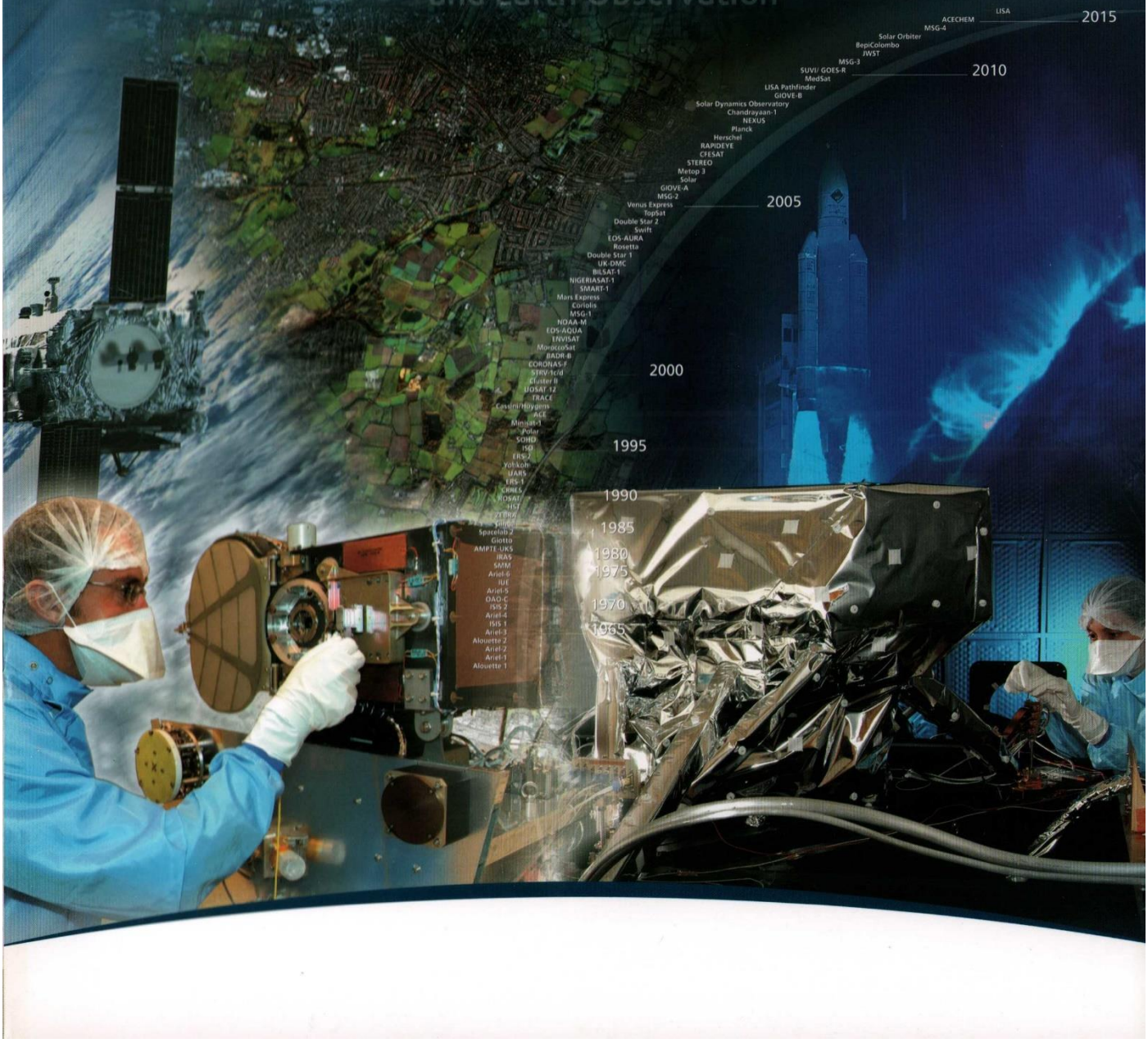
Science & Technology Facilities Council

RAL Space

developments in space science and technology

Astrophysics, Planetary, Solar, Plasma, Radio, Atmospheric Chemistry and Earth Observation



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The Space Science and Technology Department at STFC Rutherford Appleton Laboratory carries out an exciting range of world-class space research and technology development. With significant involvement in over 180 space missions, we are at the very forefront of UK space research. Our expertise covers a wide range of disciplines including: astronomy, solar physics, planetary physics, fundamental physics, earth observation, atmospheric chemistry, and radio propagation. Our engineering disciplines include space electronics, detector systems, thermal and mechanical engineering, optics design, software engineering and e-Science.

Our 200 staff are dedicated to supporting the programmes of the Science and Technology Facilities Council (STFC) and the Natural Environment Research Council (NERC), as well as undertaking a large number of space projects for UK and overseas agencies, universities, and industrial companies. We are also a member of the British National Space Centre which coordinates UK civil space activities.

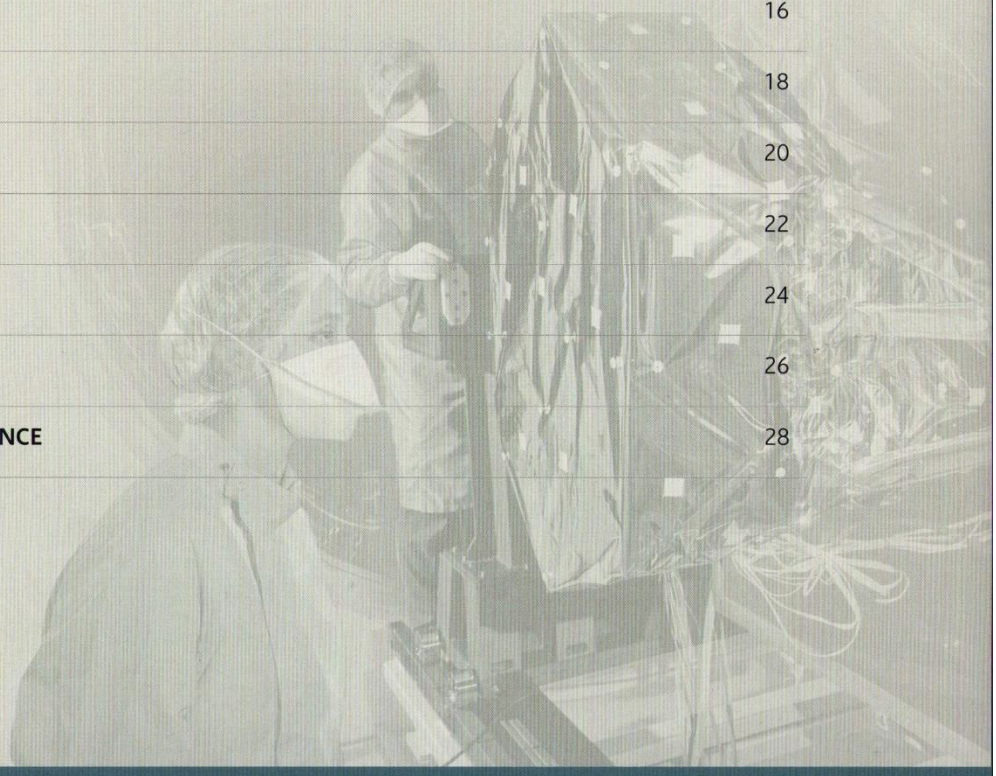
We undertake world-leading space research and technology development, provide space test and ground-based facilities, design and build instruments, analyse and process data, and operate S- and X-band ground-station facilities, and lead conceptual studies for future missions. We work with space and ground-based groups around the world.

We are always looking to exploit our technology with industry and universities. Two recent excellent examples of spin-out companies formed out of the department are Thruvision Ltd and Orbital Optics Ltd. Thruvision is developing terahertz imaging for the security market, while Orbital Optics is developing high resolution imaging from space (where MDA-Canada is now the major shareholder in the company).

Richard Holdaway

Prof Richard Holdaway
Director
RAL Space Science and Technology

RUTHERFORD APPLETON LABORATORY
SPACE SCIENCE AND TECHNOLOGY DEPARTMENT



THE SUN

RAL has a long heritage of solar space mission involvement, mainly through the development and operation of spectroscopic instrumentation in the extreme-UV and X-ray wavelengths. We use observations of the solar atmosphere to determine its plasma characteristics.

SOHO

Launched in 1995, the ESA/NASA Solar and Heliospheric Observatory (SOHO) is the world's largest solar physics space mission and it has revolutionised our understanding of the Sun. RAL's Coronal Diagnostic Spectrometer (CDS) is a unique instrument, designed to detect solar extreme ultraviolet radiation which allows us to probe conditions in the solar corona.

The spectra recorded by CDS provide information on temperature, density, elemental composition and flows of very hot plasma trapped in the Sun's magnetic field. The CDS operation is run from RAL, where the requests for observations from a user community of 15 UK institutes and over 60 world-wide groups are coordinated, planned and run. CDS has enabled the discovery of a number of phenomena, including rotating columns of plasma that resemble tornadoes and the fact that the Sun's atmosphere is riddled with Earth-sized explosions known as blinkers.

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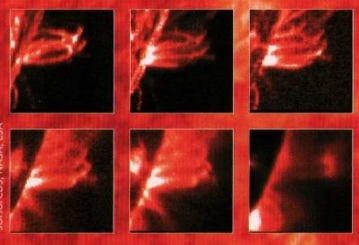

SOHO/CDS, NASA, ESA

Enormous loops containing charged gas at temperatures from 20,000 to 2 million K, reveal the magnetic structures of the Sun's atmosphere.

STEREO

The Sun occasionally ejects vast gas clouds into space. Known as coronal mass ejections (CMEs), each cloud may carry 1,000,000,000 tonnes of gas into space at several hundred km/s. When these clouds engulf Earth they can disrupt power, navigation, communication and satellite control systems.

The NASA STEREO mission was launched in October 2006. Two identical probes are now in solar orbit, one flying ahead of the Earth and one behind the Earth, from where they look back at the Sun and the space between the Sun and the Earth. This two-platform view allows 3D images of the Sun to be produced. However, it is the RAL-led Heliospheric Imagers on STEREO that look at the space between the Sun and the Earth, using wide-angle telescopes. They are being used to detect the CMEs as they propagate through interplanetary space. In addition to leading the HI instruments, all of the imaging instruments aboard the two STEREO spacecraft use a novel CCD-based camera system developed by RAL.

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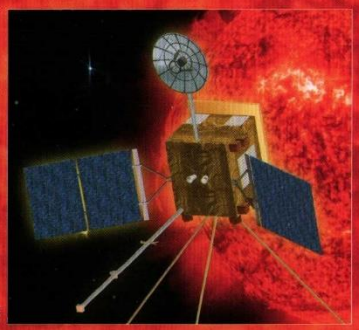

ESA

Solar Orbiter

HINODE

The Solar-B mission, now known as Hinode, was launched in September 2006, carrying instruments developed by Japan, the USA and the UK. Building on the highly successful SOHO and Yohkoh solar missions, Hinode has imagers that can map the magnetic fields at the solar surface, and resolve the structure and evolution of the different layers of the solar atmosphere with unprecedented high-resolution.

The Extreme-ultraviolet Imaging Spectrometer (EIS) was built by an international consortium led by the Mullard Space Science Laboratory (UK). EIS measures spectral emission lines in order to accurately diagnose the conditions in the solar plasma at a pixel size of 750 km on the solar surface, and RAL scientists are using the data to better understand the Sun's atmosphere and its effect on Earth. RAL was a key player in the development of EIS, providing assembly, integration and test facilities, with particular responsibility for cleanliness and contamination control.

