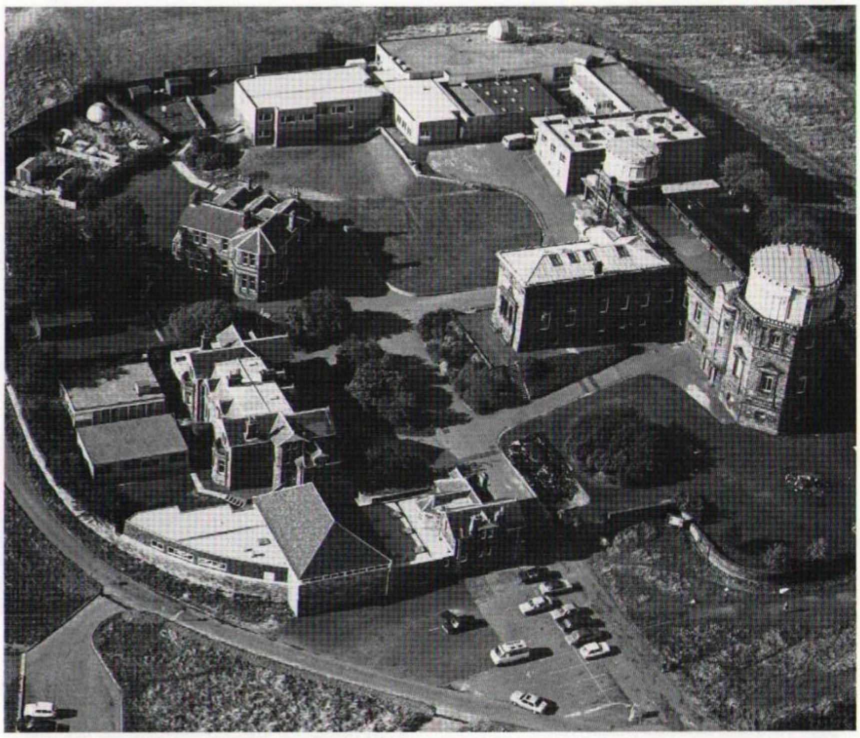
RGO is at present designing and will supervise the construction of the instrumentation for the telescope. The major instrument will be a specially designed spectrograph (ISIS) which will weigh almost as much as a small family car and yet, while operating at different attitudes as the telescope moves, will maintain its optical components in their correct positions to better than 5 microns. This requires considerable engineering design skills and is an example of the technical expertise which is now required.

With the completion of the William Herschel Telescope, British, Spanish and Dutch optical astronomers will have access to a major telescope at one of the best sites in the world. Together with the three existing telescopes, it will form a facility which will offer the best astronomy in the world.

ROYAL OBSERVATORY EDINBURGH

In 1965 the Royal Observatory, Edinburgh was growing rapidly. The period of growth began in 1957, when the arrival of a new Director, Professor H. A. Brück, coincided almost exactly with the launch of the first artificial Earth satellite, Sputnik 1. As Professor Brück has commented in his recent book The Story of Astronomy in Edinburgh "this was an event which not only stimulated popular interest in astronomy – thereby making it easier to secure financial support for astronomical research – but also drew general attention to the remarkable advances which had been made in the war and post-war years in the field of technology".

These sentiments characterise the programme of the Royal Observatory. In all projects it has developed the new technologies to tackle some of the most difficult and important problems in astronomy and cosmology in quite new and distinctive ways. All the major projects in which the Observatory has been involved over the last twenty years have resulted in world-leading facilities, which are currently producing some of the very best science being carried out in this country.



An aerial view of the Royal Observatory buildings on Blackford Hill, Edinburgh, in 1980.

In 1957 the Royal Observatory staff totalled only ten; by 1965 the staff numbered about sixty and by 1979, it had reached its present level of about 110 supplemented by the use of local employees, particularly at the overseas observing stations in Hawaii and Australia.

The programme of work undertaken by the Observatory has been almost completely turned around during the past twenty years. In 1965 the Observatory was really an autonomous research institute. The Director negotiated his annual budget with the minimum of fuss. He produced an annual report to the Secretary of State for Scotland and made an annual bid for funding more or less directly to the Treasury.

The establishment of the Science Research Council in 1965 was one of the factors that accelerated change. It coincided with growing financial support for research, with astronomy as one of the faster-growing branches of science in Britain and elsewhere. The Observatory adapted well to these changes. It welcomed the space age and the computer age and also accepted the Council's policy that involved a radical shift from autonomous research activity to the provision of facilities for astronomical research by the whole of the UK community.

Atlas of the southern skies

The Council's plan for astronomy concentrated first on the construction of new observing facilities in the southern hemisphere. One of the key elements of that plan was a survey of the whole of the southern skies with a fast and very deep wide-field camera, similar to the Mount Palomar Schmidt Telescope in California which had surveyed the northern skies.

Dr V. C. Reddish was chosen to head a small independent Unit to oversee the construction and commissioning of what is now called the UK Schmidt Telescope (UKST) at the Siding Spring Observatory in Australia, alongside the large Anglo-Australian Telescope. When Professor Brück retired in 1975 he was succeeded as Director by Dr Reddish, who brought the UKST Unit into the Observatory; this functioned as a national astronomical facility, producing an atlas of night sky photographs and responding to requests for special observations from astronomers throughout the UK and abroad. The UK Schmidt Telescope remains the world's most powerful wide-field camera and, thanks to the meticulous efforts of the team in Australia, completely new standards have been set in the quality of the plate material made available to the whole astronomical community.

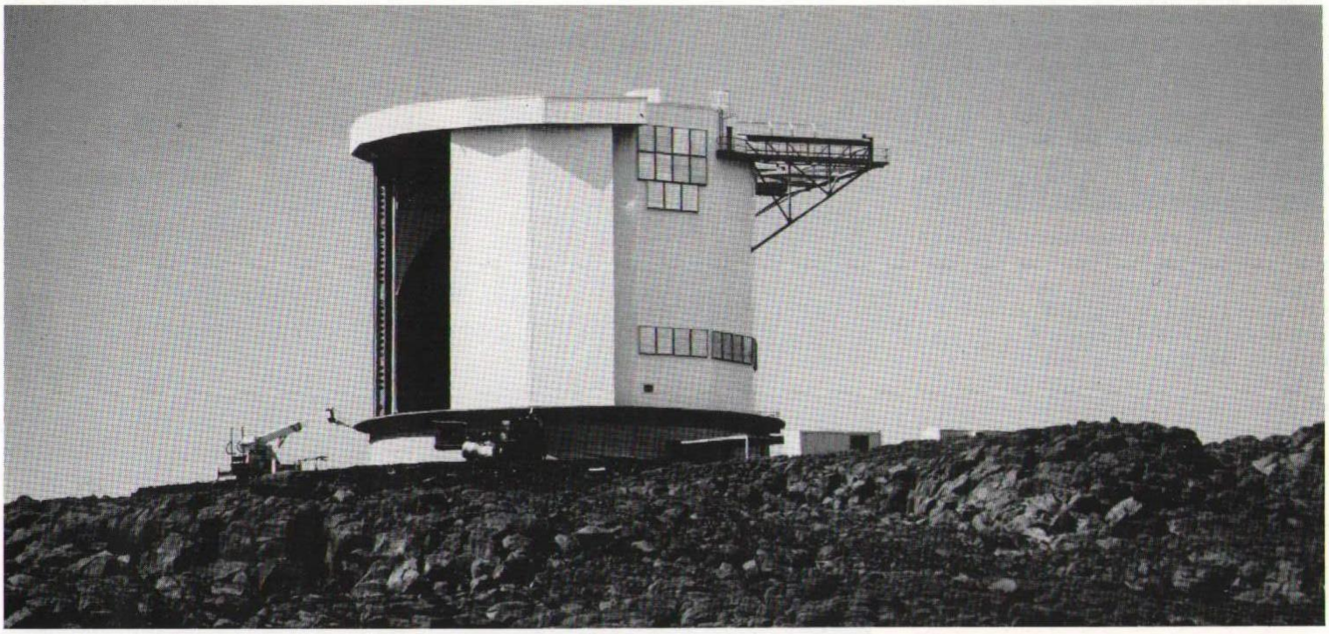
Professor Malcolm Longair, Director and Astronomer Royal for Scotland.

