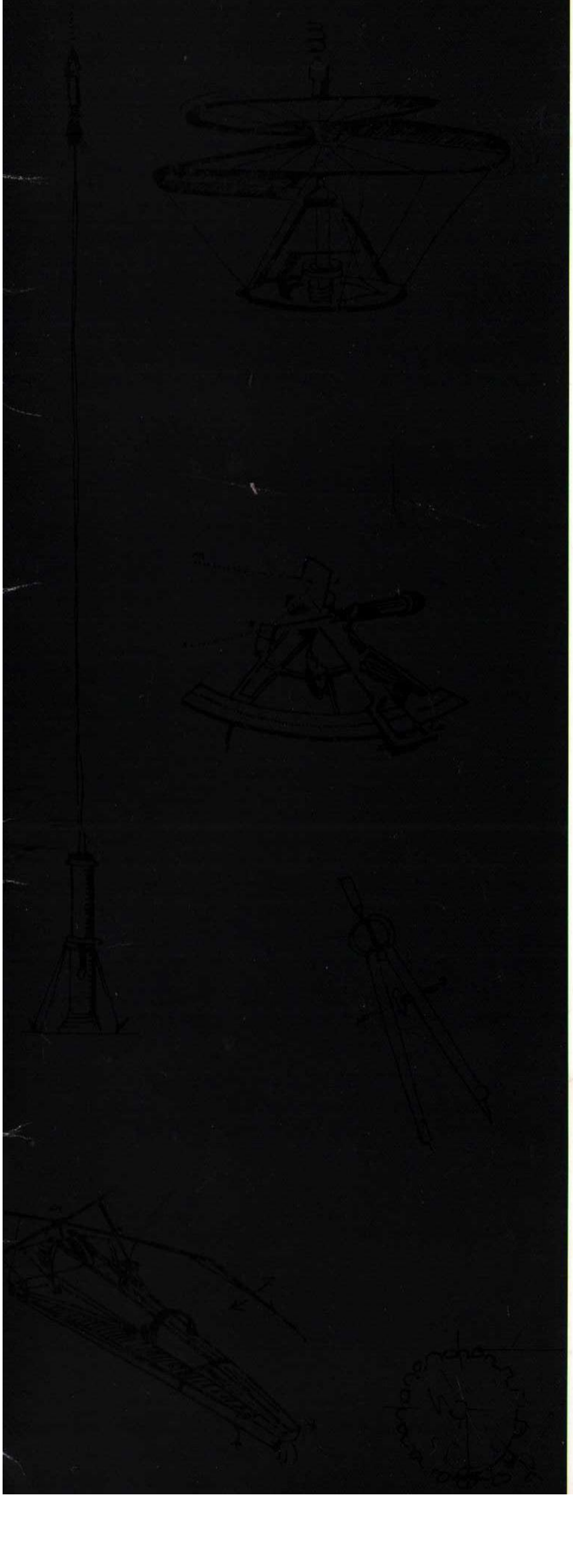
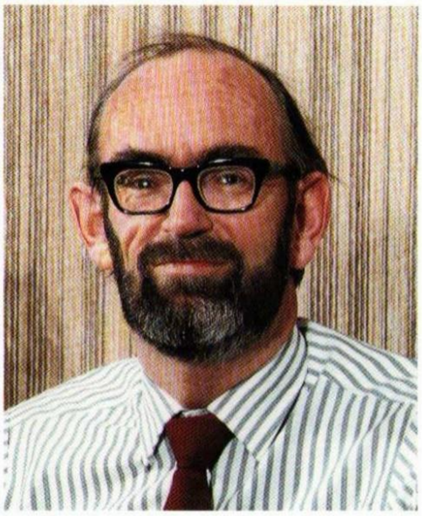
RAL



Rutherford Appleton Laboratory

SERC Science and Engineering Research Council



Foreword

Welcome to SERC's Rutherford Appleton Laboratory. I hope that you will enjoy seeing for yourself some of the exciting work we do here in support of the university and polytechnic research community and our international partners, work which keeps RAL at the forefront of science and engineering and of which we are justly proud.

RAL supports a wide variety of projects. Each year more than 1000 scientists and engineers visit RAL to use its world-class laser and neutron-scattering facilities. RAL staff design and build instruments which circle the Earth in satellites, increasing our understanding of ozone depletion and global warming, of the life cycles of stars and galaxies and, indeed, of the origin of the Universe itself. They work with their academic colleagues at international laboratories such as CERN, Geneva, where massive underground machines probe the microstructure of the atomic nucleus. Vastly complex calculations are carried out on the design of anti-cancer drugs, for example, using supercomputers at RAL.

You will find that RAL is a lively and progressive laboratory which continues the tradition of excellence for which Lord Rutherford and Sir Edward Appleton were renowned. I am confident that you will see ample evidence of the skills and industry of RAL staff and sense their great enthusiasm and commitment.

Dr Paul R Williams
Director

CONTENTS

RAL

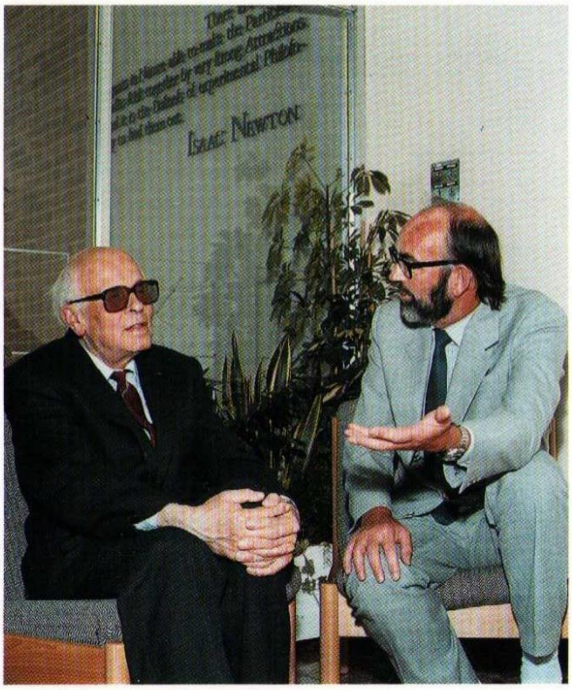
A MISSION TO EXPLO

Rutherford Appleton Laboratory (RAL) is operated by the Science and Engineering Research Council (SERC), one of five national research councils funded through the Department of Education and Science. SERC supports research and postgraduate training in science and engineering in Britain's universities and polytechnics.

RAL is the largest of four SERC laboratories whose main function is to support academic research by developing and operating world class facilities. At RAL this is mainly in the fields of space science, lasers, materials, particle physics, computing and information technology. About 6000 academic scientists and engineers make use of RAL in some way.

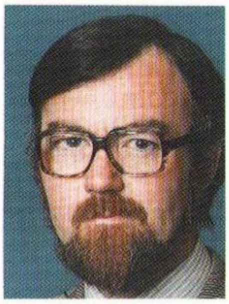
Situated fifteen miles south of Oxford on the northern slopes of the Berkshire Downs, the Laboratory presents an impressive range of expertise which has helped win its world-wide reputation. As well as supporting academic research, some of the scientists and engineers amongst RAL's 1400 staff collaborate in research projects themselves. Increasingly, research is carried out for other government departments and industry and as part of European Commission programmes.

The Laboratory welcomes many visitors each year, from primary school children to senior citizens.



The late Soviet human rights campaigner and physicist Dr Andrei Sakharov, pictured here with RAL Director Dr Paul Williams, visited the Laboratory in June 1989.

Situated in a pleasant location on the Berkshire Downs, RAL has grown considerably since its early days.



Professor John Harries, Head of Space Science Department

The UK space science community has an international reputation for the high quality of its research. World-leading instruments are designed and built by university groups in collaboration with Space Science Department. The RAL programme involves major instruments destined for space, from those designed for Earth observation satellites to those which view distant galaxies. The Department develops and operates ground-based facilities such as large radars and major data archives. RAL is the technical centre for space science for the British National Space Centre (BNSC).