RAL is also responsible for the vital radiometric calibration of EIS and for software for operations planning and support.

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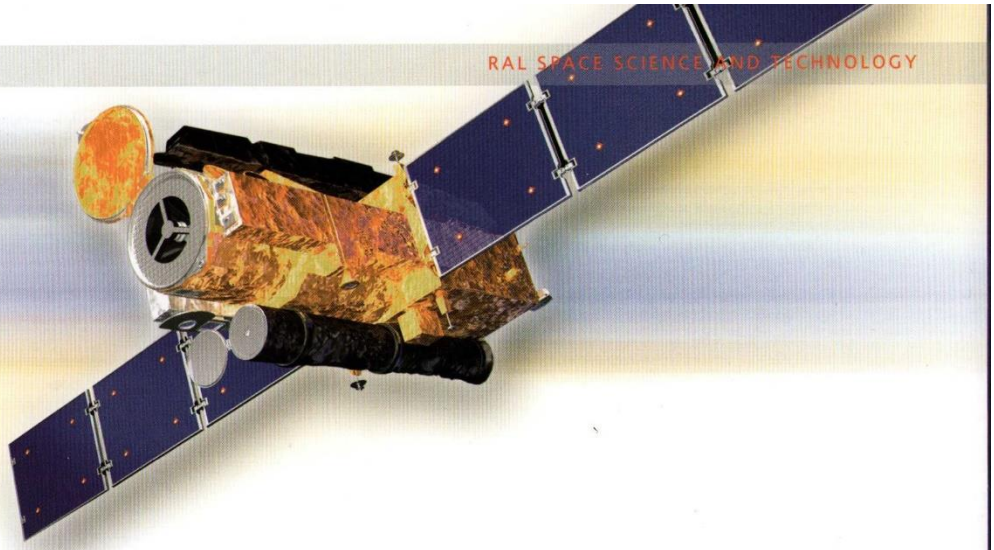

Hinode spacecraft NASA, ESA/JAXA

SOLAR ORBITER

Solar Orbiter was selected by ESA in September 2000 with a proposal led by the Max Planck Institute for Aeronomy and RAL. The mission makes use of solar electric propulsion and planetary fly-bys (Venus and Earth) to achieve a 150-day orbit with a perihelion of 40 solar radii, and thus makes numerous close encounters of the Sun.

Repeated Venus fly-bys, on every third orbit, will allow the spacecraft to climb out of the ecliptic, providing the first high latitude observations of the solar atmosphere – extremely valuable for studies of the high-speed polar wind outflows, the solar dynamo, global mass ejection and studies of fundamental processes in a stellar atmosphere.

The mission is due for launch in 2015 or 2017. From day one, RAL has been a key player in the mission conception, proposal, and studies, and continues to lead an international consortium which is proposing to build a high-resolution UV spectrometer/imager for the mission.

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SOLAR DYNAMICS OBSERVATORY

SDO is NASA's first Space Weather Research Network mission in the Living With a Star programme. RAL has provided the Lockheed Martin Solar and Astrophysics Laboratory with the CCD camera electronics systems for two of the three scientific instruments on SDO.

SDO is designed to study solar atmospheric structures and magnetic fields from their emergence at the surface into the corona, using a set of imaging systems in the UV, extreme-UV and visible light, including magnetic mapping using the Zeeman effect. It is due for launch in August 2008 and will be in a geosynchronous orbit. Its emphasis on high resolution imaging results in a data rate of 140 Mbps. In addition, RAL has a scientific interest through a co-investigator role and is heavily involved in preparation for receipt of high data-rate data, automated analysis, and storage of data for UK scientists.

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GOES-R

The Geostationary Operational Environmental Satellite (GOES) programme is a key element of the National Oceanic and Atmospheric Administration's (NOAA) operations. The GOES-R series of spacecraft are intended to provide more timely and accurate weather forecasts, and improve support for the detection and observations of meteorological phenomena that directly affect public safety, protection of property, and ultimately, economic health and development.

RAL is providing the camera electronics for the solar imaging instrument (SUVI) on GOES-R spacecraft, the first of which is due for launch in 2014.

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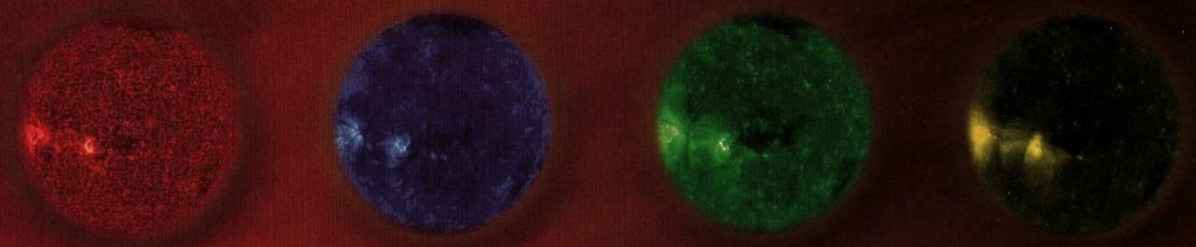
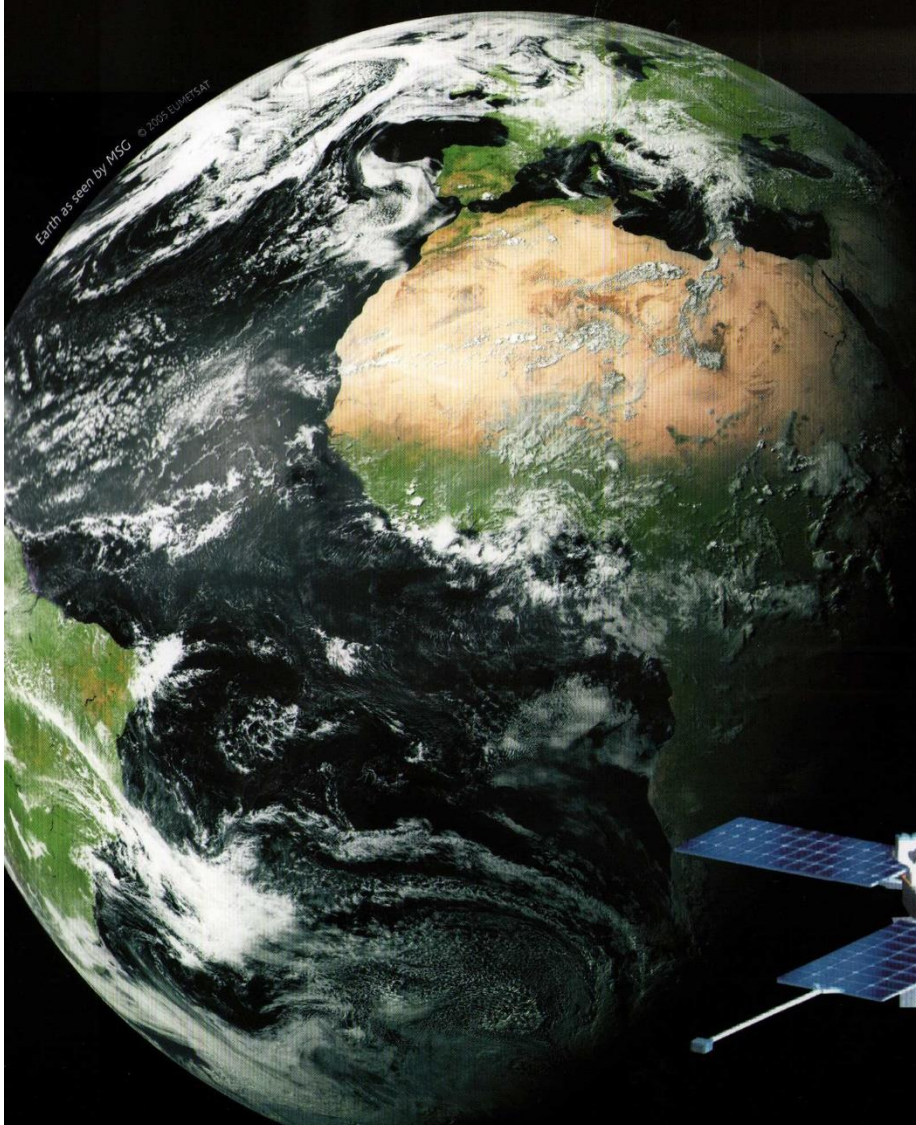


STEREO images showing the sun at four different colour temperatures (0.8 MK, 1.3 MK, 1.6 MK, 2.0 MK).

RAL has been involved in scientific missions to study the Sun for over 30 years

NEAR-EARTH ENVIRONMENT

The near-Earth environment is a wonderful natural laboratory for studying fundamental phenomena in the physics of plasmas (ionised gases). Our scientists study these phenomena using space-based and ground-based instruments. They are of great interest in understanding space weather.



Earth as seen by MSG © 2005 EUMETSAT

ACE

The RAL Ground Station receives real-time solar wind telemetry data from the NASA Advanced Composition Explorer (ACE) satellite, located at Lagrange point L1 1.5 million kilometres from Earth in the direction of the Sun. The satellite measures the particles and magnetic fields in the solar wind, enabling scientists to predict electromagnetic events that could disrupt satellite or ground-based communications systems.

The data gathered at RAL are sent in real-time to the NOAA Space Environment Center in the USA for processing, and the results can be viewed at http://sec.noaa.gov/ace/. Operations during a typical year result in 3,500 hours of real-time support.

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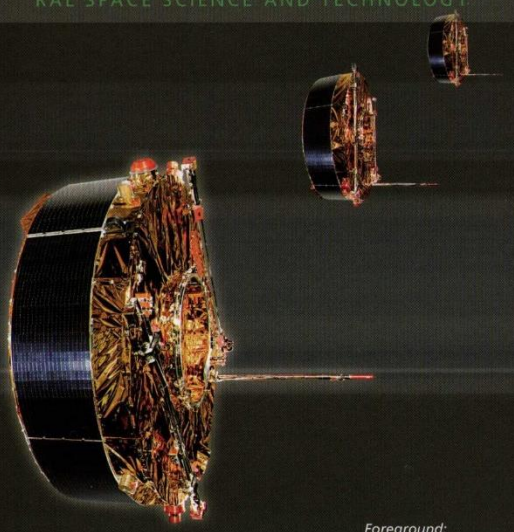
Gas clouds ejected from the Sun and travelling at hundreds km/s can engulf Earth, disrupting power, navigation, communication and satellite control systems



Foreground: Three of the four CLUSTER spacecraft
ESA

Background: TRACE image of coronal loop
NASA

CLUSTER

Cluster is an ESA mission, revolutionising our understanding of the interaction between electrically charged particles from the Sun and the Earth's magnetic field. The four Cluster spacecraft were launched in pairs on 16 July and 9 August 2000 and now orbit the Earth in formation. This unique set of multi-point measurements allows us to study, for the first time, the three-dimensional structure of the fundamental physical processes occurring in the near-Earth environment as they vary with time.

The second mission extension started in 2006 and is making use of new multi-scale formations and is visiting scientific regions not covered earlier in the mission. RAL has a major hardware involvement in two of the instruments: RAPID measures the energetic ions and electrons, while PEACE measures the lower energy electrons.

RAL runs ESA's Cluster Joint Satellite Operations Centre which has responsibility for planning and commanding the international science operations. The UK Cluster Data Centre is also located at RAL. It provides science data processing and dissemination facilities for the national Cluster community, and is responsible for the technical development of ESA's Cluster Active Archive. RAL scientists play a leading role in the science exploitation from the mission and in coordinating activities with ground-based instrumentation such as EISCAT (p. 6).