The enormous scientific potential of this plate material has stimulated many original research proposals and more than 650 research programmes have been supported by the Unit to date. Plates are taken with different filters, with prisms of different dispersions and at different epochs, so that many different classes of astronomical object can be identified, ranging from asteroids to the most distant quasars known.

Measuring with COSMOS

The Observatory's second national facility was the COSMOS high-speed automatic plate measuring machine. This was an improved version of the GALAXY measuring machine which had been developed in Edinburgh. The objective was to construct a high-speed measuring machine which would enable the wealth of scientific data contained on photographic plates to be converted into quantitative measures and so allow many large-scale statistical studies to be carried out on all classes of astronomical object.

Specifically, the intention was to convert the million images on each Schmidt plate into a catalogue of images in a matter of hours. COSMOS was required to work at the limits of current technology and it was far from easy to provide a steady service to the many astronomers who were queuing to have their plates scanned. COSMOS data are now being used to unravel the structure of our Galaxy, to map the distribution of the most distant galaxies and quasars in the Universe, and to find rare but significant objects.



The building for the Millimetre-wave Telescope at Mauna Kea.

Mauna Kea

Infrared measurements

Another major project for which the Observatory became responsible in the 1970s was the construction of a large telescope specially designed for observations at infrared wavelengths. A small Unit, modelled on the UK Schmidt Telescope Unit, was set up in 1973 with a university scientist, Professor J. Ring of the Imperial College of Science and Technology, London, as Project Scientist and Mr G. J. Carpenter, the Observatory's senior engineer, as Project Officer, to design this unique telescope and supervise its construction by various contractors.

This was the world's first large thin-mirror telescope and incorporated many advanced features in its mechanical and instrumental design. It was decided that it should be sited at the summit of Mauna Kea, 4200 metres above the Pacific Ocean on the Big Island of Hawaii: this is the best site in the world for infrared, millimetre and submillimetre observations but the high altitude does present medical and logistic problems.

The telescope was, nevertheless, completed successfully and the Observatory was given the responsibility of operating the UK Infrared Telescope as another national facility. It was opened in 1979 and has proved to be a pioneering tool in the investigation of large volumes of the Universe inaccessible to other types of observation. It is the world's largest dedicated infrared telescope and currently has the most advanced instrumentation of any infrared telescope.

The importance of the infrared waveband is multifold. In space there is a great deal of dust which is opaque to radiation in the optical waveband but transparent in the infrared waveband, and so it is possible to obtain unobscured pictures of all classes of astronomical object from the very earliest stages of star-formation to the global properties of galaxies. In addition, many astronomical objects from dust clouds to quasars emit most of their energy in this waveband. Of special importance are the dense dusty clouds in which protostars and the youngest stars are found. These young objects heat up the surrounding dust cloud which radiates away the energy in the infrared waveband.

Submillimetre observations

The growing reputation of the Mauna Kea Observatory as a site for long-wavelength astronomical work led to the Council's decision to place a new UK/Dutch Millimetre-wave Telescope there. The Royal Observatory is currently preparing to take over responsibility for this new front-line research facility when construction is completed in 1986. This will be the world's largest submillimetre telescope on the best site for these types of observation. Scientifically, this complements the capabilities in the infrared waveband provided by UKIRT.

The unique feature of observations in the millimetre and submillimetre wavebands is molecular line radiation. The strong narrow molecular lines provide the most powerful tool for studying the internal dynamics of the cool regions where stars are formed. The ability to probe to the highest frequencies in the submillimetre waveband enables the densest regions to be studied and it is within these that star formation takes place. In addition, the observation of many different chemical species enables us to study the chemical and astrophysical evolution of our own and other galaxies. The Infrared and the Millimetre-wave Telescopes will be run as a single Hawaiian facility, with remote observation from the UK.

Space projects

In order to make room for these major national responsibilities the Observatory has had to prune its other interests very rigorously. The observing station in Italy which was officially opened in 1967 was closed in 1978. The manpower allocated to in-house research has dropped from 100% in 1965 to 11% in 1985. The Space Research Division, which was involved in the design and construction of astronomical instruments for use in rockets and satellites and in the optical tracking of artificial Earth satellites, has disappeared. However, the space interest has revived in a new guise through the Observatory's participation in the Space Telescope Project and the Infrared Space Observatory.

Such drastic changes have required great flexibility and resilience in the staff, who have responded positively to these new challenges. Through these last twenty years of its much longer history the Observatory has maintained and enhanced its reputation for youthful vigour and has developed a capacity for quick response to new challenges.

The future

What of the next twenty years? We are fortunate in being responsible for projects which put us in an excellent position to remain world leaders through the 1990s and into the 21st century. There will always remain a need for deep surveys of the skies, and the significance of making a second epoch survey of the southern skies to find out how all the stars have moved is an obvious long-term goal. The proper exploitation of these data needs access to the most powerful measuring machines. Astronomy in the infrared and submillimetre wavebands is still in its infancy and there are huge gains to be made in the sizes of arrays of detectors and their sensitivities. We are in a position to be world leaders in these fields which have fundamental importance for physics, astronomy and cosmology.

The technologies we have acquired are exactly those needed for looking forward to the 1990s when we can envisage yet larger ground-based and space-based telescopes equipped with the most advanced instruments. The great scientific significance of these future developments has never been clearer.

Discovering the most distant quasars

Quasars are the most luminous objects in the Universe and so they can be observed at greater distances than any other class of astronomical object. They are so far away that the most distant of them emitted their light when the Universe was less than a fifth of its present age. They are therefore very powerful probes of the Universe in the distant past.

Studies of plates taken by the Schmidt telescope have resulted in the discovery of more quasars than by any other technique. The three most distant quasars known were all discovered on UK Schmidt plates but the techniques used to find them were totally different and illustrate the wide range of uses to which the plates can be put.

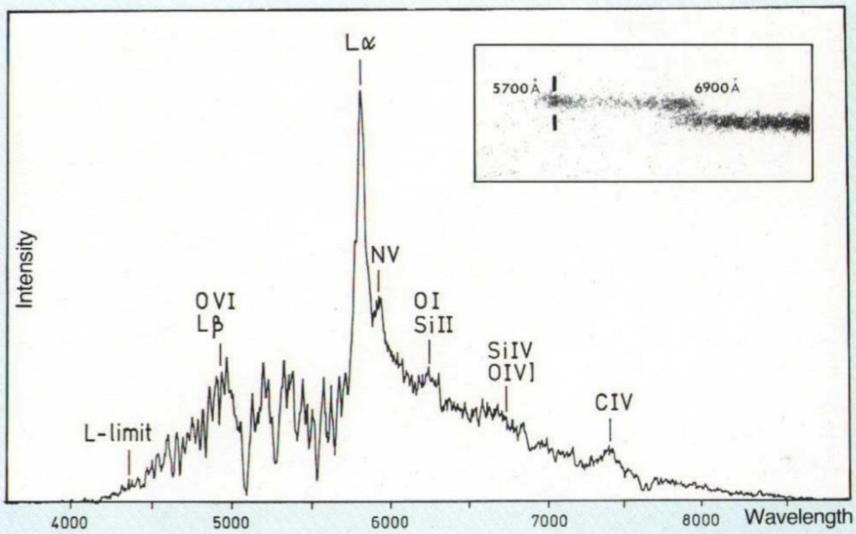
The most distant quasar PKS 2000-330 was discovered by Dr Ann Savage of the Royal Observatory and her colleagues by the radio source identification technique. A precise position for this radio source showed that it was associated with a quasar which turned out to have a redshift of 3.78.