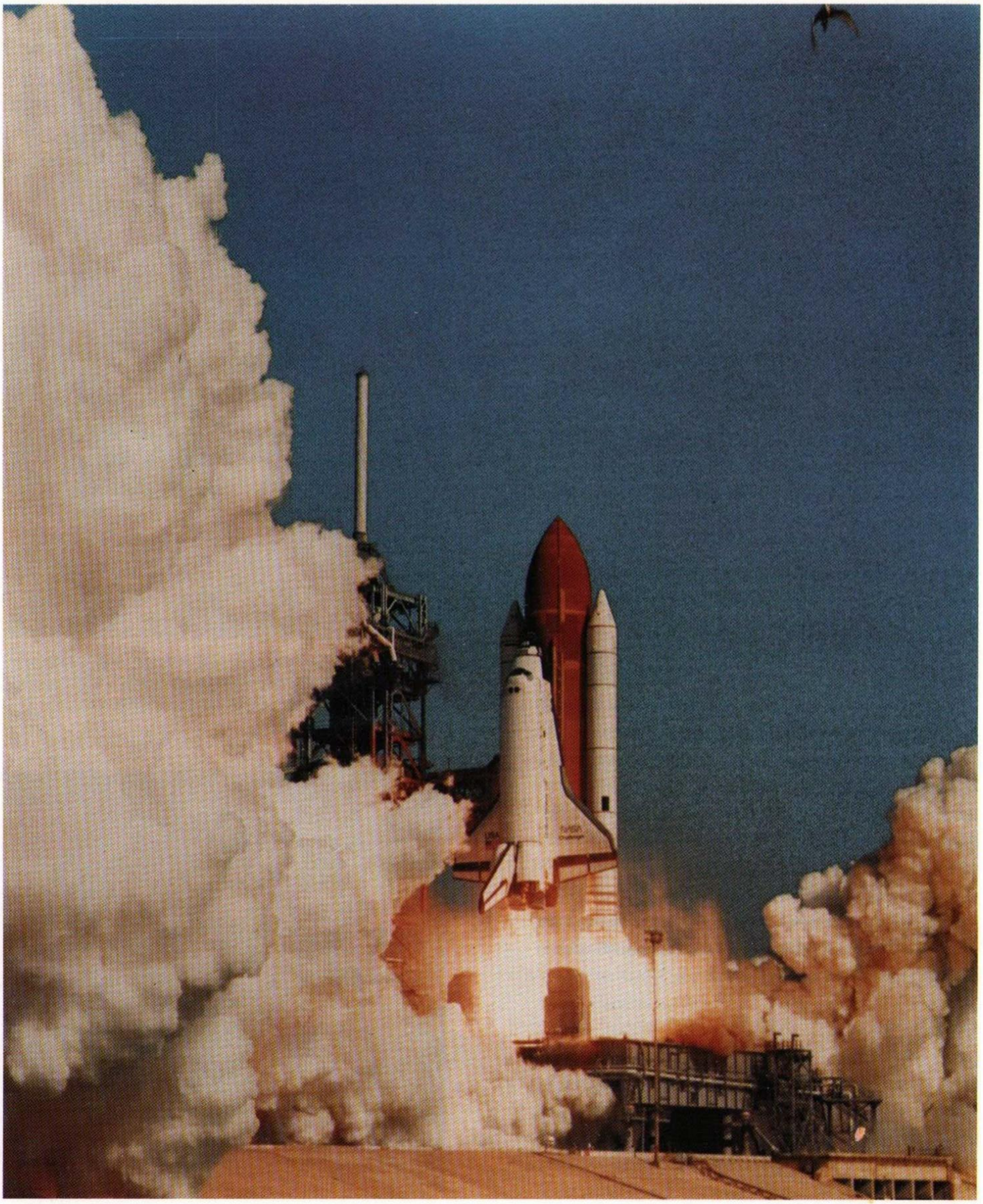
Space Science Department staff are involved in many collaborative projects with university teams, including:

- Earth observation where, from vantage points in space, the whole of the Earth's atmosphere and oceans can be surveyed in a matter of hours and with great accuracy;
- studies of the Sun and the way it affects our planet;
- a wide range of astronomy using satellites to look out at the Universe for X-ray, ultraviolet, and infrared emissions from distant stars and galaxies;
- interplanetary space missions, testing the very matter of the Universe and its planets, stars, and comets.

RAL supports university space science groups by:

- managing international satellite and ground-based projects;
- providing central facilities for developing and testing new space instrumentation;
- accommodating data acquisition and central data-processing facilities;
- maintaining its own laboratory and instrument research in support of space experiments;
- exploiting space data for research in collaboration with university groups.

From initial design to data analysis, RAL makes major contributions to the long-term research effort invested in UK space science projects and plays a leading role in the UK space science programme.



Satellites are launched into orbit on vehicles such as this NASA space shuttle. Instruments are tested at RAL to ensure they will withstand the severe vibration at take-off and the harsh environment of space once in orbit.

BUILDING INSTRUMENTS

The Space Environment Test Facility

Instruments being designed for space flight require rigorous testing during their development to ensure they will withstand the harsh environment of space. At RAL, facilities are provided to study the response of space instruments and models to various forms of vibration and to heating and cooling under vacuum. Computer programs are also used to assist in analysing how instruments respond to these conditions.

A large machine has recently been commissioned which can vibrate items weighing up to 35 kg, applying all the latest ESA and NASA environmental test specifications. Items being vibrated can be cooled to -269°C by a cryostat designed and developed at RAL - this is a unique facility for university groups in the UK. Vibration tests are particularly important in determining whether an instrument will withstand the rigours of rocket launch.

To simulate conditions when actually operating in space, instruments are placed inside a large vacuum chamber 1 metre diameter and 1.7 metres long which is repeatedly cooled (to -173°C) and heated (to 72°C).

The Facility also has large ultraclean laboratories in which instruments can be assembled for final testing prior to launch. A bakeout tank is used to clean instruments by heating them to drive out any unwanted contamination.

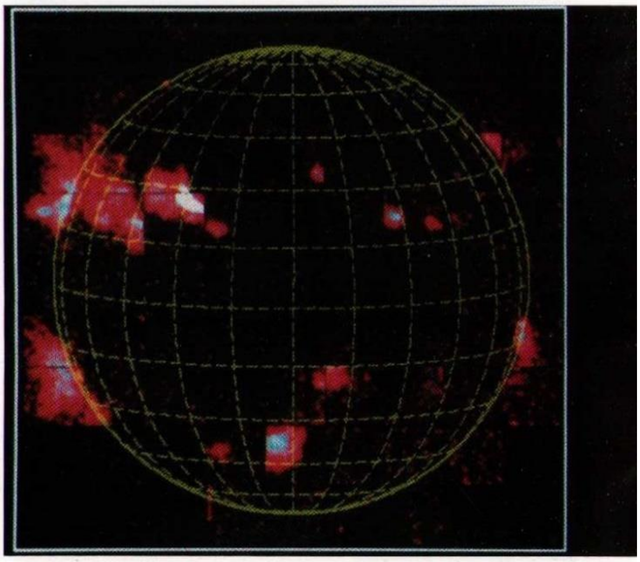
Many groups use the Facility for testing subsystems and small instruments, particularly where cleanliness of the testing or assembly environment is of paramount importance. Recent work has included testing instruments where the slightest speck of dust would spoil the high quality mirrors used to obtain very accurate measurements.

GETTING RESULTS

Scientists at RAL are working on experiments which will give us information on the Earth's environmental problems such as the greenhouse effect and holes in the ozone layer.

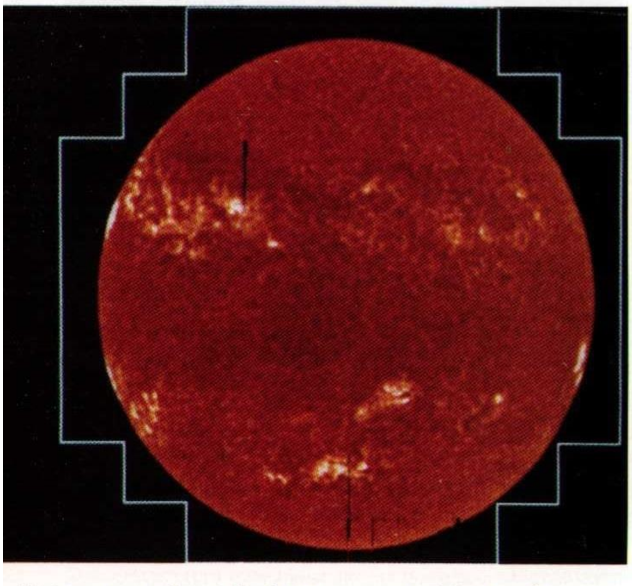
ATSR, the Along Track Scanning Radiometer, is due to be launched in 1991 on a European mission to survey the Earth.

Space instruments are built and tested under very clean conditions as the slightest speck of dust could impair the performance of equipment which cannot be cleaned once launched.



Pictures showing X-ray (left), ultraviolet (right) or optical wavelengths, giving information about the Sun's activity.

This highly polished mirror is part of the ATSR project to measure the temperature of the sea surface from 500 miles up in space. The mirror will rotate six times a second throughout the three year mission.



adiation are produced by instruments sensitive to these

This instrument will measure the temperature of the ocean surface from its position on an orbiting satellite high above the Earth. Temperatures measured to within half a degree will be more accurate than anything previously achieved by remote sensing and will help us monitor global warming.

Another instrument addressing the question of global change is ISAMS, the Improved Stratospheric and Mesospheric Sounder, due for launch on NASA's Upper Atmosphere Research Satellite (UARS) in 1991. ISAMS will study atmospheric chemistry by making measurements of gases thought to be responsible for ozone depletion and so help us identify possible solutions to the problem.

ANALYSING DATA

National and International Facilities

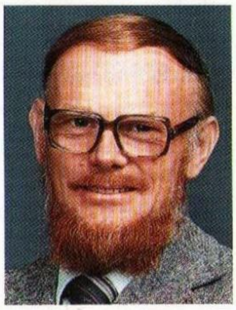
RAL acts as a centre for a range of data processing, communications and archiving systems. Amongst these are:

Starlink, a nationwide network of data analysis computers meeting the needs of more than 1000 UK astronomers. The network comprises 22 sites and a central management computer. Software development is guided by ten Special Interest Groups.

the Geophysical Data Facility (GDF), which helps UK researchers access a wide range of datasets in the fields of atmospheric science and solar-terrestrial physics. Data can be selected, browsed, plotted or networked to other computers for further processing. This data helps researchers increase their understanding of the processes which occur in the atmosphere. Data comes from satellite and aircraft missions and ground-based instruments such as radars and computer prediction models. GDF will become the main depository of data from UARS, the Upper Atmosphere Research Satellite due for launch in 1991.

the World Data Centre (WDC), part of a world-wide system of geophysical data centres. It collects a wide range of data on solar-terrestrial physics, the study of the transfer of energy between Sun and Earth. A major set of data held at RAL is an extensive collection of measurements from the ionosphere, the Earth's outer shell of electrically charged gas. WDC data is used in academic research and in many application areas such as the operation of short-wave radio systems.