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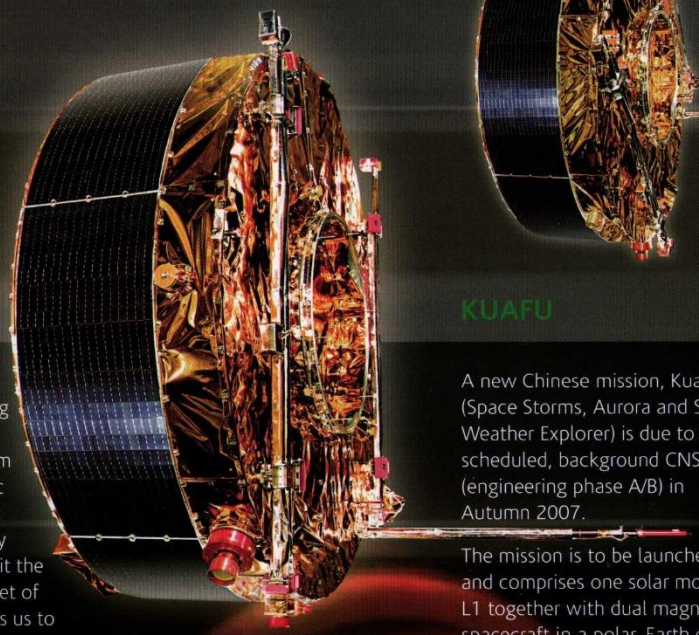

DSP

The joint Chinese-ESA Double Star programme is a dual-spacecraft mission which launched in December 2003 and July 2004, with an expected end of mission in late 2007 or 2008. Double Star has strong links with the Cluster mission, including flying many of the same instruments. The orbits of the Double Star spacecraft, one in the equatorial plane and the other over the geomagnetic poles, are providing exciting opportunities for collaborative studies with Cluster. The RAL contribution to Double Star is similar to that for Cluster, with an emphasis on the operations, science coordination and data distribution.

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KUAFU

A new Chinese mission, Kuafu (Space Storms, Aurora and Space Weather Explorer) is due to become a scheduled, background CNSA project (engineering phase A/B) in Autumn 2007.

The mission is to be launched in 2012 and comprises one solar monitor at L1 together with dual magnetospheric spacecraft in a polar, Earth orbit. The fundamental aim will be to continuously monitor auroral response to solar input. Exploration is therefore focused on both space weather science and Sun-Earth global coupling, and RAL will provide an energetic electron instrument for the magnetospheric spacecraft.

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EARTH OBSERVATION

Making observations of the land, sea and air from space allows scientists to develop and improve their models of our environment. Space instruments provide continuous, global measurements for many years at a time, allowing events like El Niño to be studied.

EISCAT

The European Incoherent SCATter facility consists of three radar systems in Northern Scandinavia. Present research is mainly into solar influences on Earth's environment in conjunction with many spacecraft, including ESA's Cluster quartet, and coupling between atmospheric layers in the context of global change driven by the Sun and by human activities. In addition, the radars monitor the rapid growth of the pollution of near-Earth space with space debris.

The next generation of radars will also study meteorites from inside and outside the solar system, give unique new understanding of the origins of our solar system, aid the search for Earth-like extrasolar planets, and provide vital monitoring of the Sun for mitigation of radiation hazards on manned and robotic missions of space discovery.

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ENVISAT

ESA's ENVIronmental monitoring SATellite was successfully launched on 1 March 2002. It carries the AATSR instrument – the third in the Along Track Scanning Radiometer (ATSR) series – which has now produced a 15–year data set. AATSR monitors global sea surface temperatures (SST) to an accuracy of 0.3°C for climate study purposes.

RAL provided subsystems and laboratory calibration, and also the reference data processing system. MIPAS, an infrared spectrometer, measures pressure, temperature and trace gases such as ozone from 6 km to 70 km in the atmosphere. RAL provided the low vibration cooler electronics. RAL is also involved with the development of new atmospheric data products from AATSR, SCHIAMACHY and MIPAS for the wider benefit of the research community.

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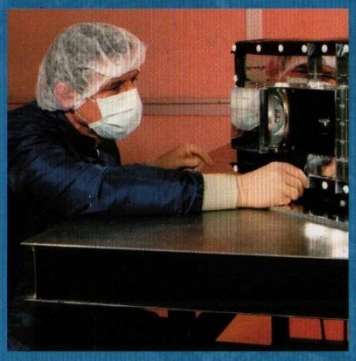
MSG (GERB)

The Geostationary Earth Radiation Budget series of instruments monitor the reflected sunlight and thermal emissions from Earth, to study daily variations and long-term climate changes. There are four instruments in the series: these have been designed and built by a European consortium led by RAL.



Checking GERB at RAL

GERB2 was launched into geo-synchronous orbit on the first of EUMETSAT's METEOSAT Second Generation Satellites (MSG-1) on 28 August 2002, and GERB1 on MSG-2 on 21 December 2005. This meets EUMETSAT's requirement to have two of the MSG satellites in orbit at any time, one providing the operational service and the other acting as a reserve. Each instrument can scan the Earth roughly every three minutes and both are designed to provide a service for more than 15 years. RAL has also developed and operates a major part of the GERB ground segment, receiving data from the instrument in near real-time, then processing and archiving it.

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Scientists are using observations from space to understand if the complex interactions between the Sun and the Earth's atmosphere affect global warming

TopSat under test in a clean room at RAL

CFARR

94 GHz & 35 GHz cloud radars at Chilbolton

The Chilbolton Facility for Atmospheric and Radio Research is equipped with a wide range of advanced meteorological radars, lidars and radiometers for remote sensing the atmosphere from the ground. The Facility makes measurements of clear air turbulence and refractivity, cloud characteristics, precipitation, water vapour, and aerosol. Measurements of these key parameters make a major contribution to reducing current uncertainties in numerical weather and climate models. In addition to improving the prediction of climate change, the measurements are being used to study the atmospheric processes that lead to storms and flooding. (Further details can be found at: http://www.chilbolton.rl.ac.uk.) The data collected at the Facility are archived and distributed by the BADC. CFARR is operated with support from the Natural Environment Research Council.

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TOPSAT

A high-resolution optical camera has been developed for the TopSat programme, producing 2.5 m resolution panchromatic images and 5 m resolution colour images. The camera has been built for approximately one-fifth of the cost of comparable cameras and was launched in October 2005.

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MARSCHALS

MARSCHALS in the foremost instrument bay of the M55 Geophysica

MARSCHALS is a millimetre-wave spectrometer designed to measure vertical profiles of ozone, water vapour, carbon monoxide, nitrous oxide, nitric acid and other gaseous components of the Earth's atmosphere from the Russian Geophysica high-altitude aeroplane. It is also a demonstrator for a future space-borne instrument on missions such as PREMIER, proposed to ESA.

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SUPPORTING GALILEO

Galileo, Europe's own GPS system, came a step closer to reality with the launch of Surrey Satellite Technology Limited's 'test bed' satellite GIOVE-A in December 2005. RAL's 12 m Ground Station provided support for spacecraft telemetry and telecommand control during the launch and early operations phase, and continues to provide a back-up service during the two-year mission. The 25 m antenna at Chilbolton Observatory is being used to carry out the crucial in-orbit testing and validation for the European Space Agency. GIOVE-B is due to be launched in March 2008.

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MST RADAR

The NERC Mesosphere-Stratosphere-Troposphere Radar at Aberystwyth is the UK's most powerful and versatile wind-profiling instrument. In the ST mode, it provides continuous measurements of the three-dimensional wind vector over the altitude range 2 km to 20 km at high resolution (300 m in altitude and a few minutes in time).

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PLANETARY SCIENCE

RAL has a very strong instrument programme, including missions to all the inner solar system planets, as well as comets and the Saturnian system. These missions continue to yield a wealth of science and help us to understand the Earth and the solar system, and the planetary systems of other stars.

CHANDRAYAAN-1

A C1XS X-ray spectrometer, currently under construction at RAL, has been selected as part of the payload for the Indian Space Research Organisation (ISRO) Chandrayaan-1 mission to the Moon. It is a sophisticated miniaturisation of an X-ray spectrometer that employs radical new technology to greatly reduce the mass and volume of the instrument. The instrument is a technological development of the RAL D-C1XS instrument, which successfully conducted science operations at the Moon aboard ESA's SMART-1 mission between 2003 and 2006.

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MARS EXPRESS

ESA

An illustration of Mars Express at Mars

RAL supplied the micro-channel plates for ASPERA-3 (Analyzer of Space Plasma and EneRgetic Atoms), one of the instruments on Mars Express. RAL is part of the team, led by IRF Sweden, studying the erosion of the atmosphere by the solar wind. RAL is also collaborating with IFSI Italy to study dust in the atmosphere. RAL provides the Payload Operations Service for Mars Express supporting science operations under contract to ESA.

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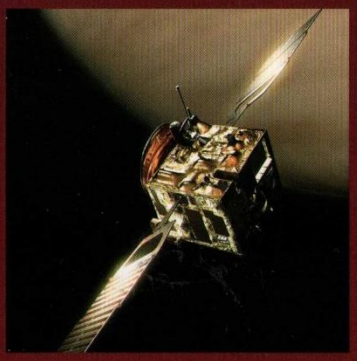
VENUS EXPRESS



An illustration of Venus Express

2005 saw the launch of Venus Express, a small ESA mission intended to build on the success of Mars Express. Venus presents many mysteries, not least the evolution of its comet-like atmosphere and its interactions with the solar wind which will be probed by the ASPERA-4 instrument in which RAL is involved.

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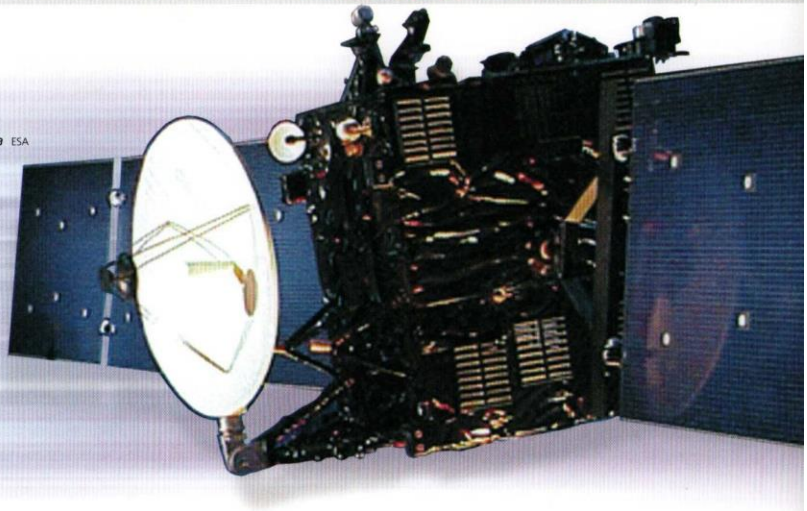
With a host of European missions underway to explore the planets in our solar system, RAL is at the forefront of instrument development and planetary science

Background: Artist's impression of CASSINI and Saturn from Titan ESA



Model of Rosetta ESA

EXOMARS

The Raman/LIBS spectrometer will carry out detailed analysis and sampling of Martian rock as part of the Pasteur payload on the ESA Exomars mission. It will determine the geochemistry, organic content and atomic composition of minerals in rocks and will provide a powerful, non-destructive technique for the analytical interrogation of geological scenarios for life. RAL is providing the CCD focal plane and readout electronics for the instrument, including custom ASICs.