The second most distant object 0055-2659 (redshift = 3.67) was discovered by Dr Cyril Hazard and his colleagues of Pittsburg and Cambridge Universities from prism plates specially taken with the Schmidt telescope. In their studies, they made visual inspections of the tens of thousands of low-dispersion spectra obtained in a single observation. They searched for faint objects with very strong broad lines and among those discovered was the object 0055-2659.

The third most distant quasar DHM 0054-284 (redshift = 3.61) was discovered by Dr Tom Shanks and his colleagues at Durham University by comparing Schmidt telescope plates taken with different filters and searching for those objects with infrared excesses from measurements made with the COSMOS high-speed measuring machine.

Other techniques have also been very successful, including the search for faint variable objects by Dr Michael Hawkins of ROE. A major programme is now under way of searching objectively for quasars in a much more systematic way.
Dr Roger Clowes of ROE has developed an algorithm called AQD (Automatic Quasar Detection) which finds quasars on deep prism plates by identifying features in the faint prism spectra. The plates are first scanned by the COSMOS high-speed measuring machine and then the images analysed by the computer algorithm.

By this means, many key cosmological questions can be addressed. Are quasars clustered? How have different classes of quasar changed as the Universe grows older? Is there a cut-off to the distribution of quasars at large redshifts corresponding to the epoch when they were born?



Spectrum of the most distant quasar, known as PKS 2000-330. It has a redshift of 3.78, a figure that implies that the object is 18 billion light years away. Inset: a photograph of the spectrum as recorded by the UK Schmidt telescope.

Below: the UK Schmidt telescope in Australia opens its 1.2 metre diameter aperture to the night sky.

The UK Infrared Telescope

Of the many exciting new discoveries made from observations with the UK Infrared Telescope, three typify the distinctive nature of the science which can be undertaken in this part of the spectrum.

Bipolar outflows in star formation

It is expected on general grounds that protostars or very young stars must lose mass so that they can get rid of the energy and angular momentum of the cloud from which they form. Unfortunately, these processes take place deep inside cool clouds which are obscured by dust from visual observation. In the infrared waveband, however, the dust is transparent and many regions in which the youngest stars are found have been mapped in various molecular lines which are found in the 1–5 micron waveband. Of special importance are the molecular hydrogen lines which are only excited at temperatures of about 1000-2000°K.

These lines have been discovered in many protostellar systems, but the big surprise is that the molecular hydrogen is in the form of high velocity jets emanating in opposite directions from the star. These are referred to as bipolar outflows. The detection of molecular hydrogen in the 1–5 micron waveband is of special significance because it is excited to temperatures at which the interstellar medium cools very rapidly. The jets must therefore be continually energised by outflows of hot gas from the protostar.

The discovery of these bipolar outflows is a key factor in understanding how young stars lose energy and angular momentum in the process of becoming standard 'main sequence' stars. The maps made with the Infrared Telescope of the spatial and velocity distribution of molecular hydrogen in these objects provide the most detailed picture of these processes so far obtained, thanks to the series of cooled grating spectrometers designed by the Royal Observatory's astronomers and constructed by the Technology Unit.

The Galactic centre

The study of galactic nuclei has been one of the great growth areas over the last twenty years. Quasars and BL Lac objects are among the most exotic and luminous objects known, but it would be extremely valuable to be able to study the nucleus of our own Galaxy where there is radio evidence of mini-quasar activity. Unfortunately, because of interstellar dust, the centre of the Galaxy is totally obscured optically. In the infrared waveband, however, the nuclear regions can be observed with very little obscuration. The stellar distribution in the nuclear regions has been determined and there is a peculiar infrared source associated with the nucleus itself.

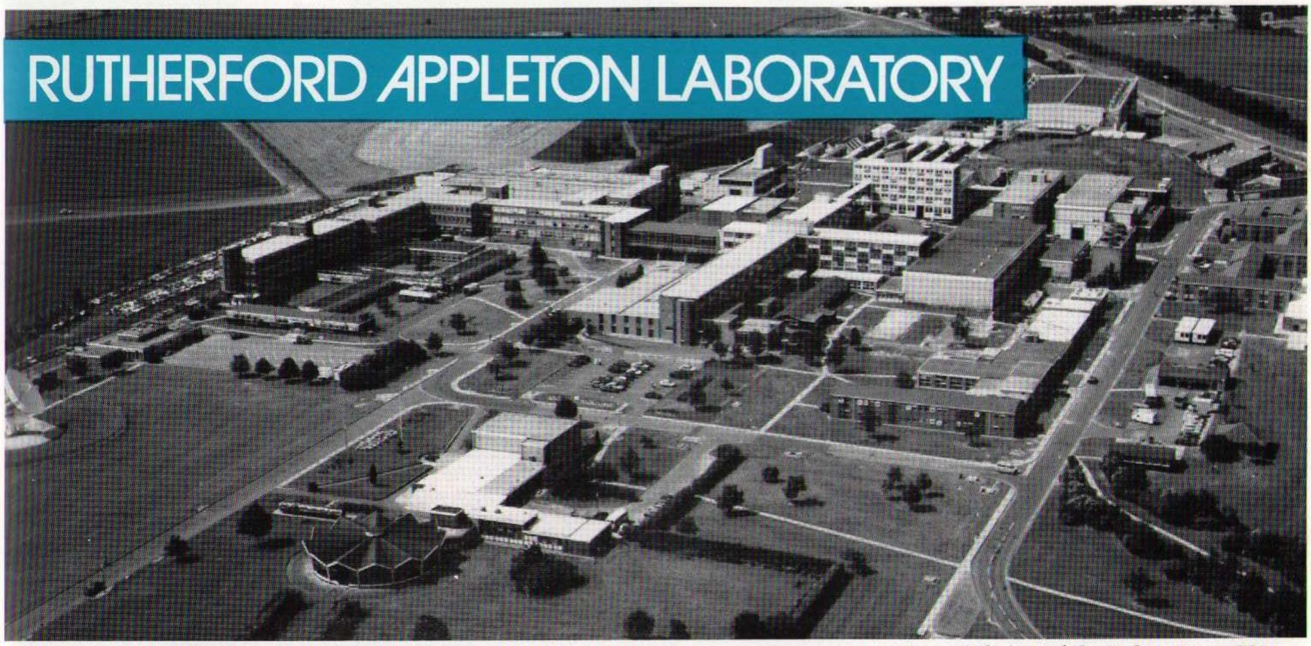
A remarkable discovery made in 1982 with the Infrared Telescope was the presence of molecular hydrogen from the nuclear regions of our Galaxy. This has now been mapped by the Telescope Unit using a circular variable filter and a Fabry-Perot spectrometer. It has been found that the molecular hydrogen is in the form of a ring rotating about the nucleus itself. This provides a very powerful diagnostic tool for studying processes occurring in the nuclear regions. The molecular hydrogen must be excited by winds blowing out of the nucleus and indeed the ring itself is probably associated with a shock wave related to the outflow from the nucleus. The outflow rate and the luminosity of the region indicate a single massive object at the Galactic centre. The data are consistent with the presence of a black hole of mass about a few million times the mass of the Sun. Our own Galactic nucleus offers the prospect of studying hydrodynamic phenomenon stimulated by winds from the closest massive black hole to the Earth.