RAL LASERS



Professor Mike Key, Head of the Laser Facility

The Central Laser Facility at RAL is one of the world's leading centres for high-power laser research. Two large lasers, VULCAN and SPRITE, are in operation and their continuing development maintains the Facility at the forefront of the laser field. An additional service is provided by the Laser Support Facility which maintains a wide range of smaller lasers for use at RAL and on loan.

Central Laser Facility

VULCAN is the most powerful laser dedicated to civil research in western Europe. It is a neodymium glass laser able to deliver over two thousand joules of energy in a pulse lasting just one billionth of a second and can reach a peak power of over five thousand billion watts. It has 12 beams which allow small spherical targets to be uniformly subjected to this intense power, heating them to temperatures approaching those at the centre of the Sun.

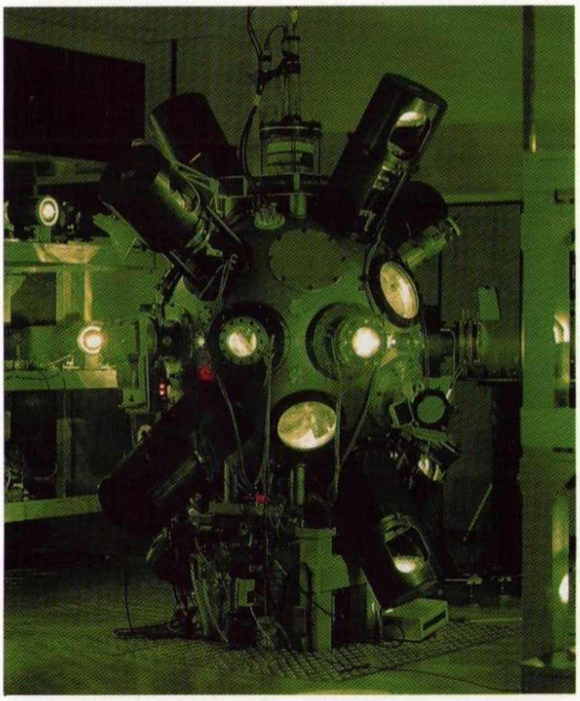
Lasers of this kind open the door to the generation and study of high density, high temperature plasmas such as those which exist at the centres of stars. In addition, scientists working at the Facility have made major contributions to the study of laser-plasma interactions.

VULCAN is also a very versatile high power laser. Successive laser pulses of different characteristics are supplied to experiments running concurrently in four separate target areas, each of which is optimised for a different application.

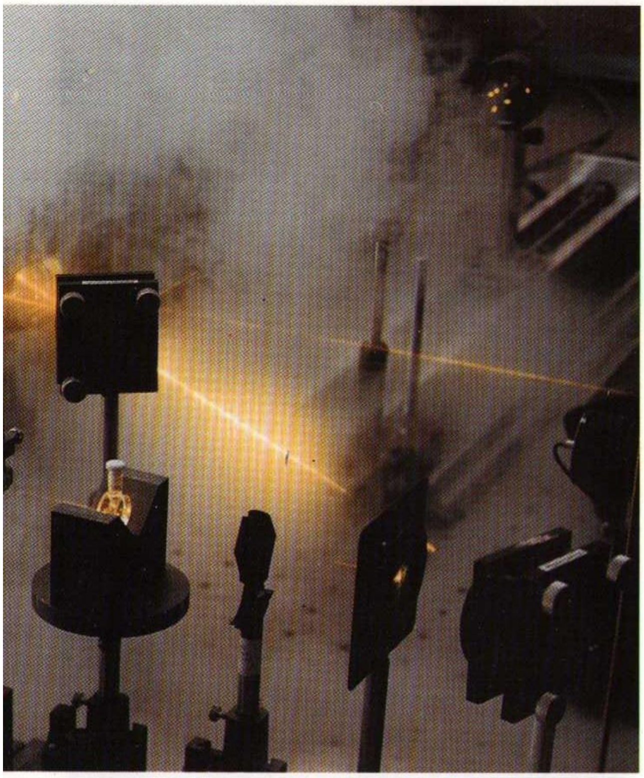
Research covers many aspects of plasma physics relevant to astrophysics, X-ray laser and fusion projects. VULCAN has recently been used to produce an X-ray laser by amplifying the X-rays emitted by a plasma. A laser system of this type could be used to study and photograph individual living cells.

SPRITE is a krypton fluoride gas laser. Its development involves a novel technique of combining laser beams which is paving the way for the development of high power lasers, both in this country and at a possible European High Performance Laser

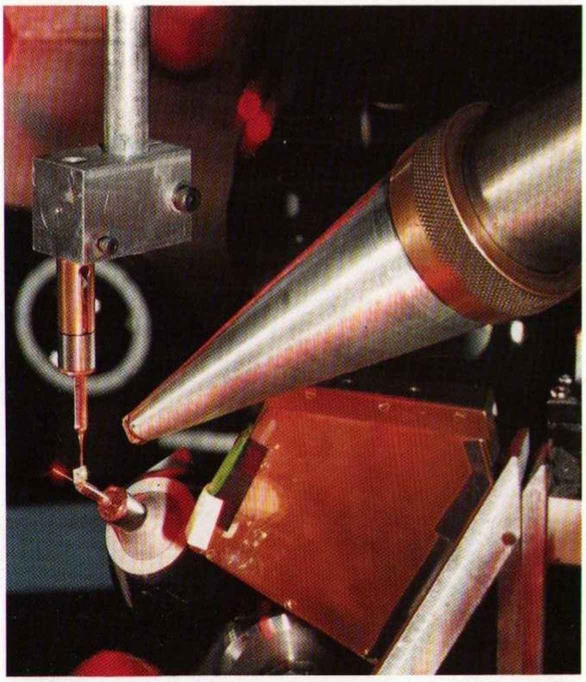
Laser beams directed on to a specimen allow the mysteries of photo-



Inside this target chamber the twelve beams of the VULCAN laser are concentrated on a glass sphere smaller than the head of a pin - the temperatures created approach those at the centre of the Sun.



nthesis to be studied.



Dense plasmas are formed when two lasers are focused on to a thin foil of plastic coated aluminium. The spacing between the ions in these plasmas can then be measured using laser-produced X-rays.

Facility. Advanced designs predict that using this system a laser capable of producing one hundred thousand joules of energy and a remarkable million billion watts of power is a distinct possibility.

Laser Support Facility

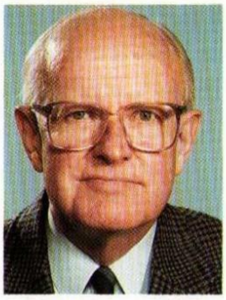
The Laser Support Facility (LSF) operates and develops a number of smaller lasers used for basic scientific research by the academic community. Frequency-tunable and ultrashort pulse lasers, delivering wavelengths from ultraviolet to the infrared, are available on loan or for use at RAL. The Facility concentrates on the provision of complex pulsed laser systems which are valuable in the study of time-dependent processes in chemistry, biology, and some areas of physics. LSF is typically host to as many as three groups of scientists visiting RAL at the same time with a further seven groups using loan pool lasers in their own laboratories. Studies carried out with LSF equipment frequently complement and extend work which users originally began using their own less complex lasers.

Research is often multidisciplinary. One subject out of many is the sophisticated mechanism by which damage to the DNA of living cells is recognised and repaired. A team of biochemists and cell biologists from the Universities of Birmingham and Sussex and the Medical Research Council, working with LSF laser scientists and engineers, have used pulsed lasers to obtain a factor greater than ten improvement in time resolution over previous techniques. Cells are first damaged using either ultraviolet laser light or X-rays produced by focused laser pulses hitting a metal target. A second laser is then used to activate a radioactively labelled repair inhibitor.

Several groups use time-resolved structural information from light-scattering to identify and follow short-lived intermediate chemical species in complex reactions in, for example, catalysis.

Pulses of light shorter than one thousand billionth of a second are available. In such short times high powers can be delivered by pulses of low energy. In one physics experiment the electric field of the focused light wave is as strong as the forces welding atoms and molecules together and can produce instantaneous disruption.

RAL MATERIALS RESEARC



Dr Bob Voss OBE FEng
Head of Science Department

ISIS is a unique neutron scattering facility based on a world-leading source of pulsed neutrons. It is in demand from scientists in the UK and overseas. Agreements for its use exist with many countries and its activities continue to expand.

ISIS is a young facility, having been inaugurated in 1985. It is the most powerful neutron source of its kind in the world and has made major contributions in many areas of physics and chemistry. Scientists from the UK, from abroad and increasingly from industry come to use ISIS. At the heart of its wide-ranging impact and success is one tiny subatomic particle, the uniquely versatile neutron.

Neutrons are produced at ISIS by accelerating pulses of protons almost to the speed of light and then directing them on to a heavy target such as uranium. (Two other particles produced are neutrinos, used at ISIS for studies in fundamental physics, and muons used primarily for materials research.) There are currently fourteen instruments situated on neutron beam lines around the ISIS target station, each optimised in a different way for a variety of scientific experiments ranging from investigations of crystal structures to studies of magnetism and the forces which hold materials together.