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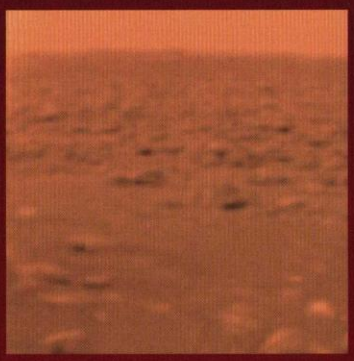
CASSINI/HUYGENS



Huygens SSP probe

The Huygens probe (built by ESA) has landed on Titan, Saturn's largest moon. It carried the surface science package, which contained RAL electronics and packaging to support the sensors from various institutes. RAL also contributed to the Cassini Plasma Sensor and the Cosmic Dust Analyser which are onboard Cassini for its four-year campaign in orbit around Saturn.

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ROSETTA

Rosetta with lander

ESA's Rosetta satellite was launched successfully in 2004 and will rendezvous with comet Churyumov-Gerasimenko in May 2014. Once it has arrived, it will carry out very precise isotopic ratio measurements as the comet evolves during its journey towards the Sun. RAL supported the Open University by building an advanced gas chromatography instrument, Ptolemy, which is part of the lander. It includes a compact, low-power, mass spectrometer, controlled by integrated circuits (ASICs) designed at RAL and making use of nanotechnology developed at RAL for the ionisation device. The challenge for the team was not only to build the instrument in an ultra-compact, low power and lightweight form, but also to ensure that it would function perfectly after several years of inactivity on the way to the comet.

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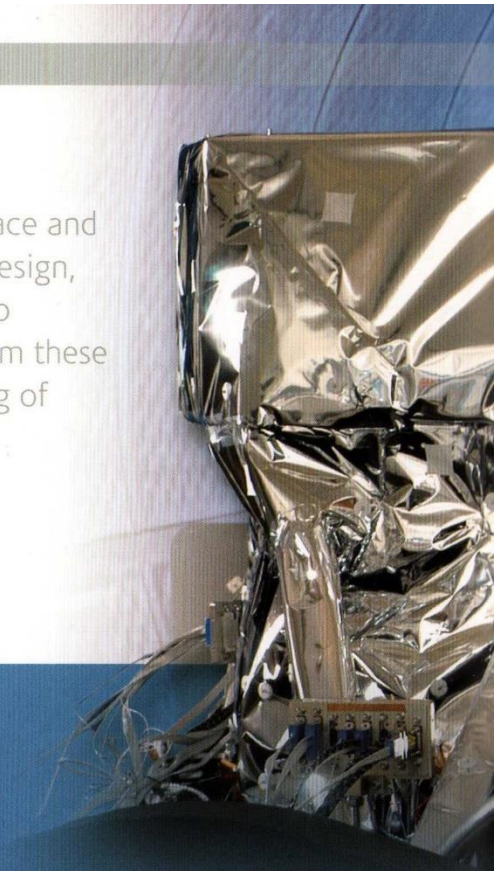
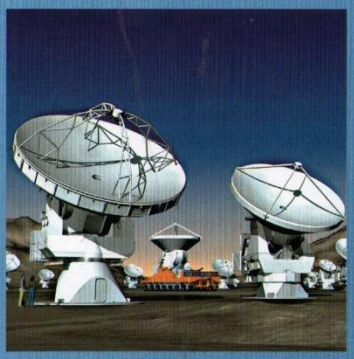
ASTRONOMY

RAL supports astronomers using instruments in space and on the ground, with a wide range of expertise in design, building, testing and calibration. RAL scientists also participate in astronomical research using data from these and other instruments to further our understanding of galaxies and the formation of stars and planets.



ALMA



An illustration of the Atacama Large Millimetre Array

RAL is participating in the construction of the Atacama Large Millimetre Array (ALMA), located in the Atacama Desert of Northern Chile at an altitude of over 5000 m. The facility will combine fifty-four 12 m diameter and twelve 7 m diameter telescopes to form an interferometric imaging array. When completed in 2012, the instrument will provide an unprecedented sensitivity and spatial resolution at millimetre and sub-millimetre wavelengths. It will be used to detect and study the earliest and most distant galaxies, and probe dust-obscured regions which are the birthplace of stars and planets.
The project is an international collaboration between Europe, North America and Japan. RAL is contributing to key areas of ALMA construction technology – cryogenics, photonics, calibration, and receiver integration – and hosts the ALMA UK Project Office.

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DARWIN

Darwin is a constellation of six spacecraft, each with a large infrared telescope which will be like a single telescope with a diameter of 400 m. Darwin will be used to search for Earth-like planets and for signs of life on them. RAL is taking part in ESA's scientific and technical studies.

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JWST MIRI

The James Webb Space Telescope (JWST) is planned to succeed the Hubble Space Telescope. The Mid-Infrared Instrument (MIRI) on JWST will provide unique capabilities to study the dust-enshrouded regions of the universe. RAL is responsible for several key areas, including assembly and verification, project science, thermal systems engineering and contamination control.

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SUBARU FMOS

The Fibre-Multi-Object Spectrograph (FMOS) is a collaboration to design and construct a fibre-fed infrared spectrograph system for the Subaru 8 m telescope on Mauna Kea in Hawaii. RAL has overall responsibility for the optical and thermal design of the spectrograph, and for the fabrication of the camera/detector system.

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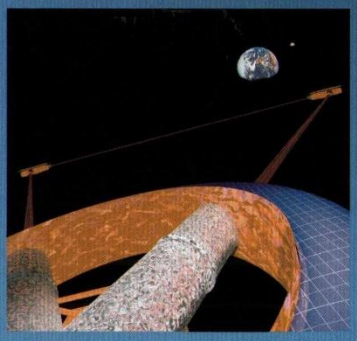
LISA AND LISA PATHFINDER



An illustration of the three LISA spacecraft

The Laser Interferometer Space Antenna will measure gravitational waves from violent events such as the merging of black holes. The unique technology is to be tested on LISA Pathfinder, due for launch in 2009. RAL was involved in the development of gravitational wave sensor, including the high precision interferometers, which will measure the position of gravitational reference masses and protect the masses from damage during launch.

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A member of the Thermal Engineering Group prepares a prototype of the Mid-Infrared Instrument (MIRI) of the James Webb Space Telescope (JWST) for cryogenic testing in SSTD's Space Test Chamber

The VISTA camera for the telescope at the European Southern Observatory in Chile weighs nearly three tonnes

HERSCHEL SPIRE

The Spectral and Photometric Imaging REceiver (SPIRE) will fly on ESA's Herschel mission in 2008. The instrument, operating between 200 and 700 microns, will search for galaxies that are 'young' in cosmological terms. The instrument is being built by a consortium of European and American groups, led by Cardiff University. RAL is responsible for the instrument conceptual design, project management, in-flight operations and instrument calibration.

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PLANCK

Planck is an ESA mission to map the structure of the Cosmic Microwave Background radiation. The detail and sensitivity of the measurements will help determine fundamental parameters relating to the origin and evolution of the universe. For frequencies higher than 100 GHz, a bolometer receiver system is used, operating at cryogenic temperatures. RAL has provided thermal analysis for the design of the system, as well as the cooling stage that reduces the temperature from 20 K to 4 K, using a Joule-Thomson system.

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VISTA

The Visible and Infrared Survey Telescope for Astronomy is a 4 m diameter wide-field survey telescope, dedicated to conducting detailed imaging surveys of the sky. The project is nearing completion at the European Southern Observatory's Cerro Paranal Observatory in Chile, with the UKATC having provided the telescope and enclosure, and RAL having led the team that built the 3 tonne, 3 m long IR Camera. The Camera comprises a large vacuum vessel with sixteen 2k x 2k pixel infrared detectors cooled to liquid nitrogen temperatures, making up the largest IR focal plane in the world.

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RESEARCH

SSTD undertakes pure research in solar physics, solar-terrestrial physics atmospheric physics, planetary and magnetospheric physics, astronomy and fundamental physics. The research encompasses a wide range of interests, running in close harmony with the space hardware projects, and involves collaboration with many university groups in the UK and abroad.

NEOS

RAL is engaged in assessing the hazards posed by asteroids and comets that pass close to the Earth (so-called Near Earth Objects) and advising the British National Space Centre on appropriate courses of action to mitigate the risk and to minimise the danger from debris impact, air-blast and tsunamis. RAL works with groups such as the Organisation for Economic Cooperation and Development (OECD) and the United Nations.

NASA

Impact of NEO on Earth (illustration)

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SPACE ENVIRONMENT PHYSICS

ESA

One of the Double Star spacecraft undergoing testing

SEP research covers a broad range of pure and strategic research, from the effects of variations in the solar wind and interplanetary magnetic field on the terrestrial plasma environment and atmosphere, to the influence of solar variability on the Earth's climate and operational systems. The research covers timescales ranging from sub-second to millennia and is based on SSTD's involvement in missions and facilities such as Cluster/ Doublestar, Polar, UKSSDC and EISCAT. In the future the work will be closely allied to magnetohydrodynamic (MHD) models of the inner heliosphere with the aim of predicting radiation hazards for manned space flight beyond the protective shield of Earth's magnetic field.

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SOLAR PHYSICS

RAL's Solar Physics Group is a cornerstone of UK solar physics research, providing an established, world-leading research programme with observational and scientific leadership over a wide range of key areas. The basic underpinning experimental expertise of the group is solar atomic spectroscopy, for the derivation of solar plasma diagnostics. The group has a long heritage, including the NASA Solar Maximum Mission (1980-89), the CHASE Spacelab 2 experiment (1985), the Japanese Yohkoh mission (1991-2001), and SOHO (p. 2). The group has major hardware roles in the NASA STEREO (p. 2) and the Japanese Hinode (p. 2) missions, and studies are underway for an RAL-led instrument for the ESA Solar Orbiter (p. 3). The Group is involved in SDO (p. 3) and also in some smaller projects such as the RESIK instrument aboard the Russian Coronas spacecraft, and the NASA SERTS and EUNIS rocket experiments. The bulk of the research effort over the last few years has been underpinned by observational work using the SOHO spacecraft and, in particular, the RAL-led Coronal Diagnostic Spectrometer (CDS) and, more recently, the STEREO and Hinode observations. Specific research areas include studies of fundamental processes in the solar atmosphere, research into solar mass ejection processes and flares, and plasma diagnostic techniques.