The most distant galaxies

Most of the light of nearby galaxies is emitted towards the red end of the optical spectrum. If these galaxies are observed at a large distance, their light is redshifted into the infrared waveband and they become principally infrared objects. Another advantage of observing distant galaxies in the infrared waveband is that the stars which dominate the light are old stars, and so the infrared masurements are much less sensitive to sporadic bursts of star formation which can strongly influence the optical luminosity.

With the Infrared Telescope, we have detected many of the most distant galaxies known in the 1–2.2 micron waveband. These are radio galaxies which are amongst the most luminous galaxies. Consequently they can be observed at great distances, the most distant having emitted their light when the Universe was less than half its present age. This means that they can be used as cosmological probes. Remarkably, we have found that there is only a small dispersion in the intrinsic infrared luminosities of these galaxies out to redshifts of 1.5. These galaxies are observed at epochs when they were very much younger than they are now and they must have been brighter in the past. We have found evidence for this effect in our observations and this is the first time that direct observational evidence has been obtained for the evolution of the stellar populations of galaxies over cosmological time-scales which extend to earlier than half the present age of the Universe. These observations and their extension to even more distant samples of galaxies are enabling us to derive direct observational evidence about the origin and evolution of galaxies in general.

RUTHERFORD APPLETON LABORATORY



An aerial view of the Laboratory, 1984.

Foundations

On 1 April 1965 the new-born Science Research Council inherited many riches from its forebears. The then Radio and Space Research Station at Ditton Park, Slough, was already a mature and world renowned scientific laboratory, founded in 1927. The early work at Ditton Park had been concerned with the ionosphere, following its historic discovery by E V Appleton. However, in the year 1985, we should remember that we are celebrating not only the 20th anniversary of SERC but also the 50th anniversary of the first demonstration of radar by Watson-Watt and others. Judged by its practical consequences, Watson-Watt's work on radar is perhaps the most important ever undertaken at any of the Council's laboratories.

The Science Research Council (SRC) also absorbed all the assets of the National Institute for Research in Nuclear Science (NIRNS): the Rutherford High Energy Laboratory, founded in 1957 at Chilton; the Atlas Computer Laboratory founded in 1961, also at Chilton; and the Daresbury Nuclear Physics Laboratory.

NIRNS had set up the Atlas Computing Laboratory, at the request of the Government, to manage 'a very fast digital computer' for use by university research workers in all subjects from mathematics to linguistics. The Laboratory was named after its original Ferranti Atlas computer. By 1965 the Atlas Laboratory was established as the main source of advanced computing for university scientists.

Over the twenty year life of the Council, much at Chilton may seem to have changed. In 1965 the Rutherford High Energy Laboratory was almost exclusively devoted to high energy and nuclear structure physics. Now the work of the Rutherford Appleton Laboratory is in a wide range of scientific and engineering projects. In the early days, users wanting to telephone the Laboratory made what were then known as 'trunk' calls – with great difficulty – through one of the last manual exchanges in England, at Abingdon. In 1985 the Laboratory is linked to fast computer networks across Europe and the Atlantic, and to satellites in space. Even the address has changed: Chilton has moved from Berkshire to Oxfordshire.

Two things have not changed: the adaptability of the Council's staff and their sense of equal partnership with university research workers in the construction and use of major research equipment. Before 1965 the Rutherford Laboratory's programme had already been extended beyond nuclear physics to include the support of university chemists and physicists using neutron beams from the reactors at the Atomic Energy Research Establishment, Harwell, and the Atomic Weapons Research Establishment, Aldermaston. The construction of the proton synchrotron Nimrod, the proton linear accelerator for nuclear structure research, and three large bubble chambers had established a strong technological base – one which by 1985 has been widened to stretch from the most delicate integrated

Dr Geoff Manning, Director of Rutherford Appleton Laboratory.

Far left: *the Atlas Computer Centre in the 1960s.*

Centre: *Sir John Cockcroft, FRS, cutting the first turf at the Rutherford High Energy Laboratory.*

circuits to the heavy engineering of the Spallation Neutron Source. This adaptability and the partnership with universities, rather than any particular piece of hardware, have determined the fate of the Chilton site over the past two decades.

Ten years at Chilton: 1965 to 1975

At the Rutherford Laboratory this period could be sub-titled 'The Nimrod Decade', under Dr T. G. Pickavance, CBE, FRS, (Director 1957-69) and Dr G. H. Stafford, CBE, FRS, (Director 1969-81). The proton synchrotron Nimrod had first accelerated protons to 7 thousand million electron volts (7 GeV) in 1963 and six physics experiments had been carried out in the first six months of 1964. Nimrod supported a thriving high energy physics programme of international standing for 14 years until it was closed (in 1978) to allow the UK effort in high energy physics to be concentrated at the European Organisation for Nuclear Research (CERN) in Geneva.

The experimental programme at Nimrod was in three main areas: the nucleon-nucleon interaction, meson-nucleon scattering and weak interactions. In the early years, university teams made precision measurements of total cross-sections. Later work used polarised targets and very large detectors. The detailed accurate measurements on the scattering of pions by protons and neutrons were "achieved in the face of initial indifference and subsequent incredulity" said Professor Dalitz, in a review. "This supposedly barren and exhausted field . . . turned out to be one of the most fruitful areas of high energy physics". It laid the foundation for the invention of quarks.

In 1964 Fitch and Cronin discovered that the laws of physics are changed if charges are reversed and the world is reflected in a mirror – CP is violated. This result generated a flurry of activity in the study of the decay of particles through the 'weak' interaction. From 1965 onwards part of the Nimrod programme was devoted to the study of these 'weak' decays. CP violation in the decay of the K meson was confirmed in 1965, but in spite of many careful experiments, no further evidence of CP violation was discovered at Nimrod, or elsewhere.

Because of the enormous volumes of data to be analysed, computing had always been an essential component of the Rutherford Laboratory's activity. In 1967 the original Ferranti Orion computer was replaced by an IBM 360/75 which, in turn, was upgraded to an IBM 360/195 in 1971.

Meanwhile the adjacent Atlas Computer Laboratory (Director Dr J. Howlett, CBE, 1961-75) had outgrown its Atlas computer, and in 1971 it also acquired an ICL 1906A. Computers, however (unlike accelerators) became cheaper, individual universities and regional centres became better equipped, and by the early 1970s the Atlas Computer Laboratory was no longer "the possessor of the largest concentration of computing power in the UK".

Above: *part of the main ring magnet of the Nimrod proton synchrotron showing a beamline (to the left) that transports high energyparticles to the experimental area.*

Above: *early laser pulse transmitting and receiving equipment shown at a Radio and Space Research Station Open Day in 1964. It was used for measuring atmospheric dust distribution and for tracking satellites.*

Ten years at Ditton Park: 1965 to 1975

With the arrival of Mr J. A. Radcliffe as Director in 1961, Ditton Park had acquired a new name (Radio and Space Research Station) and an increasing role in space research. By 1965, half the staff were engaged on the space programme, including work on the Skylark sounding rocket, the design of payloads for European satellites, the Space Data Reduction Centre, and the tracking station at Winkfield. The Station used a variety of British, Canadian and American rockets to study the ionosphere and magnetosphere at some fifteen sites, from Woomera in Australia to Kiruna in Sweden. The Station produced equipment to fly in rockets to measure the composition and behaviour of the Earth's upper atmosphere using a wide variety of techniques. Staff designed prototype instruments for satellites launched by the UK and ESRO (the former European Space Research Organisation) and supervised their construction by industry.

