RAL Space

Highlights 2017

Science driven,
technology enabled

Science & Technology
Facilities Council

Aerial view of RAL Space R100 building. Credit: STFC

Welcome

In 2017 the world celebrated 60 years since the launch of Sputnik 1, the first artificial satellite. Space technology now underpins our society and economy in ways we could never have dreamed of 60 years ago. I am proud of RAL Space's heritage and the expertise we have contributed ourselves to help make this happen.

Our highlights this year, achieved through delivery of various successful projects, are about how we, our partners and our communities are set up for the future.

This year we delivered the SPICE instrument for Solar Orbiter. When launched, this European Space Agency (ESA) mission will enable a wealth of new solar discoveries which will help us understand and mitigate the effects of space weather on our planet.

Scientists, businesses and policy makers' access to reliable weather and climate data has been assured by our technology teams' roles in instruments for both Sentinel-3 and MetOp-SG.

The Chilbolton Observatory, which itself celebrated its 50th anniversary in 2017, remains cutting edge, helping protect space assets for partners at home and abroad with our space situational awareness and tracking facilities.

We have also had a real focus on world-class skills. From preparing future planetary explorers through the MURFI rover field trial, to providing training to early-career environmental scientists on how to best exploit the data available through the JASMIN supercomputer. Not to mention the thousands of children who have been inspired by our extensive public outreach programme.

In 2018 we look forward to breaking ground on the National Satellite Test Facility, a flagship investment of the Government's Industrial Strategy Challenge Fund, to underpin and support the growth of the UK space sector.

I invite you to read about a few of our highlights from 2017 and to join me in looking to the future and the opportunities that they bring for science, innovation and our society.

Dr Chris Mutlow, Director
Science and Technology Facilities Council (STFC) RAL Space

Perfecting climate data accuracy

With 20 years of sea surface temperature data from satellites now at scientists' fingertips, RAL Space is working to ensure continuity, calibration and validation.

The Sea and Land Surface Temperature Radiometer (SLSTR) for Sentinel-3 is a next generation sensor designed to provide fundamental information for ocean and weather forecasting and advance our understanding of climate change.

The Paris Climate Agreement's central aim is to keep global temperature rise this century well below 2°C above pre-industrial levels. With a narrow margin for measurement error it is imperative that the temperature data we are using is as accurate as possible, both in order to measure global progress but also to motivate individual countries and companies to work to mitigate their impacts.

SLSTR continues the dataset of global surface temperatures collected by the successful Along Track Scanning Radiometer (ATSR) series. RAL Space was the first institute to insist on pre-launch calibration of flight instruments. As such ATSR, and its successors, are considered amongst the most reliable remote sensing instruments in terms of data calibration.

To maintain the high accuracy required, RAL Space carried out a series of thermal vacuum and calibration tests on SLSTR. A purpose built rig was designed to allow the instrument to view different calibration sources under carefully controlled conditions. This ensures that data from SLSTR, once in orbit, can be reliably traced to reference standards as required for accurate climate monitoring.

RAL Space partners with Carnival Group UK to collect ground truth data for comparison with that coming from satellite instrumentation. The Scanning Infrared Sea Surface Temperature Radiometer (SISTeR) is installed on the Queen Mary 2 ocean liner to collect in-situ water surface temperature data as the ship travels across the oceans. SISTeR is used to provide calibrated validation of satellite measurements, including SLSTR, to help improve climate records.

As part of the open international science Group for High Resolution Sea Surface Temperature, RAL Space is working towards cross-comparison of radiometers from affiliated organisations. By combining strategic partnerships with technological excellence, RAL Space is providing the accurate data needed by scientists and policy makers to understand and mitigate climate change.

Artists impression of Sentinel-3. Credit: ESA–Pierre Carril

Earth Observation at RAL Space

SLSTR instrument in the cleanroom at RAL Space.
Credit: STFC RAL Space

RAL Space scientists contribute to and underpin UK and international programmes in environmental science. As well as providing research expertise and services, RAL Space is also involved in international collaborations to develop and test new instruments, remote sensing data exploitation and environmental modelling.

Understanding the impacts of space weather

RAL Space is using its long heritage in solar and space environment sciences to help to identify the level of risk from space weather, nationally and internationally, and how to mitigate its effects.