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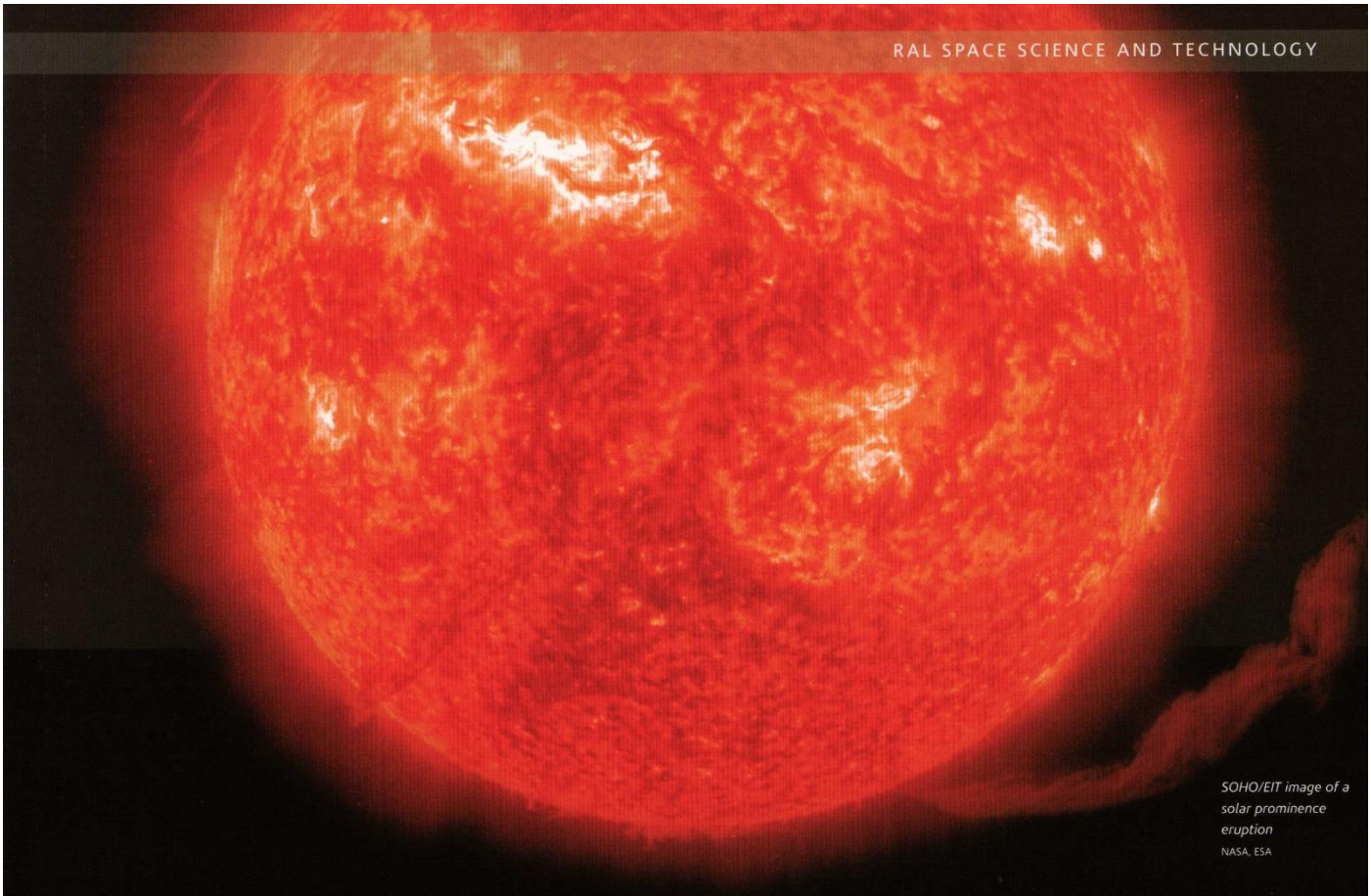

SOHO/EIT image of a solar prominence eruption
NASA, ESA

SPACE WEATHER

Space weather studies how solar activity impacts human activities, for example causing disruption to positioning and communications services, and to spacecraft operations. RAL has multidisciplinary expertise in the science of space weather and a leading role in European space weather activities. RAL is a key UK contributor to the international exchange of space weather data through its high quality monitoring of the Earth's ionosphere from Oxfordshire and the Falkland Islands.

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FUNDAMENTAL PHYSICS

Fundamental physics research at RAL explores the underlying laws which govern the behaviour of the universe. The RAL space instrument team is closely associated with the STEP satellite which will measure differences between inertial and gravitational masses predicted by string theory alternatives to General Relativity, and participates in the LISA mission (p. 10) to measure gravitational waves predicted by General Relativity. Other areas being researched are neutrino astrophysics, the Casimir Effect, quantum gravity fluctuations and laboratory astrophysics, together with instrumentation that could be deployed to measure these phenomena by the use of atom-wave interferometers.

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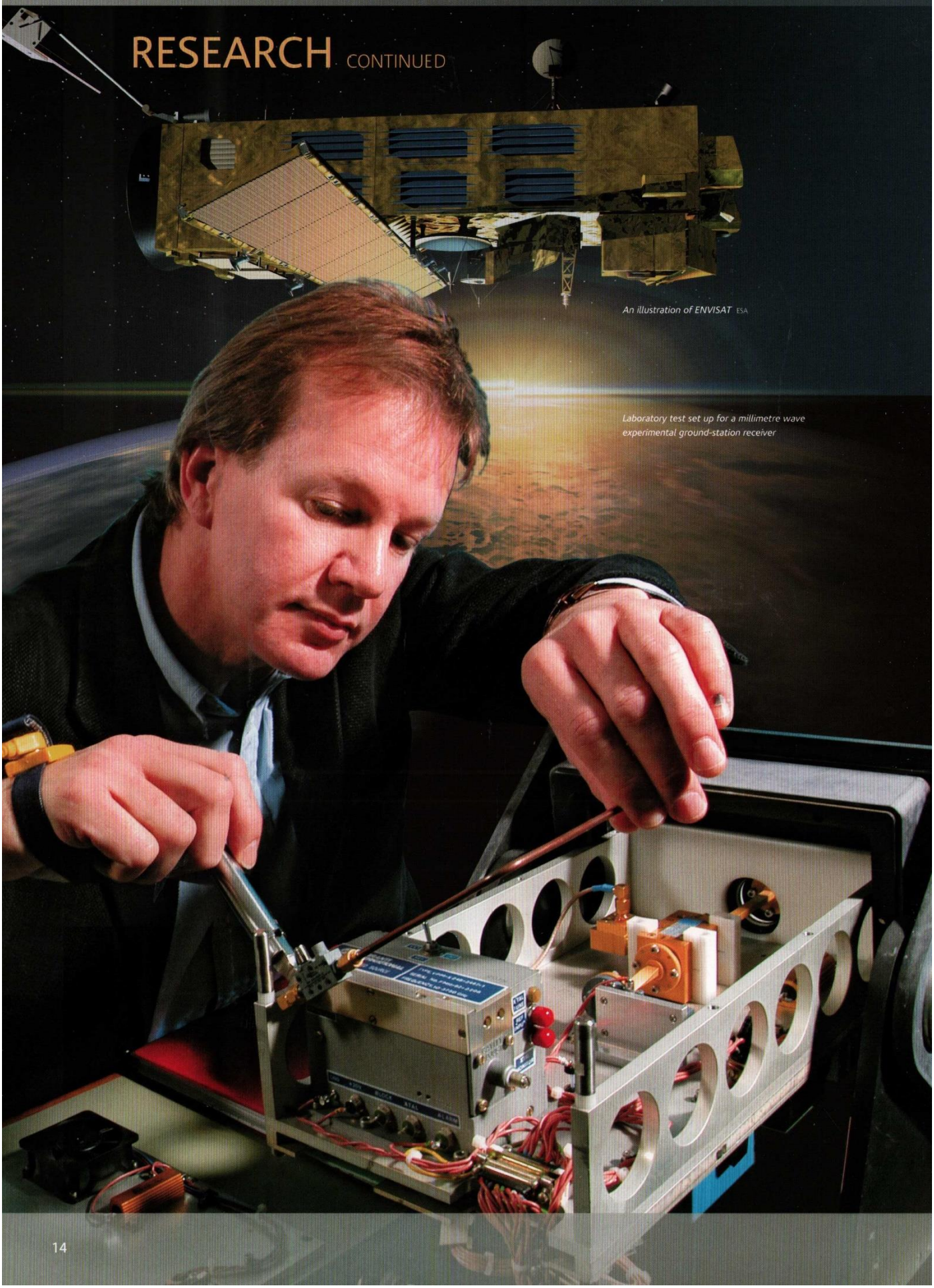
Strong space science research programmes underpin and complement the diverse hardware programmes at RAL

RESEARCH CONTINUED

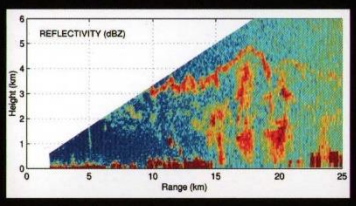


An illustration of ENVISAT ESA

Laboratory test set up for a millimetre wave experimental ground-station receiver

Communications, remote sensing and navigation all rely on radio signals passing through our atmosphere. Our atmospheric studies benefit communications systems and our communications studies benefit understanding of atmospheric processes

ATMOSPHERIC PROCESS RESEARCH



1275 MHz ACROBAT radar data showing clear air structure in the lower part of the atmosphere

The activities of the CFARR Atmospheric Science Research Group are directed to studying atmospheric physical processes; in particular those involving cloud, rain, water vapour and aerosol. Using measurements made with ground-based radars, lidars and radiometers, current research includes the establishment of spatial-temporal models of rain-rate variation, characterising water vapour density profile variations, and studying aerosol profile variations. In addition, boundary layer processes are being studied using measurements of sensible heat flux, water vapour profiles, and vertical wind profiles. It is anticipated that those measurements will soon be complemented by *in situ* measurements of turbulence, humidity and temperature made using instruments carried beneath a captive balloon. Research is also being undertaken to validate atmospheric data retrieved from Earth Observation satellite measurements; recently a technique was developed enabling CFARR radar measurements to be used to validate rainfall estimates made from data collected with the AMSU-B radiometer, which is carried on a number of NOAA satellites.

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RADIO RESEARCH

The Radio Research Group includes research activities in radio communications, radio systems and radio wave propagation modelling. It provides expert advice to government regulators and to industry on all matters related to the use of the entire radio spectrum, from HF to optical, in terrestrial and Earth-space applications. In particular the Group promotes the commercial use of higher frequency bands and provides propagation models appropriate for planning innovative new services. This modelling work is closely coupled to studies and measurements of the troposphere and the ionosphere.

Recent emphasis has been in assisting the UK regulator Ofcom in improving the efficiency with which spectrum is used in order to provide enough space for new applications. A significant proportion of the Group's work has been incorporated through international peer review into the ITU-R Study Group 3 series of recommendations on propagation prediction, which are extensively used in national planning and in international coordination of radio communications systems

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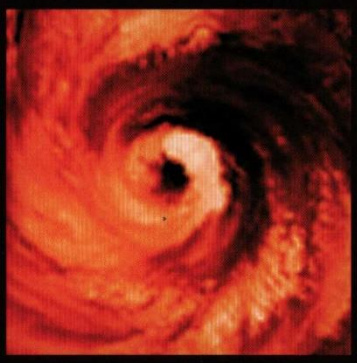
CLIMATE RESEARCH



ATSR false-colour image of a typhoon over the East China Sea

The Research Group in the British Atmospheric Data Centre is working on aspects of climate modelling and data fusion. The physical processes which make up the climate system are being studied in targeted projects. One data fusion project is concerned with global sea surface temperature distribution using a combination of satellite sensors, another is exploiting ENVISAT data to generate global fields of stratospheric ozone, methane and water vapour. A project to investigate the variation of hemispheric mean temperatures over the past millenium has been recently completed. RAL is a key member of DARC, the Data Assimilation Research Centre, one of the Centres of Excellence established by NERC, and RAL provides data support for DARC via BADC.

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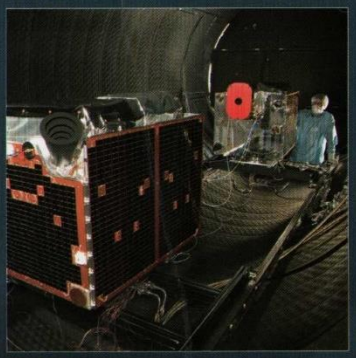
FACILITIES

We are able to provide a range of services to customers, which can enhance a project's technical and management programme. We can provide assistance through experts and managers from various related disciplines.