In 1971 the Council's Space Research Management Unit, which was responsible for the support of university rocket and balloon research, moved to Ditton Park, bringing with it work on the design of comprehensive telemetry equipment.

In 1973 the Astrophysics Research Unit at the United Kingdom Atomic Energy Authority's Culham Laboratory became an outstation of Ditton Park. The Unit's research was centred on solar and cosmic astronomy using ultraviolet and X-ray spectroscopy, from instruments mounted on rockets and satellites.

In 1973 the Station was renamed the Appleton Laboratory in honour of Sir Edward Appleton, FRS, commemorating his association with the Station.

The Appleton Laboratory also became a user of spacecraft. Instruments of greatly increased sensitivity were flown on spacecraft launched by the American National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA), and on the Ariel series of UK satellites. Ariel V was the first UK mission dedicated exclusively to space astronomy carrying a suite of instruments to survey cosmic X-ray sources. It was one of the most successful space survey missions ever, operating for five years and generating a wealth of new astrophysical data of high quality. The Laboratory also managed, in collaboration with University College London, the UK contribution to the outstandingly successful International Ultraviolet Explorer mission.

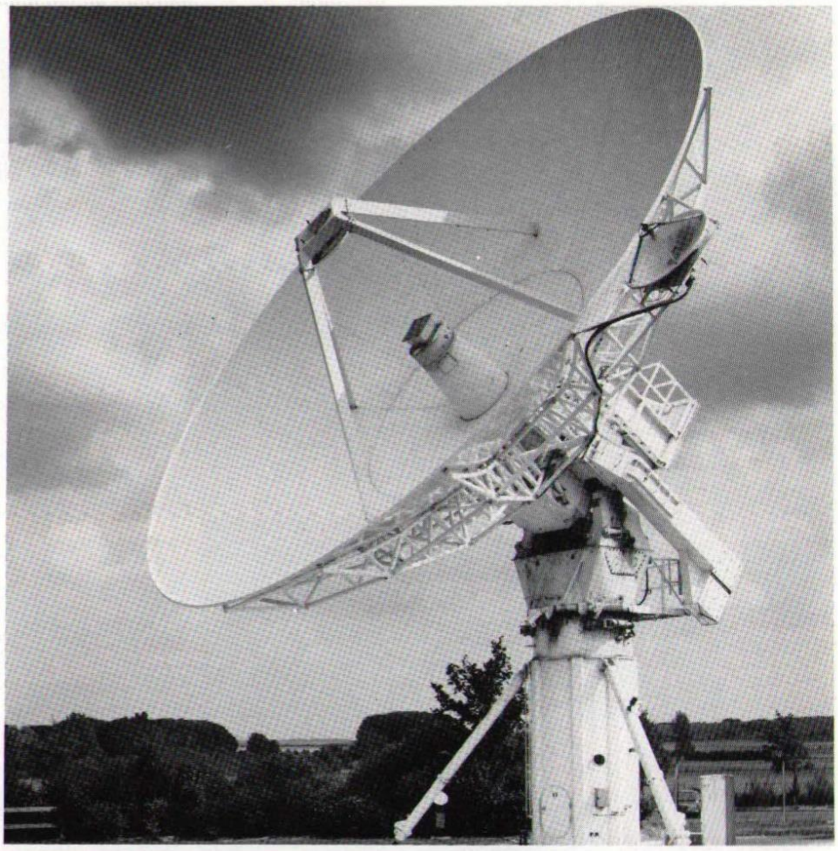
Creation of a multi-purpose Laboratory

The Atlas Computer Laboratory was merged with the Rutherford Laboratory in 1975. Two IBM 360/195 computers then provided a unified computing service for university scientists.

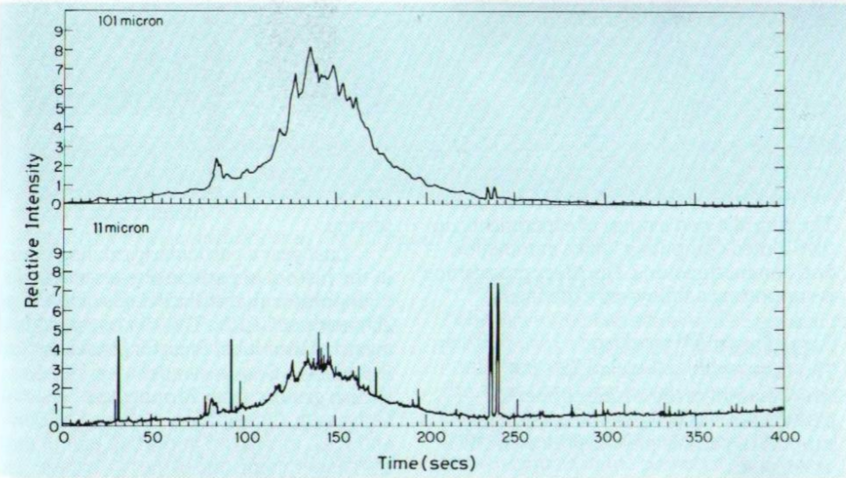
In 1979 the Council decided to merge the Appleton Laboratory with the Rutherford Laboratory on the Chilton site. The merger took about three years to complete; some 200 staff from Ditton Park and the outstation at Culham moved to Chilton. The end result was the Rutherford Appleton Laboratory (RAL), vigorously supporting the programmes of all four Boards of SERC. The next sections summarise our current work in each field.

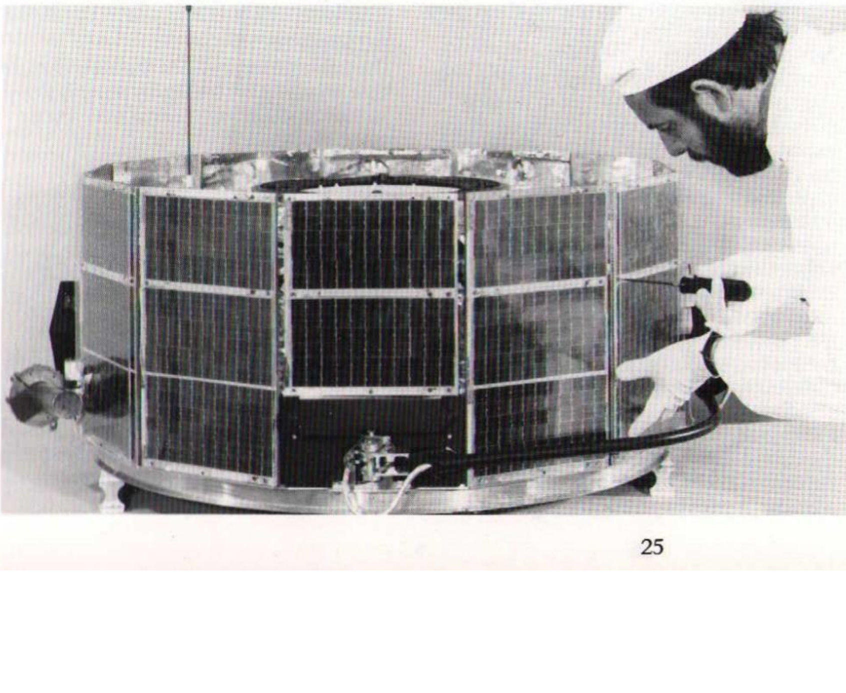
Astronomy, Space and Radio

The Laboratory works both on space projects and terrestrial observatories. RAL is constructing the 15 metre Millimetre-wave Telescope and supervising the construction of the building to house it on Mauna Kea on the island of Hawaii. The construction of the telescope presents formidable technical difficulties. For example, the reflecting surface must not deviate from a strict parabola by more than 15 microns (one-millionth of the diameter).