Understanding the Sun and its impacts on the near-Earth environment is becoming increasingly important. Over the last 50 years we have become critically dependent on advanced technologies in space and on Earth, many of which are vulnerable to space weather. Severe space weather is rare, but the potential impacts could range from power failures, to problems with satellite navigation signals and disruption to the banking systems.

The UK government is taking steps to understand and mitigate the impacts of space weather, which is part of the National Risk Register. RAL Space advises the Met Office, the Department for Business, Energy and Industrial Strategy, and the Cabinet Office, as part of the Space Environment Impact Expert Group (SEIEG). This group is providing scientific expertise to examine potential scenarios, assess the impact and plan for the UK's response.

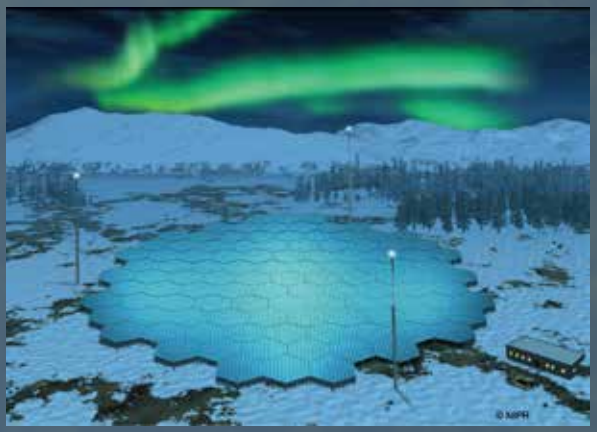
RAL Space scientists are working with economists to better quantify the socioeconomic benefits of space weather monitoring and forecasting and have helped to instigate a NERC project to study space weather impacts on UK railways and power grids.

This expertise is rooted in four decades of solar and space environment research and development of space-based and ground-based instruments. Recently, RAL Space has taken a leading role in the development of instrumentation for ESA's space weather mission, the Lagrange spacecraft, in addition to securing, in partnership with a Natural Environment Research Council (NERC), UK involvement in the most advanced space weather radar, EISCAT_3D. RAL Space is also leading the use of radio astronomy for science and forecasting, including the unification of telescope facilities globally to form the Worldwide Interplanetary Scintillation Stations (WIPSS) Network.

Once complete, these projects will significantly advance our understanding of the effects of space weather on technology, society and the environment.

Dynamic magnetic connections on the surface of the Sun. Credit: Solar Dynamic Observatory/NASA

Scientific and technological expertise



Artist's impression of the EISCAT_3D transmitter-receiver.
Credit: EISCAT Scientific Association

RAL Space is home to world leading expertise in fields as diverse as space weather to millimetre wave technology. With visiting professorships to institutions worldwide and provision of robust scientific advice to policy makers at national and international levels, RAL Space's influence extends well beyond Harwell.

Enabling environmental science

JASMIN is half super-computer, half data-centre for UK and European environmental science data.

With funding from NERC, STFC built and operate this bustling hub of scientific collaboration. Over 1500 users from a variety of scientific backgrounds now use JASMIN for its large storage and processing capabilities.

Satellites are providing us with increasingly large volumes of data about the Earth, helping to monitor everything from air pollution to agriculture. The Sentinel-3 satellites, part of the EU/ESA Copernicus programme, alone will produce up to 2 petabytes of data each year. Analysis of this data unlocks better land management practices, more sustainable agriculture, informs global policy on greenhouse gas emissions and protects homes and families from natural disaster. JASMIN provides the key for scientists to access and exploit these huge volumes of data quickly and efficiently.

Over 160 collaborative scientific projects are "tenants" of JASMIN, and have been allocated storage and computing resources on JASMIN to carry out their work.

One such tenant, the Centre for Observation and Modelling of Earthquakes, Volcanoes and Tectonics (COMET) is a NERC Centre of Excellence that uses satellite measurements alongside ground-based observations and geophysical models to study earthquakes and volcanoes, and help understand the hazards they pose. Using specialist software and computing resources tailored to their needs in the JASMIN private cloud, COMET scientists are automating the production of earthquake deformation maps using radar data from Sentinel-1. This allows measurement of surface deformation in multiple images with millimetre accuracy, furthering understanding of tectonic activity.

This "big data" project, and others like the ESA Climate Change Initiative, for which JASMIN is also being used as the large-scale production engine for several of the Essential Climate Variables, would simply not be feasible without JASMIN's unique computational and data storage capability. By funding JASMIN to underpin environmental research computing needs, NERC, the National Centre for Earth Observation (NCEO) and the National Centre for Atmospheric Science (NCAS) support their own communities and that of other related environmental science programmes.