ENVIRONMENTAL TEST, CALIBRATION FACILITIES AND CLEAN ROOMS



Rapideye inside the test chamber at RAL

The environmental test facilities at RAL have been developed to meet the exacting needs of people involved in the design, manufacture and qualification of space hardware. The facilities consist of a vibration test facility, with the capability of cryogenic vibration, numerous thermal vacuum facilities, vacuum bakeout facilities and large clean rooms for assembly and integration of sensitive flight hardware. They are all equipped with the latest instrumentation, and have modern computer-based control and monitoring/data acquisition systems. Our largest facility is a 3 m diameter by 5.5 m long thermal vacuum chamber (currently the largest in the UK), which is currently being configured to perform the thermal calibration of the MIRI Instrument, one of three instruments on the James Webb Space Telescope. The test facilities also include an extreme ultraviolet radiometric calibration facility for solar instruments, capable of taking instruments up to 3 m long. These facilities are available for use by industry and universities.

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MOLECULAR SPECTROSCOPY FACILITY

Inside the MSF long-path gas cell

The world-class MSF laboratories provide high resolution (up to 1 part per million), broad optical bandwidth (IR/visible/UV) spectrometers, variable temperature (77 - 470 K) gas cells with optical paths from less than 1 mm to 1 km, and time-resolved, aerosol, and reflectance spectroscopy accessories.

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SPACE PROJECT MANAGEMENT AND PA

SSTD has managed (and provides help for) many space projects, involving universities, UK research councils, government departments and industry, ESA, NASA, EUMETSAT and the EU. We operate our Quality Management System and Space Products Assurance to ensure that projects comply with ISO 9001:2000 and +TickIT (Software) Standards.

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RAL Space Science and Technology manages and provides help for many space projects involving universities and industry

CHILBOLTON OBSERVATORY

The Chilbolton Observatory is a research station where experimental studies, primarily of the atmosphere, are conducted. The site is dominated by the fully steerable 25 m antenna, which can host advanced powerful radars, and also sophisticated sensitive receivers for satellite and astronomy work. A significant part of the Observatory's work is performed by the Chilbolton Facility for Atmospheric and Radio Research (CFARR, p.7), a ground-based atmospheric remote sensing facility serving both the atmospheric science and the radio science communities. Data collected by the Facility's instruments are archived and distributed through the BADC (p.24). Major experimental campaigns are frequently based at the Observatory; visiting scientists from the UK and overseas are able to operate their instruments alongside those of the Facility, while as many as three research aircraft collect data overhead. In 2006, a 4.5 m S- and X-band receiving satellite Ground Station was established 300 m from the main compound; this is currently supporting real-time reception of data from the STEREO A and B satellites. The station is also capable of receiving the high data rates from earth observation satellites.

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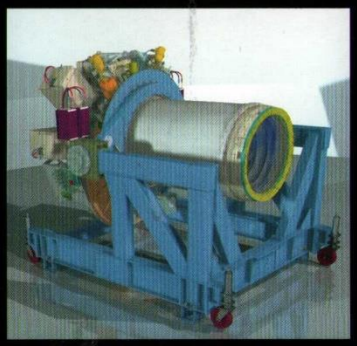
The 25 m antenna at Chilbolton Observatory

DESIGN

Our experienced engineers use the latest tools to design and build space and ground-based instruments. We adopt an integrated approach and support projects throughout the full life cycle, from requirements analysis and conceptual design through to flight or commissioning.

MECHANICAL DESIGN AND STRUCTURAL ANALYSIS

RAL has a small team of highly-skilled mechanical engineers with considerable experience in the design of lightweight subsystems for scientific instruments. We use the latest 3-D computer-aided design tools, with links to computer-aided manufacture and in-house rapid prototyping technologies. We also have finite element software tools for detailed structural analysis of parts and complete systems.



Mechanical CAD model of the VISTA IR Camera

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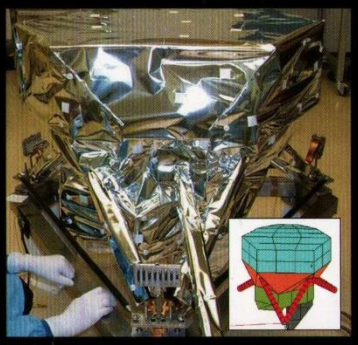
THERMAL SYSTEMS ENGINEERING



Thermal model of the JWST MIRI instrument MLI (inset) and photo-type MLI blankets during preparation for thermal balance testing

The Thermal Engineering Group designs space and ground-based instruments to meet temperature requirements, whilst surviving harsh environmental conditions. We provide a range of services from conceptual studies and detailed analysis, through to the definition and management of thermal tests. We also design, manufacture and procure thermal hardware and multilayer insulation blankets.

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INSTRUMENT DESIGN

RAL frequently assembles teams of specialists to help academia and industry to design instruments. RAL is continually searching for ways of improving the efficiency of this process by better integration of software to enable 'concurrent design', following similar innovations with its partners in NASA and ESA.

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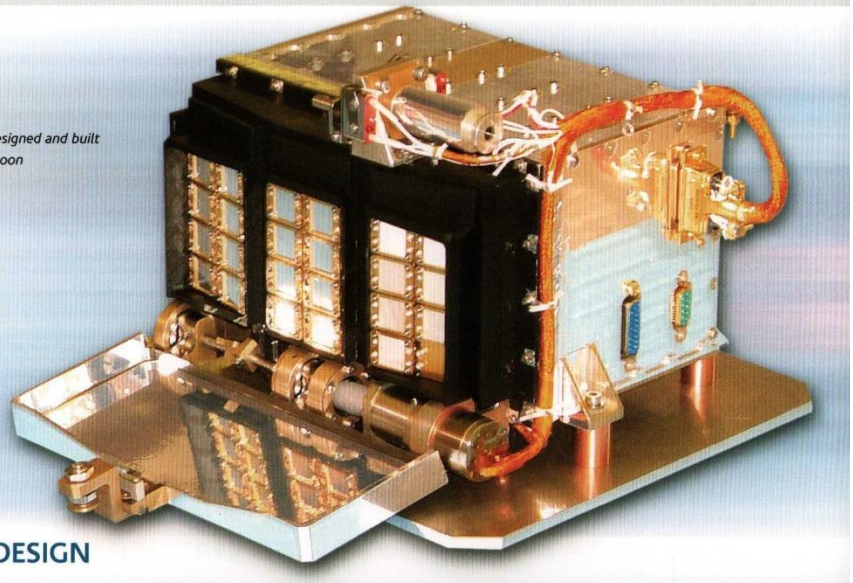
RAL engineers have designed and built instruments for operations on the ground, in Earth orbit and for other planets in our solar system



Flight model of D-CIXS (a Compact Imaging X-ray Spectrometer) designed and built by RAL and flown on the successful ESA SMART-1 mission to the moon

OPTICAL SYSTEMS

TopSat under construction at RAL

RAL designs and builds novel optical systems for a wide variety of space-borne instruments and ground-based astronomy projects. The range of applications includes high-resolution cameras for remote sensing, fibre-fed spectrographs for IR astronomy, and non-imaging systems (illumination and stray light analysis etc).

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RF DESIGN

Liquid nitrogen calibration for the microwave radiometers at Chilbolton Observatory

We are expert in the design of advanced radars, radiometers, satellite and terrestrial propagation measurement links, and their associated data acquisition systems. Our experience spans the RF range from HF to millimetre-wave, with customers in the government, academic and commercial sectors. We specialise in custom designs and prototypes, and have a proven track record of delivery encompassing concept studies, system engineering and detailed, component-level, design-and-build.

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TECHNOLOGY

RAL has a number of internationally-important technology groups, each specialising in a specific critical technology associated with cutting-edge space instrumentation. This expertise, backed by RAL's extensive engineering capability, allows us to play a leading role in defining novel scientific instruments.

RADAR SYSTEMS

We are expert in all aspects of radar design, with extensive practical experience in polarimetric, Doppler, coherent-phase, and pulse-compression techniques at UHF, microwave and millimetre wavelengths. Our operational systems span the range 1 to 94 GHz, employing advanced RF and signal processing technology to characterise precipitation, clouds and clear-air atmospheric effects.

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ELECTRONICS DESIGN

The Space Electronics Group has provided electronics packages for many of the instruments described in this brochure. Specialities include on-board processors and their software, mechanism control systems, and image processing using advanced electronics.

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HIGH RESOLUTION OPTICAL IMAGING

Building on the goals of the TopSat programme (p. 7), and on behalf of MDA Orbital Optics, RAL is developing next-generation Earth observation cameras capable of ground sampling down to 0.5 m per pixel from a small satellite. The new camera incorporates a new compact 3-mirror optical design and custom-designed TDI CCD detectors to gain sufficient sensitivity.

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CCD TECHNOLOGY

The group has a strategic programme in the development of CCD detectors, and readout electronics technology. It provides a UK lead through the development of radiation-tolerant ASICs designed specifically for science-grade CCD camera systems. A new CCD video processing ASIC provides a preamplifier, correlated double sampler and 16-bit ADC all in one low-power chip.

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COOLERS

RAL's 80 K Stirling-cycle coolers continue to function excellently in orbit on ATSR-2 (launched in 1995). 4 K coolers, using the same compressors plus a RAL Joule-Thomson head, are being provided for the Planck mission (p. 11). RAL cooler drive-electronics are used for AATSR and MIPAS on ENVISAT (p. 6). Under ESA contract, RAL developed a tool for the mathematical modelling of cryocoolers.

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MILLIMETRE AND TERAHERTZ INSTRUMENTATION

The Group is expert in technology for heterodyne radiometry between 100 GHz and 3.5 THz. Our devices, components and systems are used from ground, air and space-borne platforms for astronomy and remote sensing of the Earth's atmosphere. Examples of the Group's capabilities range from mixers and frequency multipliers, through photomixer sources and wire grid polarisers, to autonomous cryogenic radiometer systems. World class design, assembly and test skills are complemented by a Precision Development Facility and a dedicated semiconductor processing laboratory.