Above: *the 12 metre antenna at Chilton used for spacecraft command and data reception by the Operations Control Centre at the Rutherford Appleton Laboratory.*





The Laboratory also manages the Starlink computing network for astronomical image processing, the development and operation of atmospheric and ionospheric sounders, and support to UK users of the auroral radar EISCAT (European Incoherent Scatter Facility).

Collaboration with university groups in several major current space projects include:

detailed analysis of the unique data obtained from the highly successful infrared astronomical satellite (IRAS);

the active magnetospheric particle tracer explorers experiment (AMPTE);

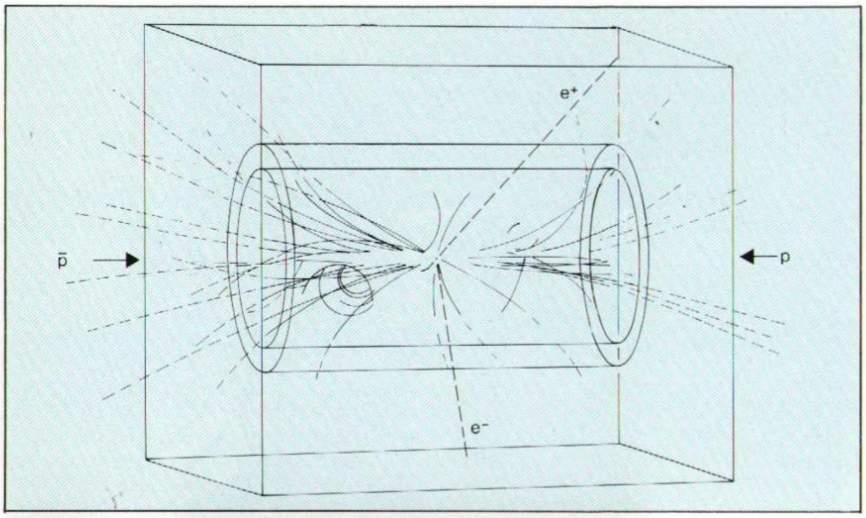
preparations for an experiment to measure the relative abundance of helium and hydrogen in the Sun;

construction of payloads for the German Roentgen (X-ray) satellite (ROSAT), the international Giotto mission to study Halley's Comet, the atmospheric science mission ISAMS (improved stratospheric and mesospheric sounder) and the along-track scanning radiometer for remote sensing of sea surface temperature.

The Laboratory's programme thus stretches from the Earth's atmosphere through the solar system to beyond the Galaxy.

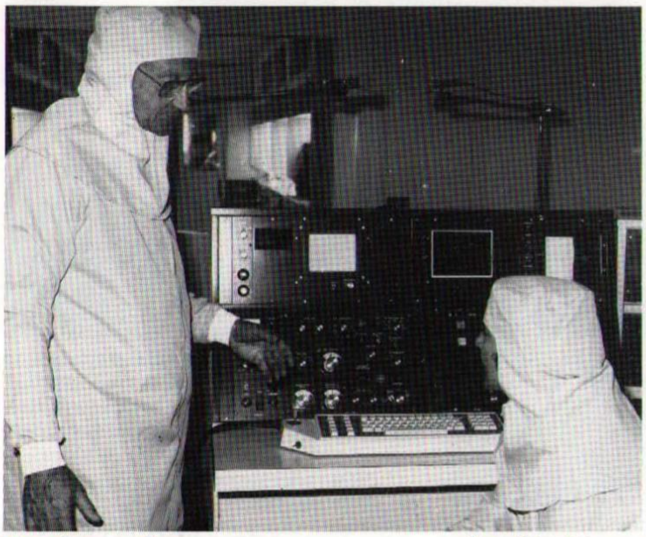
Above left: *first results from the infrared astronomical satellite (IRAS) – a scan across the Milky Way.*

Left: *the UK spacecraft for the active magnetospheric particle tracer explorers experiment (AMPTE).*



Discovery of the W and Z particles
Left: *the Z boson – a 3D computer reconstruction of the particle interaction.*

Below: *the Prime Minister hears about the search for the W particle as she stands in the heart of a massive detector of proton-antiproton collisions at the European Organisation for Nuclear Research. (Photo: CERN).*



Electron Beam Lithography
Left: *Dr Godfrey Stafford, Director, discusses the EBL facility with the Rt Hon Shirley Williams during the official opening in 1979 at Rutherford Laboratory.*

Engineering

The Laboratory played a major role in the planning of the Alvey programme in advanced information technology, and will take part both in the research and the coordination of the programme. SERC staff are working alongside the Alvey Directorate in all the main components of the programme: software engineering, very large scale integration, the man-machine interface, intelligent knowledge-based systems, infrastructure and networking.

The long tradition of radio research continues in the Departmental users' radio propagation programme in support of several Government Departments. The Laboratory also undertakes national and international work on utilisation of the radio spectrum. As part of the Council's specially promoted programme on radio communications, the Laboratory is working on mobile communications and, in collaboration with university groups, on the definition of an advanced communications engineering research satellite.

A consortium, including RAL, British Telecom, Cambridge University, University College London, Loughborough University, GEC-Marconi Electronics Ltd and Logica (UK) Ltd, has completed the Universities Expanded Ring and Satellite Experiment (Universe) which connected local area networks on seven separated sites at speeds of 1 million bits per second, via a satellite. The ring allowed a range of experiments on distributed computing, office automation and communications. The Alvey programme is supporting a follow-up experiment.

Nuclear Physics

The Laboratory is responsible for the coordination of the UK experimental particle physics programme and for the support of particle physics groups in UK universities.

This support of experiments at overseas laboratories pre-dates the operation of Nimrod. However, during Nimrod's working life, it was a relatively small part of the Laboratory's involvement in particle physics. Since the closure of Nimrod all the experiments have been carried out abroad, mainly at CERN, in Geneva. Particle physics experiments are now undertaken by international collaborations involving many physicists from several countries. The Laboratory has developed a particular expertise in integrating into these international collaborations the efforts of UK physicists, engineers, technicians and computing specialists both from the universities and from the Laboratory. In addition, the support groups at the Laboratory have unrivalled experience in the design and construction of sophisticated apparatus and modern electronics for particle physics experiments, together with the provision of a vital central computing service.

Last year a particularly exciting period in the history of particle physics reached a high point with the discoveries of the W and Z bosons at CERN. This discovery led to the award of the Nobel Prize for physics to Carlo Rubbia and Simon van der Meer. Three British groups, from Birmingham University, Queen Mary College London and RAL formed an important part of the UA1 experiment, one of the two experiments which have observed the W and Z particles.