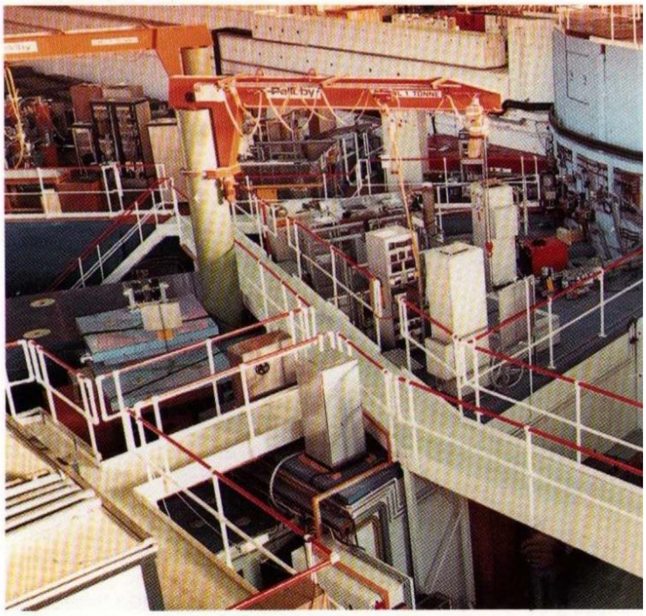
Superconductors and surface science, discussed below, are only two of the many areas of scientific study at ISIS. Nevertheless, they highlight the power of ISIS and the unique versatility of the neutron which helps provide answers to a broad range of academic and industrial problems.

High Temperature Superconductivity

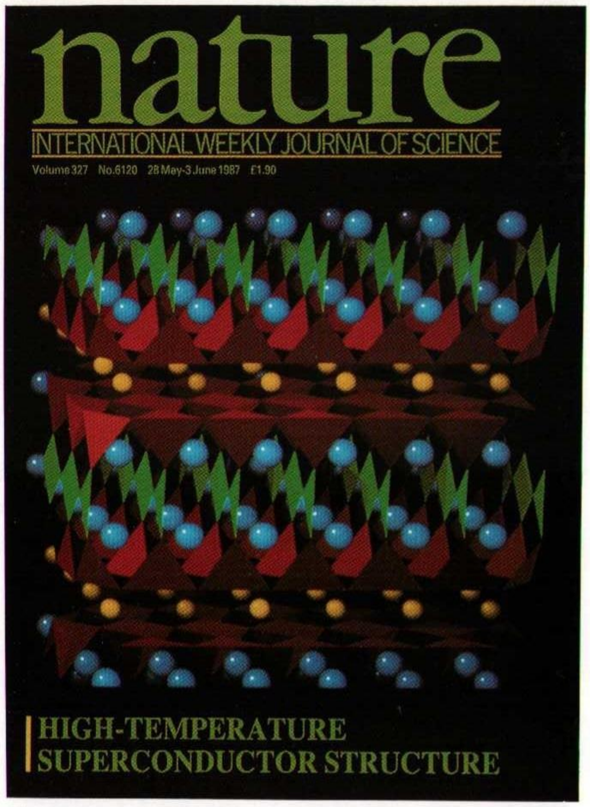
Why is diamond so hard? Why does ice float on water? Such questions can only be answered at the fundamental level by examining the arrangement of atoms inside the material - its crystal structure. Following the recent discovery of a new type of ceramic superconductor, its atomic structure was measured at ISIS.

Superconductivity is the loss of all electrical resistance when a

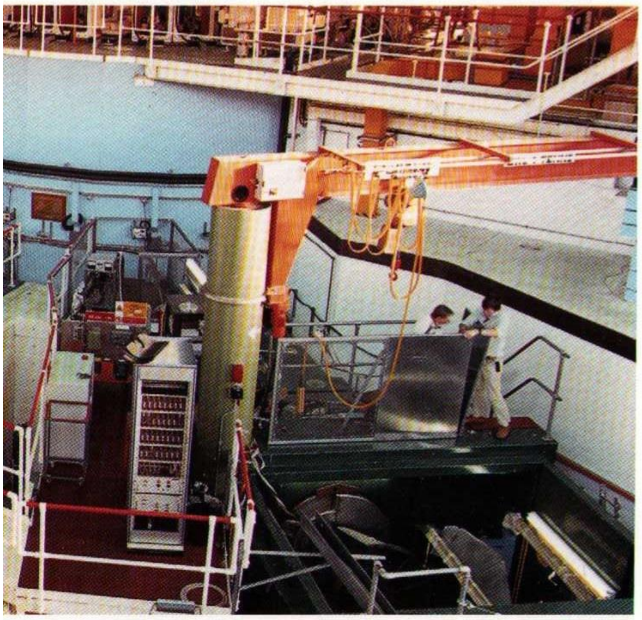
This 52 metre diameter circular machine (a synchrotron) is used to accelerate protons before they are diverted down a tunnel to collide with a uranium target.



The central target station is surrounded by instruments using fourteen



Using ISIS, the common factor in the structure of the new high temperature superconductors was discovered - the structure contains planes made up of copper atoms surrounded by a square of four oxygen atoms. The publication of this research had an impact across the world.



utron beams.

material is cooled below a certain temperature. Previously only observed near absolute zero, superconductivity was discovered in 1986 in a range of ceramic materials at the relatively warm temperature of –200°C. This discovery created a flurry of activity amongst researchers world-wide because of its many potential benefits such as ultrafast computers and cheap generation and distribution of electricity.

But what properties made the new material a superconductor? Scientists at ISIS were the first to publish the correct structure of the superconductor yttrium barium copper oxide. Neutrons were the ideal probe providing a complete picture of the positions of light and heavy atoms. The square arrangement of the oxygen atoms around the copper atoms has proved to be the key feature of all these materials.

Other experiments have investigated the superconductor surface and the motion of its internal structure. These measurements and associated theoretical studies at ISIS are revealing more about this new phenomenon.

Surface Reflection

A surface, although representing only a minute fraction of any material, has an importance which far outweighs its weight! Corrosion starts at a surface. Surface properties determine why Teflon is used for non-stick frying pans. The microscopic structure of a thin magnetic film defines the quality of a video tape recording. Such problems can be investigated by the CRISP reflectometer at ISIS where neutrons are reflected from the surface under study as light is from a mirror. The neutrons hardly penetrate the surface and can probe chemical and magnetic changes over very short distances ranging from the width of an atom to the breadth of a hair.

Scientists using CRISP showed that, whereas the magnetism in iron disappears as a magnetic film gets thinner, films of cobalt remain magnetic down to a single layer of atoms. This is of great interest to the magnetic tape industry. CRISP has also been used to study the drying of paint and to determine the arrangement of detergent molecules on an oily surface with unique clarity. Perhaps one of the most exciting uses of CRISP is in the study of plastics, investigating such varied topics as bonding and the nature of plastic blends.

RAL PARTICLE PHYSICS

Professor George Kalmus FRS, Head of Particle Physics Department

RAL scientists and engineers play leading roles in the international world of particle physics. Major pieces of hardware and software associated with experiments at European laboratories have been designed, constructed, and commissioned by RAL staff and the Laboratory acts as a focus for the collection and analysis of data.

Particle physics is the study of the properties and interactions of the elementary constituents of matter. These, according to our present level of knowledge, are quarks (which form protons and neutrons) and leptons (such as the electron). The interactions give rise to the four forces of Nature: gravity, electromagnetism and the strong and weak nuclear forces. All known particles and resulting matter are formed from these quarks and leptons. The study of all the particles is important in understanding the world we live in.

PARTICLE ACCELERATORS

LEP, the Large Electron Positron Collider

Many of the more unusual particles are best produced by recreating the conditions of the "Big Bang" thought to have formed our Universe. At that time, huge amounts of energy resulted in particles being created from the vacuum of space. This process is now reproduced in huge accelerators where simple particles like electrons or protons are accelerated to very high speeds and smashed together to produce massive bursts of energy.

LEP is a particle accelerator at CERN, the European laboratory for particle physics near Geneva. LEP is the world's biggest scientific instrument and came into service in 1989. It is housed in a circular tunnel 27 km in circumference and uses powerful electromagnets to keep the particles on a circular course. Four detectors sited around the ring record tracks left by particles produced when bunches of electrons and positrons collide. RAL staff designed and built major components for three of these detectors and provide technical and computer support to the fourteen UK university groups involved.

Each experiment is performed by an international collaboration involving hundreds of people and will continue over the next decade, during which millions of particle collisions will be observed. Computers are used to reconstruct flight paths of particles produced in the detectors to try to understand each particular pattern of particles.

In 1983 an experiment with a large input from RAL resulted in the discovery of the W and Z particles based on the observation of just a handful of these rare objects. At LEP thousands of Z particles are detected every day and new discoveries are eagerly anticipated.

With the large amounts of data produced in these experiments, Particle Physics Department makes extensive use of the IBM computer in RAL's Atlas Centre and also has its own machine (a DEC Vax cluster) with about 20 workstations.