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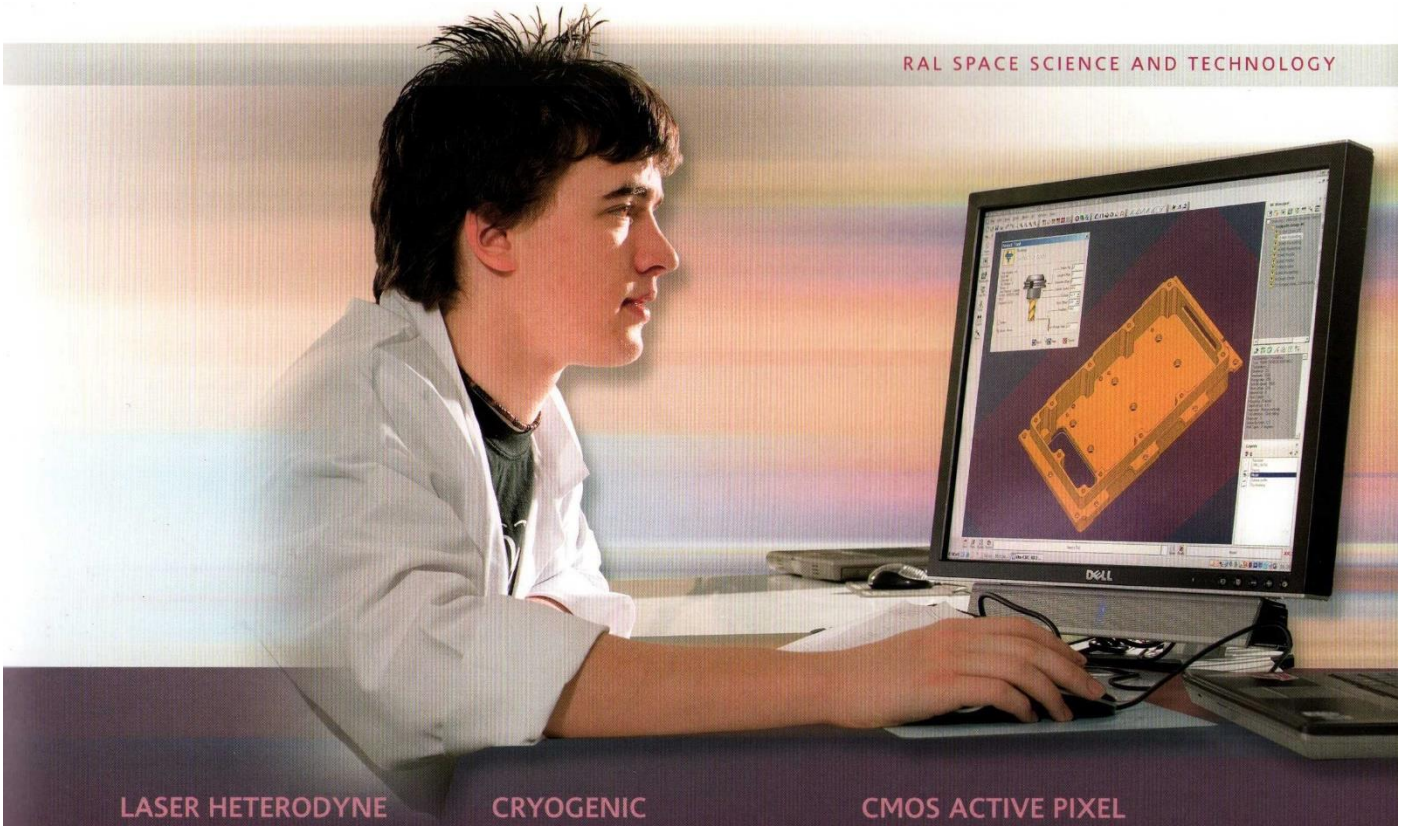

LASER HETERODYNE RADIOMETER

The prototype LHR

The mid-infrared Laser Heterodyne Radiometer (LHR) is a ground-based prototype instrument offering high spectral and spatial resolutions using a passive detection technique. The prototype has been developed to evaluate quantum cascade laser-based optical heterodyne detection for Earth observation applications. The LHR has been successfully demonstrated in the field, yielding atmospheric ozone profile retrievals with a vertical resolution of up to 2 km.

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CRYOGENIC ENGINEERING

RAL has a specialist capability in cryogenic engineering for space projects. We are involved throughout the full project life cycle, and have the expertise to cover all areas of instrument design and testing. A number of project-dedicated cryostats are currently being used to verify flight hardware designed and built at RAL.

1.7 K test cryostat for the Herschel/SPIRE instrument. Thermal design, analysis and verification of the instrument was carried out at RAL

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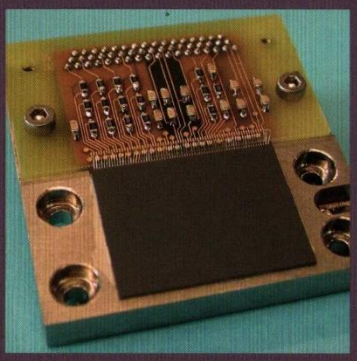
CMOS ACTIVE PIXEL SENSOR TECHNOLOGY



12 million pixel sensor

RAL has a UK lead in the development of science-grade CMOS Active Pixel Sensors as an alternative to CCD detectors. A 12 million pixel sensor has been demonstrated. Samples have also been thinned by e2v technologies plc in work leading towards the development of a back-thinned EUV sensitive detector for the extreme ultraviolet sensitive cameras for instrumentation on ESA's forthcoming Solar Orbiter mission (p. 3).

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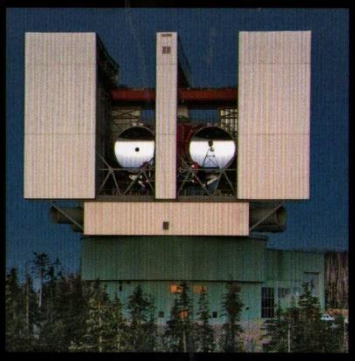
RAL is developing the next-generation Earth observation camera, capable of one metre per pixel ground sampling from a micro-satellite

OPERATIONS

RAL has a proven track record, recognised internationally, in the areas of satellite mission planning and payload science operations, providing ground-station services and software for the precision control of a wide variety of telescope systems.

TELESCOPE CONTROL



Large Binocular Telescope

RAL played a major role in developing the control system for the two 8 m Gemini astronomy telescopes operating in Hawaii and Chile. Current projects include the 2 x 8 m Large Binocular Telescope in Arizona, the 4 m Advanced Technology Solar Telescope on Maui, the 8 m Large Synoptic Survey Telescope in Chile and the VISTA 4 m infrared survey telescope at ESO's Cerro Paranal observatory in Chile (p. 11). RAL also played a leading role in the evaluation of the pointing performance of the prototype 12 m ALMA mm telescopes (p. 10). RAL is also involved in the baseline calibration of the ESO Very Large Telescope Interferometer in Chile.

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MISSION PLANNING AND OPERATIONS

RAL has been carrying out satellite mission planning and payload science operations since the 1970s, with missions such as Ariel 5, IRAS, AMPTE-UKS and ISO. More recent work includes the design, implementation and execution of science operations services for three of ESA's missions. The first of these is the Joint Science Operations Centre for the four-satellite Cluster mission (p. 5), launched in 2000 and the first of ESA's Cornerstone missions. The second is the Payload Operations Service for ESA's Mars Express mission (p. 8), operating since early 2004 and Europe's first mission to Mars. The third is the European Payload Operation Service for the two satellite Double Star Programme mission, launched in late 2003 and mid 2004, the first joint mission between ESA and the China National Space Administration (p. 5).

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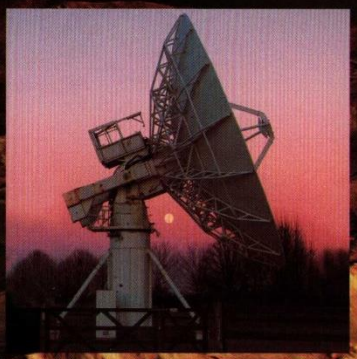
www.sstd.rl.ac.uk/SOGweb/a

SSTD SATELLITE GROUND STATION FACILITY

The Ground Station Group at RAL currently has 2.4 m and 12 m antennas, and has the capability for both S-band uplink command and downlink telemetry. At the Chilbolton Observatory, there is a 4.5 m antenna capable of S- and X-band telemetry reception, and the 25 m antenna can be made available as well. The Group is currently receiving data from the ACE (p. 4) and STEREO (p. 2) spacecraft, and routinely providing support to SSTL for Galileo GIOVE-A satellite. The Ground Station has the capability to support various other EO satellites, for example TopSat (p. 22).



12 m antenna at RAL

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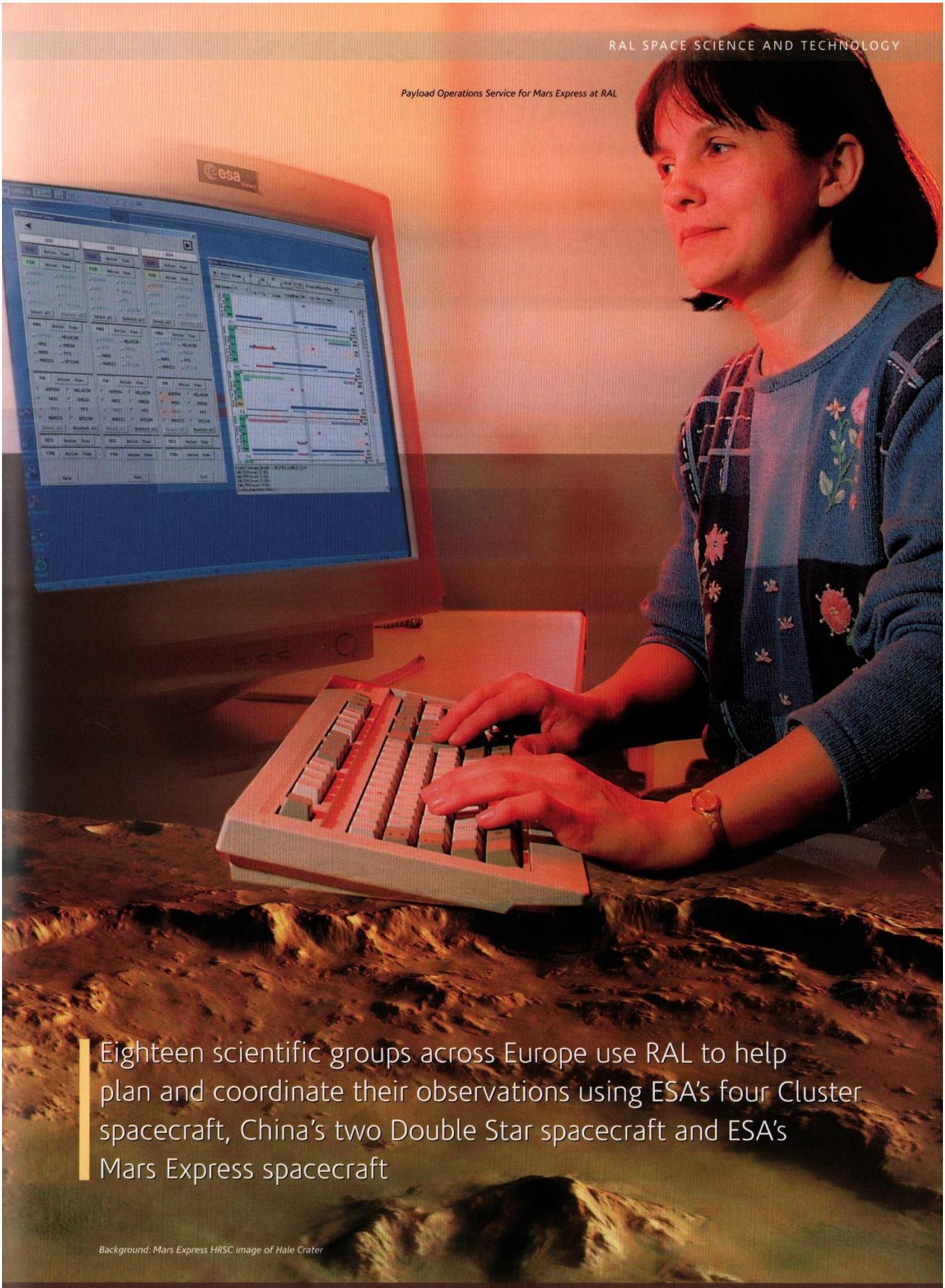

Payload Operations Service for Mars Express at RAL

Eighteen scientific groups across Europe use RAL to help plan and coordinate their observations using ESA's four Cluster spacecraft, China's two Double Star spacecraft and ESA's Mars Express spacecraft

Background: Mars Express HRSC image of Hale Crater

DATA MANAGEMENT

SSTD has very wide experience in the processing, analysis and archiving of science data. This expertise covers the fields of ground and space-based astronomy, solar terrestrial physics, and ionospheric, atmospheric and Earth observation. Allied to this, it has set up and maintains many web sites providing the science community with access to archived data.