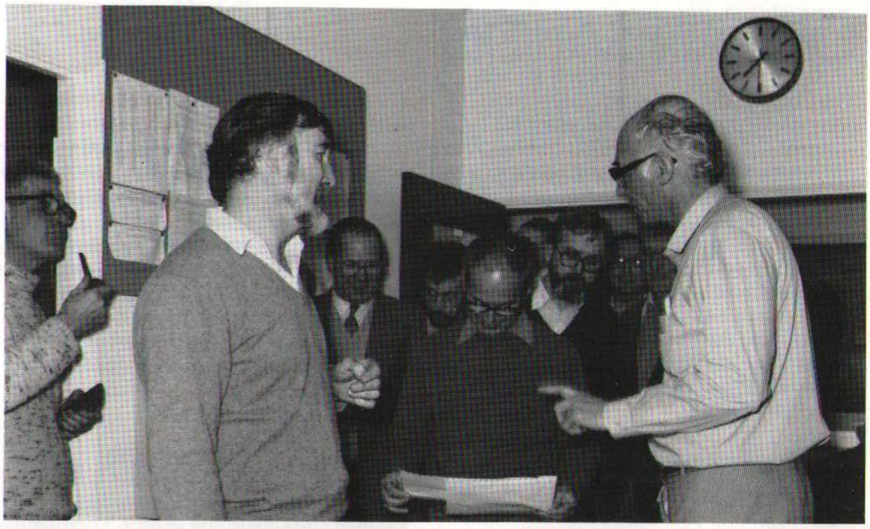
Science

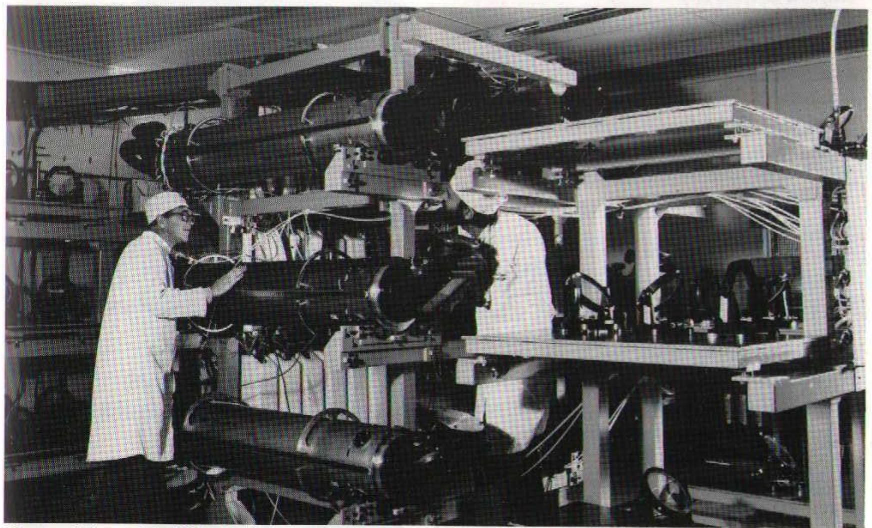
The Laboratory provides neutron beams and high power lasers for use by university and polytechnic staff in research over a wide range of science.

After a contruction programme stretching over seven years, RAL has nearly completed the most powerful pulsed source of neutron beams in the world, the Spallation Neutron Source (SNS). The first neutrons were produced on schedule at the end of 1984 and the commissioning run was extremely successful. The experimental programme will start with six instruments and three development instruments. The 400-strong UK university neutron scattering community has begun to form user groups for each instrument, and in early 1985 they were planning their first experiments.

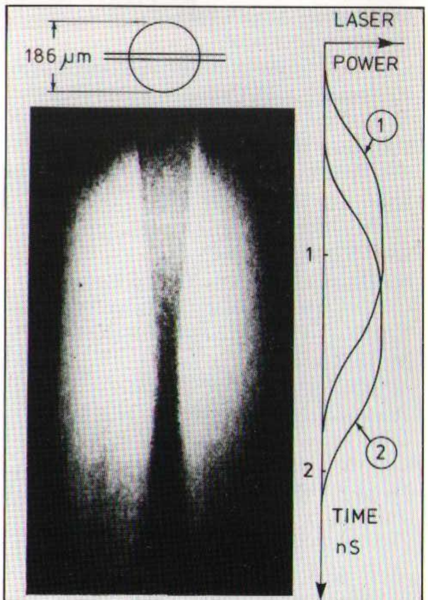
Complementing the SNS, the

Spallation Neutron Source
Right: *first neutron scattering results being examined 14 minutes after switch-on by (left to right): Alan Leadbetter, Head of Neutron Division, Geoff Manning, Director, and Harold Wroe. On 16 December 1984, 550 MeV protons, having travelled 1500 kilometres during their acceleration process, were focussed on to the neutron production target. The neutrons were channelled to six sets of neutron detecting equipment which were used to confirm the basic design of the whole system. This was a culmination of eight years' intensive work to build the £100 million facility.*





Central Laser Facility
Above: *array of disc amplifiers at the output of the multi-terawatt glass laser VULCAN.*



Above: *a time resolved radiograph – the first – of a spherical target imploded by six green second-harmonic laser beams.*

Laboratory provides support for experiments by UK university scientists using neutron beams from the reactor at the Institut Laue-Langevin in Grenoble, and a small number of experiments done at other overseas sources.

A Central Laser Facility was set up at Chilton and the first laser-driven implosion experiments began in 1977. The multi-terawatt (10^{12} watt) neodymium glass laser serves about 100 university researchers studying laser-produced plasmas. This facility has rapidly established an international reputation, particularly for new techniques. In 1983 the Council approved a major programme for enhancement of the glass laser, which gave new research opportunities in laser development and X-ray source applications, as well as 12 powerful green beams for implosion studies. The range of lasers now available includes smaller tunable lasers for research applications in chemistry, biology and engineering as well as physics, and the Laboratory has developed a new kind of high-power ultraviolet gas laser.

The Laboratory's programme also includes nuclear magnetic resonance instruments for biochemistry and a helium dilution refrigerator for university users.

Computing

Believers in reincarnation will be pleased to see that the Laboratory's mainframe computers still include an Atlas machine – the Atlas 10 sold by International Computers Ltd – which is operated in tandem with an IBM 3081. Important as they are, the improvements in the power of the central hardware have been overshadowed by developments in its distribution. By the early 1970s, Star networks provided entry to the central machines at Chilton from most universities. During the latter half of the 1970s multi-user minicomputers (GEC 4000 and PRIME) were installed in the universities and the Star networks were gradually developed to provide better services.

The first half of the 1980s has seen a trend towards distributed computers and the Laboratory now has ten times more power distributed within the universities than it provides centrally. The Joint Academic Network, a general purpose network for mail and file transfers serving all universities, is run from Chilton.

Computing has become a general commodity – not only essential for research work but also necessary for administration and management.

Looking forward

The Rutherford Appleton Laboratory is the largest laboratory in Britain dedicated to the support of university research. It employs about 1500 people and has an annual budget of about £55 million. The total number of university research workers supported by the Laboratory is around 4000.

Each of the three units which combined to make up the Laboratory brought with it expertise in various scientific disciplines. However the most important asset which the Laboratory possesses is its ability to interact with universities in collaborations in which we provide support, while at the same time retaining a small but credible presence in front-line research. Of the Laboratory's total resources about 93% is dedicated to the support role – but the 7% used on research is vital for replenishing its intellectual capital. This strength, together with its breadth of interest and ability to adapt to changing programmes, makes it possible for the Laboratory to face the uncertain future with confidence.

ORGANISATION

The Council, the governing body of SERC, is composed of a full-time Chairman and eminent scientists and engineers drawn from universities, polytechnics and industry. Currently it includes members from three government departments (the Departments of Trade and Industry, of the Environment and of Energy). Assessors represent other bodies with a direct interest in SERC activities: such as the Council of Engineering Institutions, the Council of Science and Technology Institutes, the Royal Society, the University Grants Committee and other Research Councils.

Four Boards, similarly constituted but with part-time Chairmen, cover the four main areas into which the Council's activities are split: Astronomy, Space and Radio; Engineering; Nuclear Physics; and Science.

The regular rotation of membership of the Council and its Boards and Committees maintain the principle of judgements by peers in scientific research and ensures that decisions regarding the support of research and postgraduate training are taken in the widest context.