HERA, the Hadron Electron Ring Accelerator

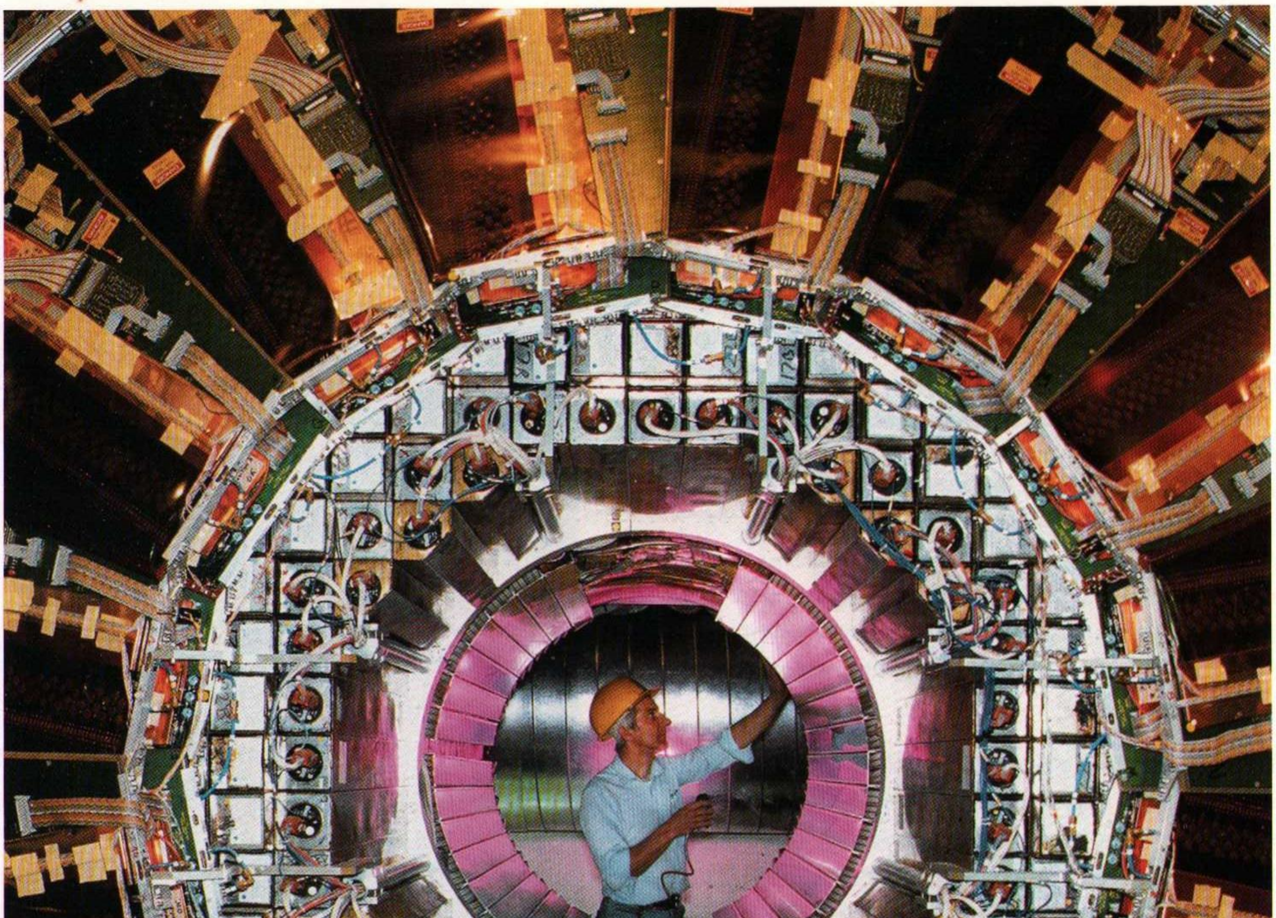
HERA, an electron-proton collider, is sited at DESY near Hamburg. RAL staff are working on HERA experiments which will be similar in some ways to the LEP experiments but collision of electrons with the much heavier protons will produce a different range of physics results.

OTHER EXPERIMENTS

Some interesting studies are done without accelerators. RAL has contributed to a 1000 tonne detector set about half a mile underground in Minnesota to detect proton decay. By carefully monitoring the enormous number of protons (about 10^{33}) in the iron of the detector one decay may be seen. This would once again change our theory of how the Universe works.

"Dark" matter is thought to make up about 90% of the Universe but has not been detected so far. RAL is collaborating with university groups in developing very sensitive new detectors. These will also be housed deep underground in Yorkshire in order to shield the detectors from cosmic rays.

The Particle Physics Theory Group at RAL is continually testing and revising the theoretical models which describe the fundamental interactions of particles. The Group also supports experimenters by interpreting the complexities of the theories and testing them against experimental data.



DAVID PARKER/ SCIENCE PHOTO LIBRARY

After years of careful design and development the final pieces of a particle detector are put in place.

RAL COMPUTING

Dr Brian Davies, Atlas Centre, Head of Central Computing Department

Access to powerful computers is vital to today's researchers. These computers are used to perform enormous calculations and to process vast amounts of data quickly. The Atlas Centre provides a range of advanced computing facilities, including two supercomputers which constitute a unique resource for numerically intensive computing in the UK, accessible to users in the UK and abroad through a computer network.

SUPERCOMPUTERS

IBM 3090-600E

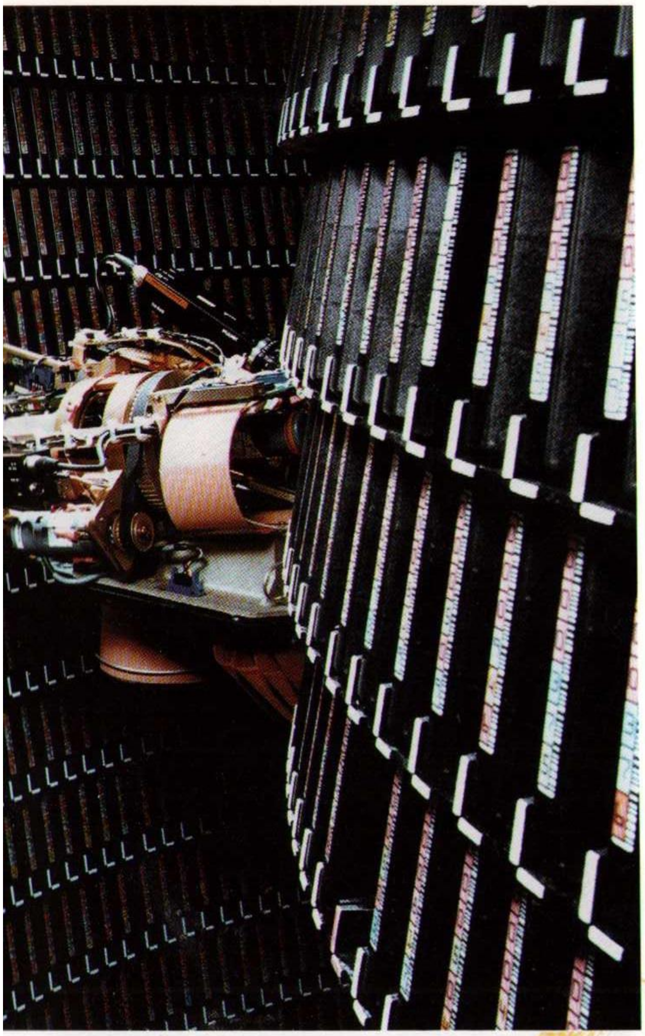
The IBM machine is a supercomputer with six processors. A share is allocated to a joint study between SERC and IBM on supercomputing and its applications, including drug design and computer modelling.

Another use of this computer is handling and analysing data from the LEP experiments at CERN. Data arrives on sealed magnetic cartridge tapes, each of which can hold up to 200 million bits of information. The cartridges are stored in a robot-controlled library. Under the control of an operating system on the mainframe computer the robot fetches a cartridge from its storage slot and mounts it into a drive. Data is then read from the magnetic tape and transferred to the computer's main memory for processing by the user.

The IBM also hosts PROFS, the professional office system which provides office automation facilities for RAL staff. Documents can be created, edited and viewed at the user's terminal or printed on the user's printer. Electronic mail can be sent and received and there is a comprehensive diary facility for keeping a note of appointments, scheduling meetings and booking conference rooms. Databases containing personnel and financial information also assist in the management of this large Laboratory.

Vast amounts of information are stored at the Atlas Centre including data Once data tapes are loaded they are selected by robots as requested by

The Cray supercomputer is built in this unusual shape to minimise the length of electrical connections, thereby increasing its speed of operation.



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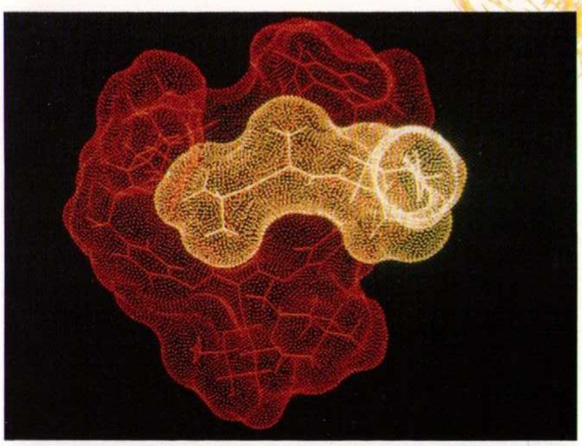


The power of supercomputers is being used to great effect in drug design and modelling.

Cray X-MP/416

The Cray supercomputer is provided as a joint facility for all the Research Councils. It is a powerful computer consisting of four computer processors, each capable of running up to a quarter of a billion operations every second. A wide range of scientific research is being carried out with the aid of this supercomputer including protein crystallography, drug design, oceanic and atmospheric modelling, structural engineering and atomic and particle physics.

A project which has made very successful use of the Cray is the UK Universities Global Atmospheric Modelling Project (UGAMP). This has involved a collaboration of seven university research departments and has led to a greater understanding of the large-scale motion of the atmosphere, the dynamics of the troposphere and stratosphere and the chemistry and radiation of the stratosphere and mesosphere.

NETWORKING

The Joint Network Team (JNT) is based at the Atlas Centre. This team develops and supports the Joint Academic Network (JANET) which provides links between RAL, other SERC establishments, UK universities and polytechnics, and access to networks in other countries. This enables scientific research workers to communicate with each other, sharing data and submitting computer programs to be run on other computers such as those at the Atlas Centre. Output from these programs, including graphics files, can be returned over the network to be viewed locally by the user. JNT has been instrumental in setting up many international network links such as that between JANET and NSFnet, the National Science Foundation's network in the USA, thus assisting the work of the many multinational collaborations in which RAL and other UK scientists are involved.