RAL Space is also working to ensure that users have the skills to exploit this data, by running an 'Introduction to Scientific Computing' course for early-career scientists, and also hosting an annual JASMIN user conference. Over a hundred (mostly doctoral) students register to use JASMIN every year, with around 2000 more registering to exploit data via the CEDA archive.

CEDA provides, in parallel, both the archiving and fast processing required by today's data intensive and collaborative science.

The JASMIN supercomputer Credit: STFC RAL Space

Centre for Environmental Data Analysis (CEDA)

The JASMIN super computer. Credit: STFC RAL Space.

CEDA serves the UK and European climate, Earth-observation and environmental science communities through maintaining several data centres, large scale data analysis environments, and participation in a host of relevant research projects. JASMIN enables CEDA to carry out its mission more efficiently. With 20 petabytes of disk storage and over 6000 computing cores, JASMIN is a globally unique platform for computing and storing UK and European environmental science data. Jointly managed by CEDA and STFC Scientific Computing Department, JASMIN is funded by NERC, NCAS, NCEO and the UK Space Agency.

Providing early warning of hazards in orbit

RAL Space supports Space Surveillance and Tracking (SST) in collaboration with partners around the world.

There are currently around 1000 active satellites orbiting Earth and millions of pieces of debris from paint flecks to rocket bodies. Collisions are rare, but satellites and debris require routine monitoring to minimise the risks to the operators and users of active satellites.

RAL Space's Chilbolton Observatory plays an increasingly important role in tracking objects. The recently modified Chilbolton Advanced Satellite Tracking Radar (CASTR), can detect and track objects with Radar Cross Sections larger than 0.5m² in Low Earth Orbit out to 2000km.

The UK Government's Space Operations Centre (SpOC) tasks CASTR to provide accurate range information on specific objects to support space agencies across Europe. In autumn 2017, a request was made on behalf of the French space agency (CNES) to detect and range a rocket body, predicted to pass close to a satellite. CASTR tracked it over four days, assisting CNES to establish an accurate orbit for the object.

Further planned upgrades to CASTR will provide better sensitivity, range accuracy and a greater degree of automation. Once complete, sensitivity will increase by a factor of more than 100, enhancing its ability to track and characterise the increasing number of operational micro-satellites and smaller space debris.

Chilbolton Observatory has also developed the Chilbolton Optical Advanced Tracking System (COATS); this is a transportable optical tracking system small enough to take to a remote location and track objects in all orbital regimes.

RAL Space is working with the UK Space Agency and the EU to establish a European network to provide capability to monitor collision, re-entry and fragmentation events. Improvements to CASTR and development of modelling and forecasting tools are a vital part of the UK's growing SST capability.

25m dish at Chilbolton Observatory. Credit: STFC RAL Space

Chilbolton Observatory

Artist's impression of space debris in orbit around the Earth (not to scale). Credit: ESA

Chilbolton Observatory is home to a wide range of instruments for making meteorological measurements, performing radio and microwave propagation experiments and for tracking and communicating with satellites. The facility frequently welcomes visiting instruments from UK and European universities for research programmes and field campaigns. The site is dominated by the fully steerable 25m antenna, which can host advanced powerful radars and also sophisticated sensitive receivers for atmospheric research, satellite communications and radio astronomy work.

Delivering technology for solar physics

RAL Space leads the international consortium developing the SPectral Imaging of the Coronal Environment (SPICE) instrument for ESA's Solar Orbiter.

SPICE is one of ten instruments that will fly on board Solar Orbiter, a mission that orbits close to the Sun to understand how it creates and controls the heliosphere, the volume of space in which we live. The mission will help answer fundamental questions about how our star works and its influence on the solar system, including Earth. Solar activity can cause what are called space weather events, which can have an impact on critical infrastructure such as power grids, communications and aviation. The more that is understood of our closest star, the more can be learned about how to predict and mitigate against the adverse impacts of its activity.

RAL Space, alongside the Max Planck Institute for Solar System Sciences and other European partners led the early mission concept studies, putting forward the original project proposal for Solar Orbiter in 2000. Since 2012 RAL Space has managed the development of the SPICE instrument. Collaborators and subcontractors from the UK, Europe and the USA provided key sub-systems.