John Visser, Director of Administration

Members of the Council

Sir John Kingman, FRS
Chairman

Sir Michael Atiyah, FRS
Research Professor,
Oxford University Mathematics Institute

Professor J. I. G. Cadogan, CBE, FRS
Research Director, British Petroleum plc

Professor B. L. Clarkson
The Principal, University College, Swansea

Professor A. H. Cook, FRS
Head of Physics Department,
Cambridge University

Sir Diarmuid Downs, CBE, F Eng, FRS
Chairman and Managing Director,
Ricardo Consulting Engineers plc

Mr G. R. Hall, F Eng
Director, Brighton Polytechnic

Professor C. Hilsum, F Eng, FRS
Chief Scientist,
GEC Research Laboratories

Dr M. W. Holdgate, CB
The Director General of Research,
Department of the Environment

Mr P. A. B. Hughes, CBE
Chairman of Logica Holdings Ltd

Professor A. G. J. MacFarlane, F Eng, FRS
Professor of Engineering,
Control & Management Systems Division,
Cambridge University

Professor E. W. J. Mitchell, CBE
Head of Clarendon Laboratory and
Professor of Experimental Philosophy,
Oxford University

Professor R. O. C. Norman, FRS
Chief Scientific Advisor,
Ministry of Defence and Professor of
Chemistry, York University

Professor M. H. Richmond, FRS
Vice Chancellor and Professor of
Molecular Microbiology,
Manchester University

Mr O. Roith, F Eng
Chief Engineer and Scientist,
Department of Trade and Industry

Sir Francis Tombs, F Eng
Chairman, Turner and Newall plc
and Rolls-Royce; Director N. M.
Rothschild & Sons and Celltech

Professor J. J. Turner
Professor of Inorganic Chemistry,
Nottingham University

Professor W. L. Wilcock
Professor of Physics,
University College of North Wales

Dr J. A. Catterall
Secretary

Assessors

University Grants Committee
Sir Peter Swinnerton-Dyer, Bt, FRS

Fellowship of Engineering
Dr A. A. Wells, OBE, F Eng, FRS

Royal Society
Professor R. J. Elliott, FRS

Council of Science and Technology Institutes
Dr P. G. Wakely

Department of Energy
Dr D. Pooley

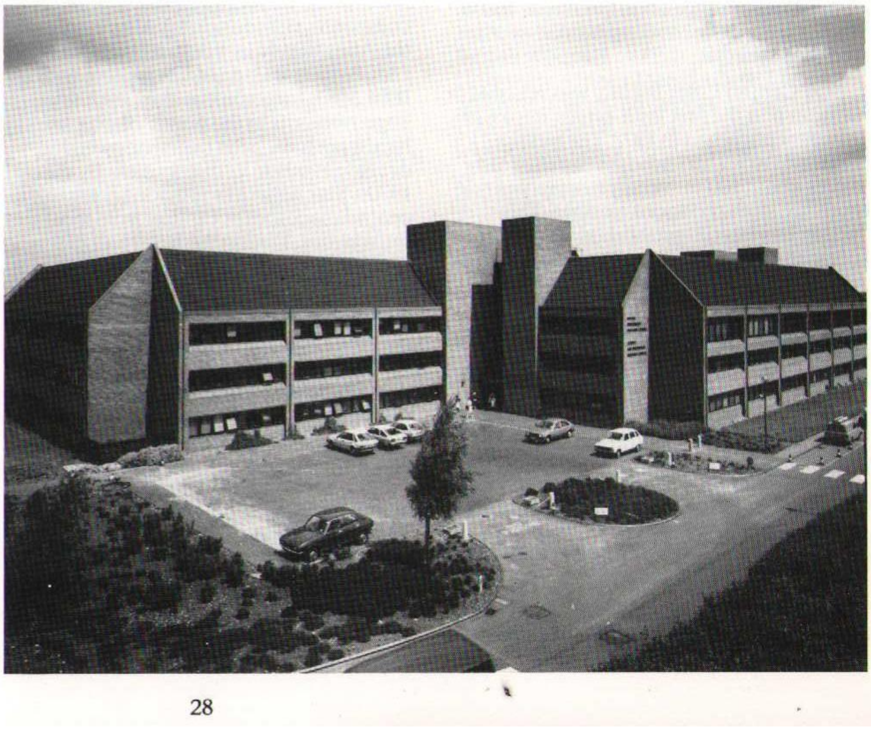
Foreign and Commonwealth Office
Mr R. Q. Braithwaite, CMG

Agricultural and Food Research Council
Sir Ralph Riley, FRS

Medical Research Council
Sir James Gowans, CBE, FRS

Natural Environment Research Council
Mr H. Fish, CBE

Economic and Social Research Council
Sir Douglas Hague, CBE



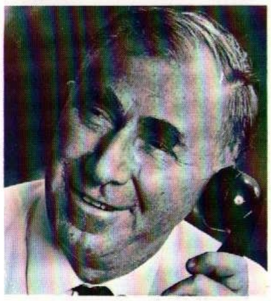
SERC Central Office, seen from Swindon BR Station.

SECRETARIES TO THE COUNCIL 1965-1985

1965-72

Dr W. L. Francis, CBE
1940-45 Radar research and administration in Ministries of Supply and Aircraft Production; 1945-65 Department of Scientific and Industrial Research (DSIR); 1978-83 member of Oxfam Council.

1972-78

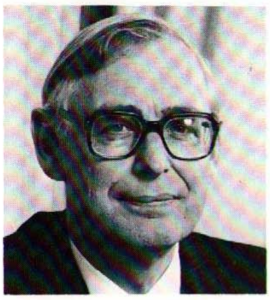


R. St. J. Walker, CBE (late)
1947-61 Administrative Civil Servant in Ministries of Supply and Aviation and the Imperial Defence College; 1962-64 Finance Officer, DSIR; 1965-71 Director of Administration, SERC.

1978-83

B. W. Oakley, CBE
1966-69 Radar Research Establishment Malvern; 1969-72 Ministry of Technology Computer Systems; 1972-78 Head of Research Requirements, Department of Trade and Industry (DTI). Since 1983 Deputy Secretary DTI and Director of the Alvey Programme.

1983-



Dr J. A. Catterall
1952-75 National Physical Laboratory; 1975-81 Department of Industry; 1981-83 Head of Energy Technology Division, Department of Energy.

Back cover:
SOME INTERESTING ACTIVITIES
(left to right from top):
The design of the first tension-leg platform. (Photo: Conoco).

A microcircuit made at Edinburgh University.

Study of mechanical properties of polymers at low temperatures, at Bristol University.

The Isaac Newton Telescope building on La Palma.

A sensor-guided arc welding robot system. (Photo: Oxford University).

Fluorescent X-radiation detection equipment at the Synchrotron Radiation Source.

ESTABLISHMENTS OF THE SCIENCE AND ENGINEERING RESEARCH COUNCIL

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

SERC London Office,
3-5 Charing Cross Road,
London WC2H 0HW
Telephone: 01-930 9162

Rutherford Appleton Laboratory,
Chilton, Didcot, Oxon OX11 0QX
Director: Dr G. Manning
Telephone: Abingdon (0235) 21900

Daresbury Laboratory,
Daresbury, Warrington, Cheshire WA4 4AD
Director: Professor L. L. Green
Telephone: Warrington (0925) 65000

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

Royal Observatory, Edinburgh,
Blackford Hill, Edinburgh EH9 3HJ
Astronomer Royal for Scotland & Director:
Professor M. S. Longair
Telephone: 031-667 3321

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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.
Telephone: Swindon (0793) 26222.

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