USER SUPPORT

The Department mounts a comprehensive user support service providing a help desk, a program advisory office, documentation services and a wide range of educational courses on all aspects of Atlas computing facilities.

Professor Bob Hopgood, Head of Informatics Department

Today's world of ever more powerful computing tools still relies on human users to make the most of new advances. Informatics Department places a strong emphasis on helping users, from making best use of existing software to incorporating new technology such as the transputer into their workplaces.

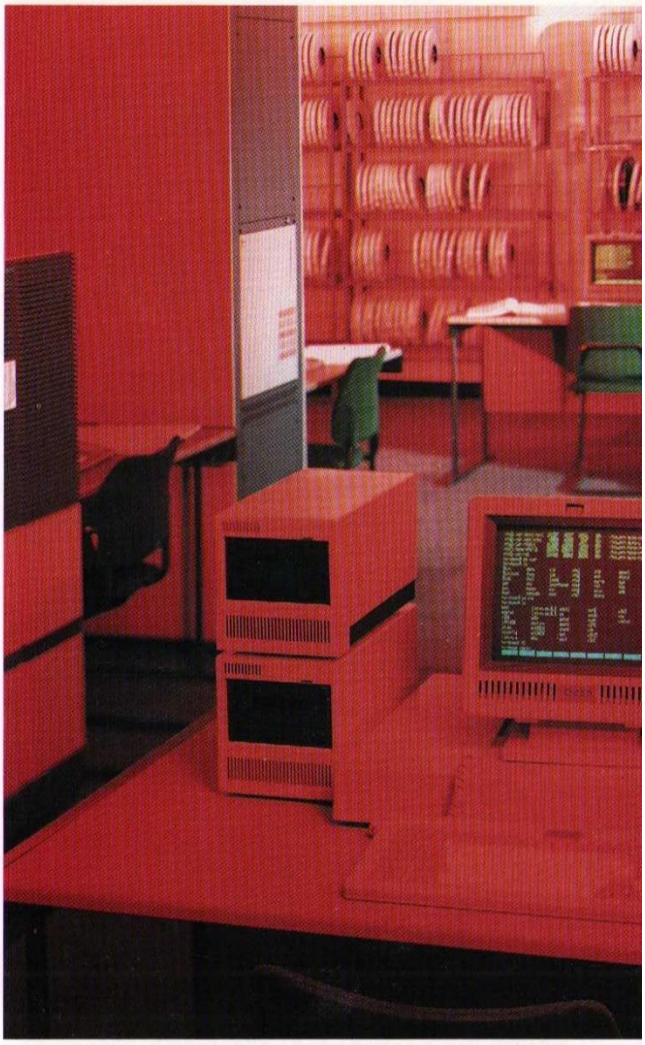
Informatics Department exists to provide the best and most suitable information technology, and advice on how to make the best use of it, to engineers carrying out research in universities and polytechnics. It also carries out research itself to determine what 'the best' really is.

Informatics, from the French word informatique, is really shorthand for Information Technology. Information is anything which can be stored as strings of 1s or 0s in a computer. It could be numbers, words, pictures, sounds, facts, descriptions of objects but not the scent of a rose or the quality of mercy, for example.

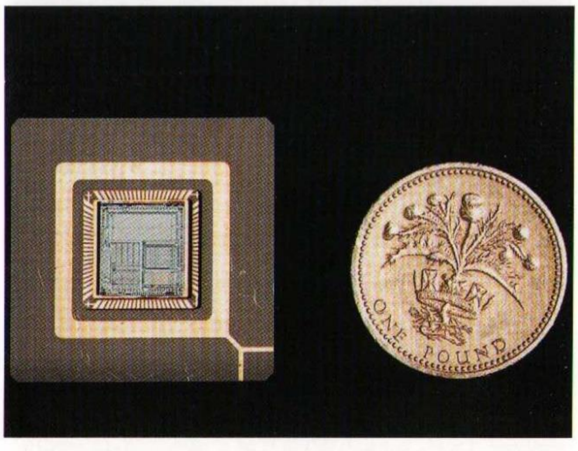
Support for Engineers

Support for engineers is concentrated on evaluating the very latest technology, adapting it for engineers and then informing them about it.

Many of today's engineers write computer programs. This is usually because they have a new idea or technique they wish to try or because existing products do not do quite what they want. Unfortunately, once they have written the new and exciting part of the program, they have to build a user interface, generate graphical output, agree data exchange formats with other applications and so on. This can be tedious. By providing a set of tools which can be thought of as a ready made kit of parts, guaranteed to fit together in many different ways provided that the engineers build their basic structure in the right way, the engineering researcher's productivity can be improved.



These computers ('servers') require very little human intervention.



The transputer is a computer on a single chip which can be connected to many others to build a supercomputer.

Finite Element Methods

Engineers now use computers to study how objects will behave under certain, often extreme, conditions without having to build them first. This ensures, for example, that structures can be designed to withstand earthquakes or high winds or that fuel is burned more efficiently in a car engine, thus reducing the amount of harmful pollution produced.

Engineers divide objects into small regions (finite elements) in which variations in the quantities of interest (such as displacement or stress) can be computed. They then assign material properties and external forces to all the elements, assemble all the equations, find a solution for the total system, display the results and try again with different parameters. Complex objects may need many thousands of elements. Their design and analysis can be very demanding, requiring use of sophisticated software and powerful computers.

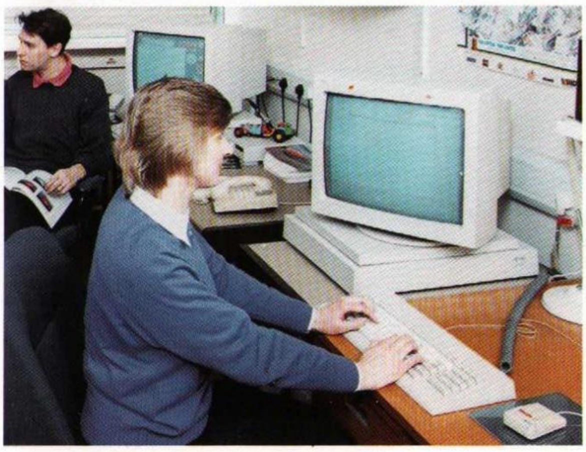
Informatics staff are working with engineers to provide the tools required for specific applications and are investigating the use of advanced computer systems to solve engineering problems such as the design of electromagnets for body scanners and particle detectors, modelling the transistors in silicon chips, and studying complex fluid flows.

Visualisation

Engineers are used to looking at engineering drawings, and graphics designers at sketches. Modern computer graphics make it possible to provide an astonishingly realistic picture of any object - real or imaginary - complete with coloured lighting, soft shadows and reflections.

Modern supercomputers like RAL's IBM 3090 and Cray X/MP solve many problems but create others, one of which is how to understand the torrent of numbers produced. One picture is worth a million numbers, especially if it enables the user to explore the vast multi-dimensional dataset as easily as the USS Enterprise explores hyperspace!

A number of different computer architectures are being compared which might be used for the visualisation of engineering data. These include graphics supercomputers (now almost as powerful as their big and costly brothers), the distributed array processor (combining over a thousand computers) and various parallel processors which exploit the transputer (still the leading computer on a single chip). An amazing amount of computer power can now be packed into a small box on a desk.



Users access servers from engineering workstations in their offices.

RAL ENGINEERING

Mike Morris, Head of Technology Department

Technology Department is a centre of engineering expertise in a number of areas. It undertakes a wide range of work, from engineering on the minute scale of a microchip to the building of massive instruments such as telescopes and superconducting magnets. It turns concepts into finished products to meet the requirements of research scientists.

Astronomical Telescopes

The James Clerk Maxwell Telescope (JCMT) is the largest of a new generation of radio telescopes designed to receive sub-millimetre signals from space. These wavelengths reveal the clouds of dust and molecules where stars are born and other interesting regions of the Universe hidden to visible light and to traditional radio-wave astronomy.

JCMT has a reflector 15 metres in diameter with a surface accurate to a fortieth of a millimetre or one part in 600,000. Despite its size, it points to within a thousandth of a degree. It is sited on a 4,000 metre mountain top in Hawaii where the best observing conditions are found. Such an environment can be very harsh. The wind is strong and the Sun's rays are unattenuated so a telescope as sensitive as JCMT needs to be protected by an enclosure.

The reflector and enclosure were designed at RAL and were assembled, tested and commissioned in Hawaii by RAL staff. The telescope was completed in 1987 and opened by HRH Prince Philip The Duke of Edinburgh. Since then it has been used by many astronomers from UK universities and other establishments world-wide.

Large Magnets

The latest generation of particle physics collider experiments requires large volumes of high magnetic field to assist in particle detection. Such fields can only be generated economically over long periods by using superconducting magnets.

RAL recently constructed two of the world's largest superconducting solenoids for particle physics experiments at CERN and at DESY. RAL undertook their design, fabrication, assembly, testing and installation.

The coils were designed to be cooled to a temperature of -268°C using liquid helium. They carry a current of 5,000 amps and produce a field uniform throughout the bore of the magnet, 5 metres diameter and 6 metres long. The coils were constructed by winding superconducting cable in the form of a solenoid, supported within a thick cylinder to restrain the large magnetic forces. Specially designed coil winding and assembly facilities were set up. Contracts for major components, superconductors, coil shells, and vacuum vessels were placed throughout Europe and the larger components brought to RAL for assembly.