SPICE is an ultraviolet spectrometer which will provide remote sensing data of plasma dynamics at the Sun's surface and chemical composition in the solar corona. The mission will provide a better view of the Sun's poles by flying up out of the ecliptic plane and will fly within just 0.28 astronomical units of the Sun (inside the orbit of Mercury), a challenge for the design and testing of the sensitive instruments. The highly stable carbon fibre optical bench for the instrument was designed by RAL Space and built by URT, a small company based in Bognor Regis who have heritage in the automotive and auto-sports industries, allowing them to expand into a new business area.

The flight instrument was assembled at RAL Space and required a dedicated facility for the final thermal, optical performance and calibration tests. The instrument was tested up to its expected maximum operating temperature, 60°C, when Solar Orbiter is at its closest to the Sun. The optical tests used a specialist short-wavelength ultraviolet spectral lamp to check the instrument is correctly aligned and focused, and to calibrate its sensitivity.

In a culmination of five years of design and development, the SPICE optics and electronics boxes were safely installed onto Solar Orbiter at the Airbus cleanroom in Stevenage.

RAL Space is responsible for the three month 'near-earth commissioning' phase after launch; executing engineering calibrations and ensuring the health and operation of the instrument. Drawing on decades of expertise in solar missions operations, RAL Space is also responsible for instrument control and supporting the SPICE operations and science team optimise the observing strategy throughout the mission.

Artist's impression of Solar Orbiter. Credit: ESA/ATG medialab; Sun: NASA/SDO/ P. Testa (CfA)

Solar Physics at RAL Space

SPICE Optics Unit being assembled on to the Solar Orbiter spacecraft. Credit: Airbus DS

A cornerstone of UK solar physics research, RAL Space provides a world-leading research programme to help understand and predict how the Sun works and affects the solar system and the Earth's environment. The team delivers observational and scientific leadership in areas including physics of the solar corona and the heliosphere, X-ray and EUV spectroscopy, solar wind and Coronal Mass Ejections. Alongside research, the team is currently involved in operating and/or exploiting a number of instruments aboard major international missions including SOHO, Hinode, STEREO, SDO and IRIS. RAL Space is also leading a Europe wide consortium to develop a suite of instruments for a future operational mission to allow continuous monitoring of the Sun and provision of data to allow the Met Office forecasting of the space weather around the Earth.

Advancing Autonomous Systems

The UK Space Agency Mars Rover Field trial in Utah (MURFI) brought together scientists and engineers to build UK expertise to support future planetary exploration.

Robotic rovers and autonomous spacecraft play an important role in helping explore our solar system with RAL Space built systems currently on the surface of Mars, Titan and Comet 67P. Back on Earth, robotic systems, some of which have their roots in space exploration missions, have applications in industries including healthcare and agriculture. RAL Space facilitates UK academia and industry's capability to develop and operate these systems.

RAL Space coordinated the trial in November 2016, designed to prepare UK science teams for future Mars rover mission operations. Participants from seven universities spent three weeks based in a Mission Operations Centre in Harwell, with additional team members supporting at the field trial site in Utah, USA.

The Operations team only had access to data returned by the rover and from "Mars-like" satellite images. They used this to define and upload instructions each day to direct the rover to explore the terrain, deploy its various instruments and gather data with the aim of emulating an ExoMars-like mission scenario. These instructions were then carried out by the rover under the supervision of the Field team.

RAL Space and external experts worked to equip participants with a fuller understanding of missions operations and field trials. The simulation prepared participants, in particular Post-Doctoral or PhD candidates, to more effectively exploit future rover missions like ESA's ExoMars mission for data. STFC and RAL Space partnered with the Canadian Space Agency, working with them for part of the field trial and built links with the German space agency (DLR).

RAL Space is uniquely positioned between industry and academia to coordinate field trials like MURFI. The whole team benefited from RAL Space's extensive experience in conducting and supporting field trials for robotic hardware and software as consortium lead for the SEEKER and SAFER trials in 2011 and 2013 as well as the HRAF Pilot 2 project.

The rover in action in Utah. Credit: STFC RAL Space

Harwell Robotics and Autonomy Facility (HRAF)

MURFI Mission Operations Centre in Harwell.
Credit: STFC RAL Space

RAL Space is at the heart of efforts to coordinate and enhance European development of robotic and autonomous solutions for planetary exploration. HRAF is being established with STFC by ESA and the UK Space Agency to support space robotics and exploration programmes at all stages of the project lifecycle, from incubation of new system concepts to field trials. The facility builds on the experience of RAL Space's in-house autonomous systems team to support field-testing, knowledge sharing and validation and verification of spacecraft autonomy systems across the UK and Europe.