BADC

An example of atmospheric data held by the BADC: a sky-camera image taken at the MST Radar site in Aberystwyth. Images taken at 1 minute intervals can be animated to allow user-scientists to interpret observations made by other instruments at the site.

The British Atmospheric Data Centre supplies meteorological and other atmospheric data to the scientific community. It also provides a long-term archive for data collected by NERC-funded research. Data suppliers include the UK Meteorological Office, the European Centre for Medium-range Weather Forecasts, and NASA. Distribution of data and services is done via the World Wide Web.

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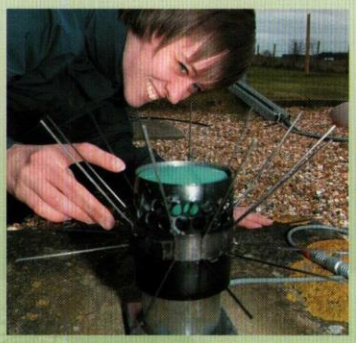
UKSSDC



Distometer on the rain-gauge site at Chilbolton Observatory

The UK Solar System Data Centre, incorporating the World Data Centre for STP, archives and distributes data, encompassing a diverse set of satellite and ground-based observations concerning the Sun, the planets, interplanetary space and the Earth's magnetosphere and ionosphere (spanning many solar cycles).

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CDHF

The Cluster Data Handling Facility is a national facility for the collection and distribution of data from the ESA Cluster and related Solar Terrestrial Physics missions. The CDHF is part of a European network of data centres for the Cluster and Double Star missions (p. 5), and also provides a mirror site of survey data from all of NASA's related missions. The CDHF is actively involved in heliophysics virtual observatory activities and standards development, and is one of the founding members of the international Space Physics Archive Search and Extract (SPASE) consortium, which aims to improve access to space physics data.

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High-resolution sea surface temperature observations from (A)ATSR now span 16 years, providing a key input to studies of climate change

AATSR image of New Zealand (in false colour)

NEODC

Aerial photograph of Eastbourne by NERC Airborne Research and Survey Facility, digitised image held in NEODC archive

The NERC Earth Observation Data Centre is one of eight NERC Designated Data Centres. It carries out professional data curation and archiving activities, and provides the NERC and wider environmental science communities with access to a rapidly-growing collection of EO data from a variety of satellite and airborne sensors. Recent highlights include the provision of access to data from the (A)ATSR instruments, the NEXTMap high-resolution terrain model of the UK, and digitised aerial photography from scientific surveys since 1981.

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CCSDS

The Consultative Committee for Space Data Systems is the body that develops standards for space data and information transfer systems. The member agencies of CCSDS include NASA, ESA, JAXA and BNSC. These standards are essential to ensure that cooperating space agencies can communicate with each other's spacecraft and control centres. As well as enabling interoperability between agencies, this also drives cost reduction, since having clear standards for communication and control means that each agency does not need to develop separate protocols for its own missions. RAL represents BNSC on the management council and contributes to work on data archiving standards.

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ASTROGRID

AstroGrid is an e-Science project; a UK contribution to the global 'Virtual Observatory'. It provides astronomers with easy access to the very large amounts of data (hundreds of thousands of terabytes) produced by modern instruments. The data cover a wide range of wavelengths (radio to X-ray), and include solar and space plasma data as well as traditional 'dark sky' astronomical data. Astrogrid is being developed by a collaboration of eight UK partners including RAL.

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RAL SPACE MISSIONS

RAL has been involved with more than 160 space missions and instruments (186 space instruments, as of 15 May 2007). The RAL involvement and main objectives are linked to the appropriate section(s) in the brochure and, where missions are mentioned explicitly, the page number is given.

Launch year	Mission	RAL involvement	Main objectives	Page
1974	**Ariel-5**	Services, operations	Astronomy	22
1978	**IUE**	Design, technology, data management	Astronomy	
1979	**Ariel-6**	Services, operations	Astronomy	
1980	**SMM** (XRP)	Technology, operations, data management	Sun	
1983	**IRAS**	Operations	Astronomy	22
1984	**AMPTE-UKS**	Design, technology, operations, data management	Near-Earth	22
1985	**Giotto** (DIDSY, JPA)	Services, technology, data management	Near-Earth	
1985	**Spacelab 2** (CHASE)	Services, design, technology	Sun	
1987	**Ginga** (Astro C, LAC)	Services, technology	Astronomy	
1989	**ZEBRA** (balloon-borne)	Services, technology, operations	Astronomy	
1990	**HST**	Data management	Astronomy	
1990	**ROSAT** (WFC)	Technology, data management	Astronomy	
1990	**CRRES** (MICS)	Technology	Near-Earth	
1991	**ERS-1** (ATSR-1)	Services, technology, operations, data management	Earth	6
1991	**UARS** (ISAMS, MLS)	Technology	Earth	
1991	**Yohkoh** (BCS)	Technology	Sun	2
1995	**ERS-2** (ATSR-2)	Services, technology, operations, data management	Earth	6
1995	**ISO** (LWS, PHT, CAM)	Services, technology, operations, data management	Astronomy	22
1995	**SOHO** (CDS)	Services, design, technology, data management	Sun	2
1996	**Polar** (CEPPAD,CAMMICE)	Technology	Near-Earth	12
1997	**Minisat-1** (LEGRI)	Technology	Astronomy	
1997	**ACE**	Operations	Sun	4
1997	**Cassini/Huygens** (CAPS, CDA, SSP)	Technology	Planetary	9
1998	**TRACE**	Data management	Sun	
1999	**UOSAT 12**	Services	Earth	
2000	**Cluster II** (RAPID, PEACE)	Services, technology, operations, data management	Near-Earth	5
2000	**STRV-1c/d**	Operations	Earth	
2001	**CORONAS-F** (RESIK)	Services, technology	Sun	12
2001	**BADR-B**	Technology	Earth	
2001	**MoroccoSat**	Technology	Earth	
2002	**ENVISAT-1** (AATSR, MIPAS)	Services, technology	Earth	6
2002	**EOS-AQUA** (HSB)	Technology	Earth	
2002	**NOAA-M** (AMSU-B)	Technology	Earth	15
2002	**MSG-1** (GERB2)	Services, design, technology	Earth	6
2002	**Coriolis** (SMEI)	Electronics	Sun	

The STFC Rutherford Appleton Laboratory provides world-leading research and technology development, space test facilities, instrument and mission design, and studies of science and technology requirements for new missions.

Launch year	Mission	RAL involvement	Main objectives	Page
2003	**Mars Express** (ASPERA)	Design, technology, operations	Planetary	8
2003	**SMART-1**	Technology	Planetary	8
2003	**NIGERIASAT-1**	Services	Earth	
2003	**BILSAT-1**	Services	Earth	
2003	**UK-DMC**	Services	Earth	
2004	**Double Star** (Equatorial)	Operations	Near-Earth	5
2004	**Rosetta** (MODULUS)	Services, design, technology	Planetary	9
2004	**EOS-AURA** (HIRDLS)	Services, design	Earth	
2004	**Swift**	Services	Astronomy	
2004	**Double Star** (Polar)	Operations, technology	Near-Earth	5
2005	**TopSat**	Technology	Earth	7
2005	**Venus Express**	Technology	Planetary	8
2005	**MSG-2** (GERB1)	Services, design, technology	Earth	6
2005	**GIOVE-A**	Services	Earth	7
2006	**Solar-B** (EIS, HINODE)	Services, technology, data management	Sun	2
2006	**Metop 3**	Services	Earth	
2006	**STEREO** (SECCHI)	Services, design, technology	Sun	2
2007	**CFESAT**	Services	Earth	
2007	**RAPIDEYE**	Services	Earth	16
2008	**Herschel** (SPIRE)	Services, design, technology, operations	Astronomy	11
2008	**Planck** (HFI, LFI)	Services, design, technology	Astronomy	11
2008	**NEXUS**	Services, operations	Sun	
2008	**Chadrayaan-1**	Design, technology	Planetary	8
2008	**Solar Dynamics Observatory**	Services, design, technology	Sun	3
2008	**GIOVE-B**	Services	Earth	7
2009	**LISA Pathfinder**	Design, technology	Astronomy	10
2009	**MedSat**	Design, technology	Earth	
2012	**SUVI** or **GOES-R**	Design, technology	Sun	3
2011	**MSG-3** (GERB3)	Services, design, technology	Earth	6
2011	**JWST** (MIRI)	Services, design, technology	Astronomy	10
2013	**BepiColombo**	Services, design, technology	Planetary	
2013	**Solar Orbiter**	Services, design, technology	Sun	3
2013	**MSG-4** (GERB4)	Services, design, technology	Earth	6
2015	**ACECHEM**	Technology	Earth	4
2017	**LISA**	Services, design, technology	Astronomy	10

Science & Technology Facilities Council

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Further information

The Rutherford Appleton Laboratory is part of the Science and Technology Facilities Council and is a partner member of the British National Space Centre (BNSC).

The Space Science and Technology Department (SSTD) conducts the bulk of its programmes in collaboration with other UK scientific institutes and universities. These include the following:

ATC
Bath
Birmingham
BNSC
Bristol
Cambridge
Cardiff
Central Lancashire
Cranfield
DEFRA
De Montfort
DSTL
DTI
Durham
East Anglia
Edinburgh
EPSRC
Essex
FCO
Glamorgan
Glasgow
Hertfordshire
Hull
Imperial College, London
Keele
Kent
Kings College, London
Leeds
Leicester
Liverpool John Moores
Manchester
Met Office
MOD
Mullard Space Science Laboratory
NERC
Nottingham
Ofcom
Open University
Oxford
Plymouth
Portsmouth
PPARC
Qinetiq
Queen's, Belfast
Queen Mary, London
Reading
Salford
Sheffield
Southampton
St. Andrews
Strathclyde
Surrey
Sussex
Swansea
University College, London
Warwick

SSTD also works with many international agencies, including:

ASI (Italy)
CAST (China)
CNES (France)
CNR (Italy)
CNSA (China)
CONAE (Argentina)
COSPAR (International)
CRCSS (Australia)
CRERS (Morocco)
CSA (Canada)
CSIRO (Australia)
DLR (Germany)
DoD (USA)
DSRI (Denmark)
EUMETSAT (Europe)
ESA (Europe)
ESO (Europe)
EU (Europe)
IAA (International)
IAF (International)
IFSI (Italy)
IKI (Russia)
INPE (Brazil)
INTA (Spain)
IRF (Sweden)
ISRO (India)
ITU (International)
JAXA (Japan)
KARI (Korea)
NASA (USA)
NRL (USA)
NCAR (USA)
NDRE (Norway)
NIVR (Netherlands)
NOAA (USA)
NSPO (Taiwan)
OECD (International)
PSI (Switzerland)
Roskosmos (Russia)
SSA (Sweden)
SSTC (Belgium)
SUPARCO (Pakistan)
UN (International)
USNO (USA)

The Department provides opportunities for hosting senior scientist and engineers on sabbatical leave, visiting scientists on short-term visits, and university sandwich course students on one-year placements. SSTD also provides graduate engineer training and CASE studentships. For more information see the Council's website.

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Science and Technology Facilities Council www.scitech.ac.uk

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