The magnets were shipped to Geneva and Hamburg by a specialist company since the 75 tonne, 6 metre high loads were at the limit of what could be transported by road.

Microstructure Fabrication

Electron and ion beams are used to produce structures with features far narrower than a human hair. The Electron Beam Lithography Facility (EBLF) at RAL supports state-of-the-art research in microelectronics and microengineering.

Modern electronic equipment is often made up of microchips. A microchip is a collection of tiny transistors, capacitors and resistors manufactured in a multi-layer sandwich to make up a three dimensional circuit. Manufacturing a chip usually involves making 'masks' which are used as stencils to etch the pattern of each layer. Up to 16 of these masks may be required to produce a chip - EBLF handles their production.

As the features are so small and because each layer of the chip must register exactly with those above and beneath the technological demands are very high. EBLF has a range of high-precision machines in an ultraclean suite of rooms. The equipment writes and inspects the masks in virtually dust-free conditions of not more than 10 particles per cubic foot (a typical "clean" living area has about 1 million particles per cubic foot). These techniques are also being used for the production of very fine structures such as microfilters used for the determination of blood cell characteristics.

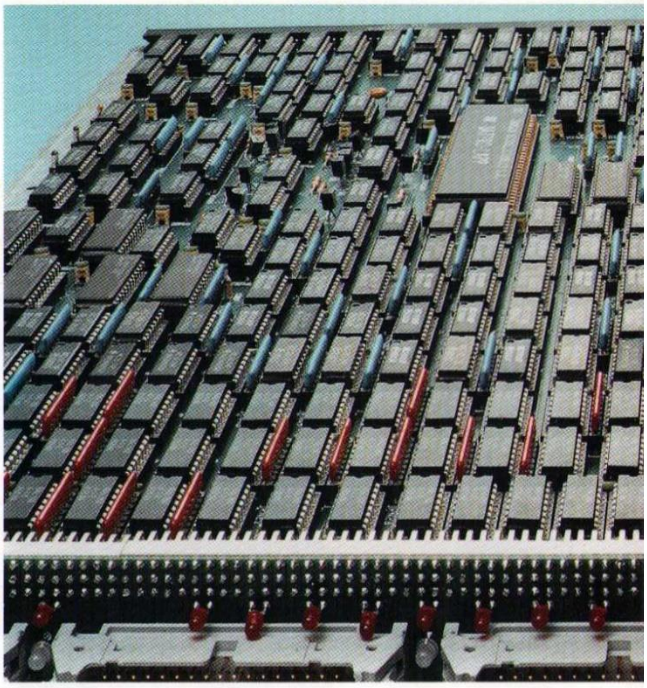
The James Clerk Maxwell radio telescope. The blind protecting the telescope from extremes of wind and Sun was made by Portsmouth sailmakers.

Electronics

Electronic technology increasingly forms the heart of modern research equipment. RAL provides state-of-the-art electronic systems for research projects funded by SERC and has a growing involvement in international and industrially-sponsored activities. Electronics is a rapidly advancing and exciting engineering discipline. It is an essential element in the quest to obtain the best technological solutions to a diversity of fascinating problems such as how to recognise a W or Z particle in a particle physics experiment or how to measure sea temperature from a satellite.

RAL provides a comprehensive range of electronic and microelectronic facilities throughout a project. These include design and simulation using the latest computer-aided design techniques, fabrication, testing, commissioning and maintenance.

Training plays a vital role in maintaining the up-to-date professional ability of engineers. The need to train engineers in the latest technology, especially in microelectronics, has been recognised by the EC in awarding RAL (in collaboration with four other leading European technology institutes) a major role in organising an ESPRIT project to train 3000 microelectronics engineers throughout Europe per year.



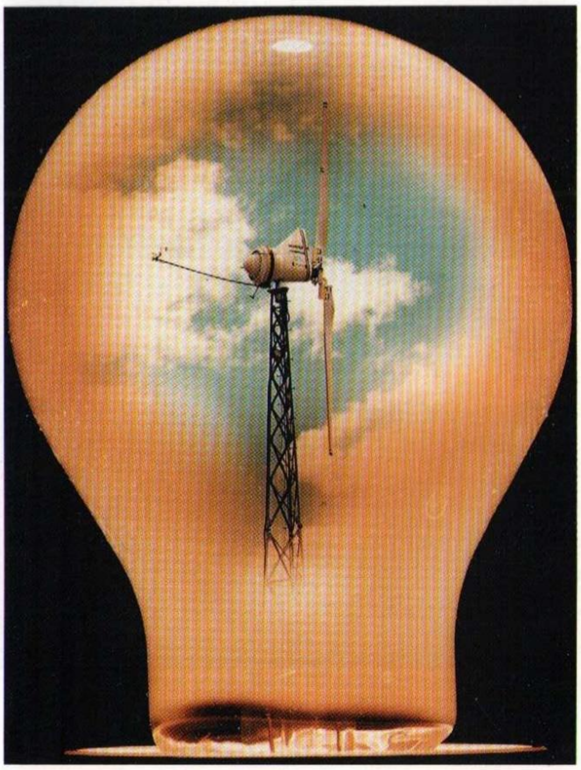
Systems like this, incorporating chips designed at RAL, are also for one of the LEP particle physics experiments at CERN.

Wind Energy

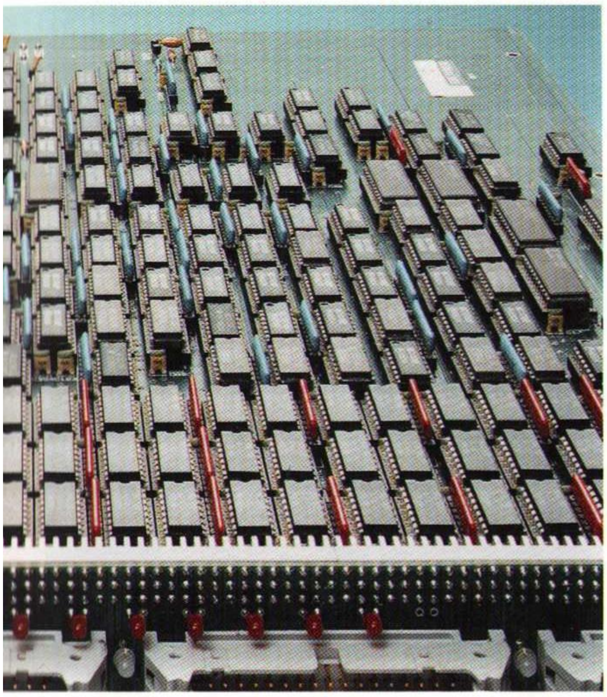
Research on alternative energy sources is receiving greater attention but there has been a lively research programme in wind energy at RAL since 1977.

Universities are playing an important role in UK developments in wind power. Pioneering work at the RAL wind energy test site has included development of novel machine designs (since adopted by industry), investigation of wind prospecting methods and the use of computer simulation models to investigate the problems of incorporating wind power into large and small electricity networks.

The largest of the current projects will take wind system integration a further step towards possible commercial realisation. It involves novel work using a flywheel to buffer



Wind energy is becoming increasingly important as other energy sources become more costly or environmentally unacceptable.

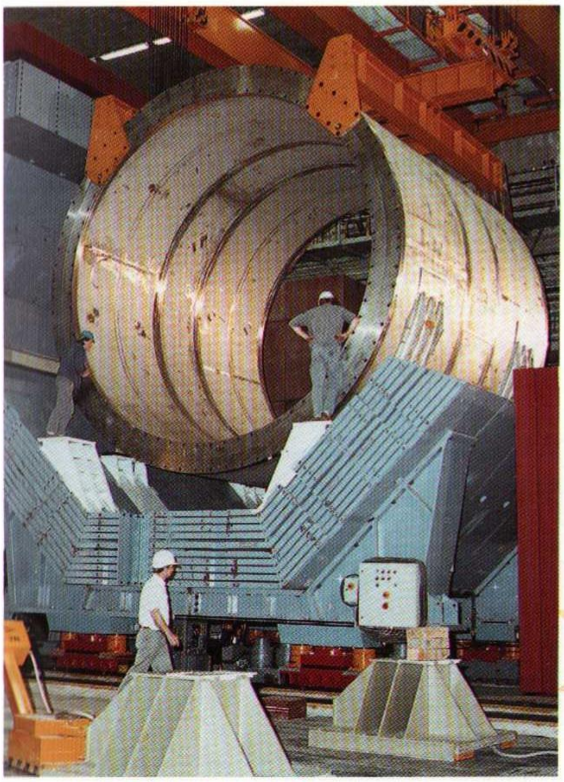


esigned and built here. This electronic readout system was produced

the fluctuating output of a wind turbine and will be extended to building and researching a system with a nominal power output of 40 kilowatts.

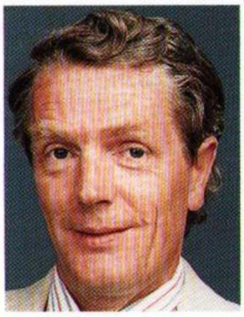
Radio Communications

Radio plays a vital role in today's communication systems. Broadcasting systems, the international telephone network and mobile telephones are all highly dependent on radio-based technology. Understanding the propagation of radio waves between transmitter and receiver is vital in implementing new systems in an environment of ever increasing spectrum congestion. The Radio Communications Research Unit conducts a range of propagation studies to investigate these phenomena for current and future systems. Radar meteorology and the development of novel radio communication technology are additional aspects of this research activity.



The huge magnet built at RAL for the H1 particle physics experiment in Hamburg is one of the largest in the world.