Innovating for precise weather forecasting

Meteorological Operational Satellite - Second Generation (MetOp-SG) is a EUMETSAT and ESA collaboration involving three pairs of satellites to be launched between 2021 and 2031.

Thanks to previous meteorological satellites, weather prediction and climate models have become increasingly accurate and reliable over the past few decades. Many sectors of the economy (from ice cream sellers to international haulage companies) depend on this information for day to day and long term planning. Meanwhile individuals and governments can trust this data to take action in advance of extreme weather events.

The new generation of meteorological satellites are benefiting from RAL Space excellence in calibration and millimetre-wave technology to continue to provide and improve this vital data for meteorological services worldwide.

RAL Space is involved in three instruments for each pair of satellites. The Microwave Sounder (MWS) will measure temperature and humidity. The Microwave Imager (MWI) will provide higher-quality now-casting data on precipitation than is currently available. The Ice Cloud Imager (ICI) will, for the first time, provide qualitative data on ice cloud composition, believed to play a key role in climate.

This generation of MetOp satellites will have higher sensitivity and higher operation frequency thanks in part to the RAL Space designed millimetre-wave technology for the front-end receivers. As well as helping provide more precise weather measurements than ever before, this work is extremely relevant to future telecommunication systems as the atmospheric effects measured will affect the data rates available from many of the future constellations looking to provide broadband connectivity from space.

RAL Space is one of only a few facilities worldwide with the expertise to produce highly specialised calibration targets, particularly for microwave instruments. Maintaining the required temperature control is a significant technical challenge for targets of such large size and surface area. Engineers at RAL Space have developed innovative methods to overcome this as well as for the production and integration of the targets.

With a long heritage in both calibration and millimetre-wave technology, RAL Space continues to generate innovative solutions to meet the need for accurate, high performance instrumentation. Access to this expertise has positioned UK industry to win contracts to provide ESA and EUMETSAT with advanced instrumentation.

Artists impression of MetOp-SG. Credit: ESA

Instrument development at RAL Space

Black body calibration target former for MetOp-SG.
Credit: STFC RAL Space

RAL Space is home to a number of internationally-leading technology groups, which specialise in specific critical technologies associated with cutting-edge space instrumentation. Specialist disciplines include mechanical, thermal and systems engineering, detector electronics, along with particular expertise in millimetre-wave and terahertz technologies. RAL Space provides the full life-cycle of a space project ranging from pre-feasibility study through design, manufacture, assembly, integration, test, calibration and operations support.

Inspiring the future space community

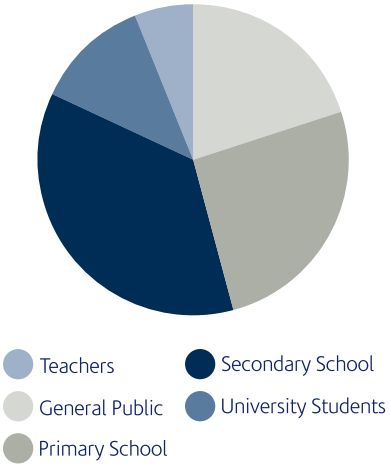
RAL Space's extensive outreach programme maximises the impact of our knowledge, skills and facilities to inspire and involve schools and the public in cutting edge science and technology. During 2017 RAL Space organised, supported and participated in over 200 outreach and engagement activities, reaching over 28,000 people.

RAL Space gives students from all backgrounds the opportunity to experience and explore Science, Technology, Engineering, Arts and Maths (STEAM) subjects and careers first hand. We inspire the next generation of scientists, engineers and technologists, providing world-class skills vital for the continued growth of the space sector.

In 2017 RAL Space reached over 28,000 people

Through more than 200 events

Including over 80 outreach events



Involving people across the UK

Beavers dressing up in clean room suits to celebrate World Space Week 2017. Credit: STFC RAL Space

For more information please contact:
Robert Elliott, Head of Business Development, RAL Space
Robert.Elliott@stfc.ac.uk
Tel: +44 (0) 1235446453

www.ralspace.stfc.ac.uk

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