RAL RESEARCH SERVICES



Dr Gordon Walker, Deputy Director

Whilst the primary funding for RAL comes from SERC to support academic research, the Laboratory also undertakes commercial work which allows its facilities and skills to be exploited by a wider community.

The facility which attracts the greatest additional income is the pulsed neutron source, ISIS, through various agreements for its use by other countries. Other projects attracting funding from outside sources are radio communication (sponsored by DTI and MoD), various EC programmes such as ESPRIT (microelectronics), BRITE/EURAM (airport security) and JOULE (wind energy). Funds are also received from the Computer Board (which reports to the Department of Education and Science) for the management of JANET, the joint academic computer network.

RAL SUPPORT SERVICES

Site Servicing

All maintenance and minor new works involving RAL buildings and roads and the provision of electrical and mechanical services to the buildings are supervised byEngineering and Building Works Division. This work can be divided into two areas of activity - building and civil work and mechanical and electrical services.

Building and civil maintenance activities include planned work such as flat roof maintenance and painting and breakdown repairs which are dealt with on a day-to-day basis.

The electricity distribution system and the lighting and power systems also require local support, as do the steam distribution and heating systems and the distribution of water, gas and compressed air. Regular maintenance is carried out on RAL's air conditioning systems, lifts, cranes, and electric vehicles. Tariffs are negotiated and the use of electricity and other services is closely monitored.

ISIS target station under construction.

Council Works Unit

The Council Works Unit (CWU) is responsible for the design and construction of new buildings and alterations to existing buildings at all SERC establishments. In addition to RAL, CWU also services Daresbury Laboratory, the Royal Greenwich Observatory, the Royal Observatory Edinburgh and SERC's overseas observatories at La Palma (in the Canary Islands) and Hawaii.

Work carried out by CWU spans that of architect and consulting engineer, covering building design, structural engineering and all types of electrical and mechanical services. CWU has been responsible for all new buildings seen at the Laboratory and alterations to buildings and services required to accommodate new projects and equipment such as ISIS, the James Clerk Maxwell Telescope, the Laser Facility and the IBM and Cray supercomputers.

CWU work starts at the feasibility stage and continues through the detailed design and construction phases to commissioning and handover to the client. Much of the design work is carried out using a computer-based drafting system.

SERC's new Royal Greenwich Observatory building in Cambridge, designed and construeted by the Council Works Unit.

Administration

Richard Lawrence-Wilson, Laboratory Secretary and Head of Administration Department

Administration can be taken for granted in an organisation like RAL whose main purpose is the pursuit of a full and varied scientific programme. In the background, however, administration plays a key role in supporting the Laboratory's programmes.

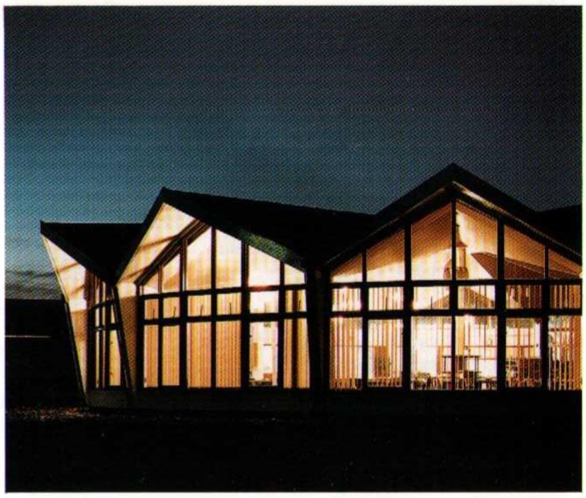
Every scientific project depends upon the smooth and efficient provision of administration services, from expert photography and reprographics services through comprehensive financial and personnel support to the management of the domestic infrastructure such as catering, transport, accommodation and security.

RAL publishes and prints a variety of publicity material and internal reports. The Library is a good example of a specialist service, providing essential data to research scientists and engineers. Databases are used for information storage and retrieval and the Library holds the latest technical information on standards and specifications.

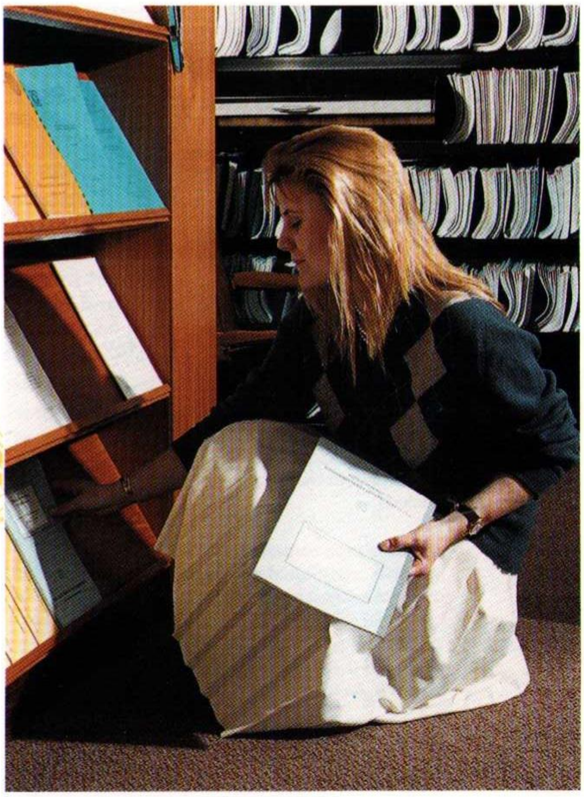
The Department deals with thousands of finance and personnel transactions and the many tricky problems which arise from handling a substantial annual budget and the employment and training of a large workforce.

Domestic support is provided for the Laboratory's staff and its thousands of visitors. A recent development has been a major extension to The Cosener's House, RAL's residential conference centre in Abingdon, providing up-to-date seminar rooms and additional study bedrooms for visitors using the Laboratory's research facilities and attending meetings of the UK and international academic communities.

A small specialist group provides expert monitoring and guidance on Health and Safety aspects of the Laboratory's work, a crucial aspect of management in an advanced scientific environment.



The restaurant provides an evening service to cater for researchers working through the night (many RAL facilities run twenty four hours a day).



The Library provides a specialist service to RAL's scientists and engineers, supplying the latest reports and publications as well as providing on-line links to information databases all over the world.

GLOSSARY

billion 1,000,000,000

capacitor a charge storage device

collider a machine which accelerates particles in opposite directions, then directs them into head-on collisions

cosmic rays energetic showers of particles which reach the Earth from space

cryostat a vessel designed to be maintained at a specified low temperature

DNA deoxyribonucleic acid - the gene-carrying constituent of living cells

elementary or fundamental particle a collective name for those particles of matter which cannot be subdivided into smaller particles

hadron a family of fundamental particles subject to the strong nuclear force

ISIS RAL's pulsed neutron source

leptons a family of fundamental particles subject to the weak nuclear force

mesosphere the third layer of the Earth's atmosphere, between approximately 50 km and 85 km, just above the ozone layer

muon elementary particle, similar to the electron but 207 times heavier

neutrino elementary particle subject to the weak nuclear force

neutron a particle with zero charge, a constituent of the atomic nucleus

plasma an ionised gas containing approximately equal numbers of electrons and positive ions

positron the electron's 'anti-particle' - similar to the electron but with positive electric charge

proton a positively charged particle made from three quarks, a constituent of all atomic nuclei

quark a fundamental particle, the building block for hadrons such as protons and neutrons

reflectometer an instrument used to measure the reflection of beams from surfaces and interfaces

solenoid a coil of wire with a length longer than its diameter

SPRITE a large krypton fluoride gas laser, part of RAL's Central Laser Facility

stratosphere the second layer of the Earth's atmosphere, between approximately 10km and 50km, just below the ozone layer

strong nuclear force one of the four fundamental forces of nature

synchrotron a circular particle accelerator

transputer a computer built on a single silicon chip, a building block for powerful computers

troposphere the layer of the atmosphere nearest the Earth, between ground level and approximately 10 km

VULCAN a large neodymium glass laser, part of RAL's Central Laser Facility

W Particle first discovered at CERN which advanced our understanding of the electromagnetic force and the weak nuclear force

weak nuclear force one of the four fundamental forces of nature

Z and Z° See W

10^{33} 1,000,000,000,000,000,000,000,000,000,000,000

Acronyms

ATSR Along Track Scanning Radiometer

BNSC British National Space Centre

BRITE/EURAM Community Research and Development Programme on Manufacturing and Technologies in Advanced Materials

CERN European Centre for Nuclear Research, Geneva

CLF Central Laser Facility

CRISP Critical Reflection Spectrometer

CWU Council Works Unit

DESY Deutsches Elektronen-Synchrotron, Hamburg

DTI Department of Trade and Industry

EARN European Academic Research Network

EBLF Electron Beam Lithography Facility

EC European Commission

ESA European Space Agency

ESPRIT European Strategic Programme for Research and Development in Information Technology

HERA Hadron Electron Ring Accelerator

ISAMS Improved Stratospheric and Mesospheric Sounder

JANET Joint Academic Network

JCMT James Clerk Maxwell Telescope

JNT Joint Network Team

JOULE Joint Opportunities for Unconventional or Long-Term Energy supply

LEP Large Electron Positron Collider

LSF Laser Support Facility

MoD Ministry of Defence

MRC Medical Research Council

NASA National Aeronautics and Space Administration

NSFnet National Science Foundation network

PROFS IBM Professional Office System

RAL Rutherford Appleton Laboratory

SERC Science and Engineering Research Council

WDC World Data Centre

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