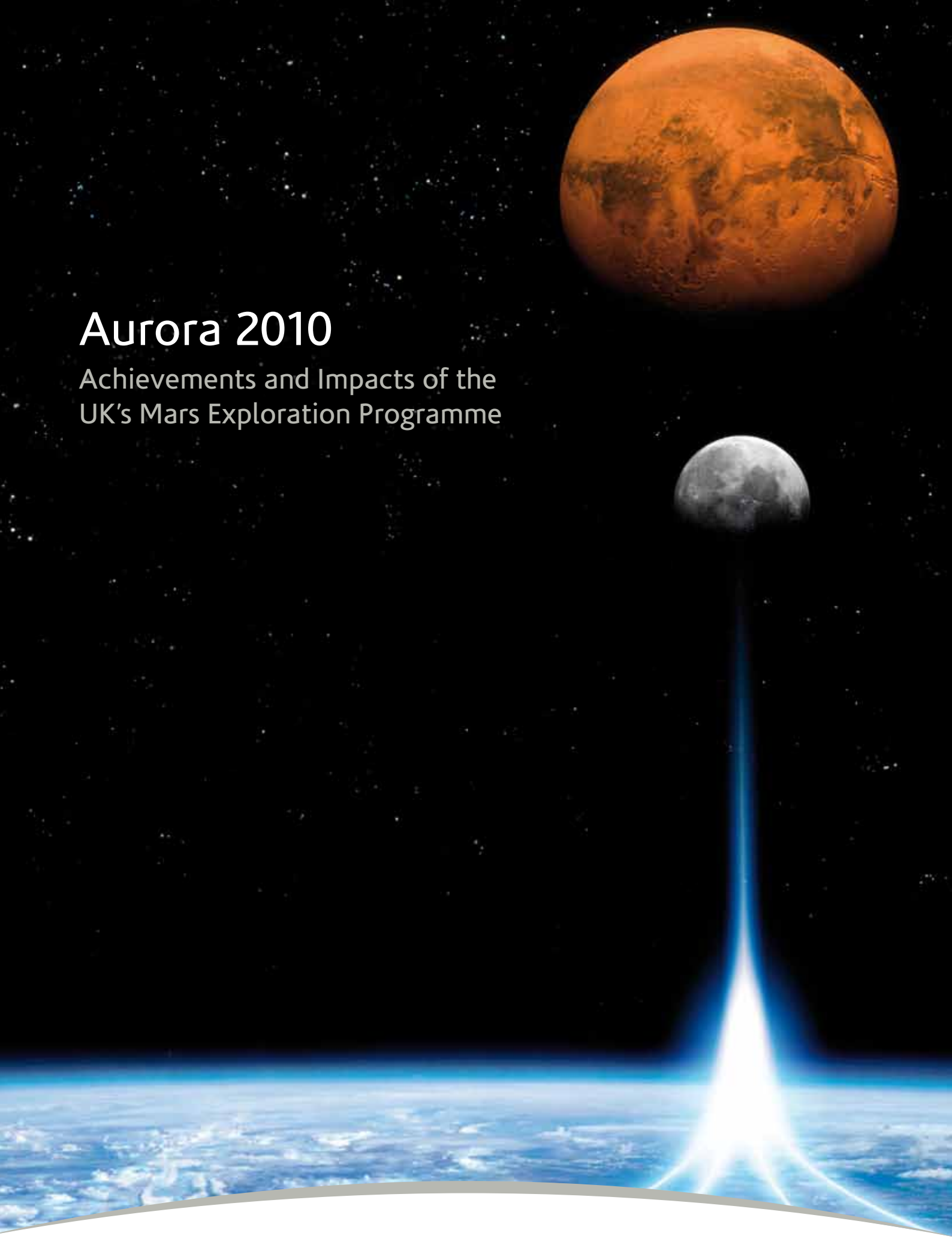


Aurora 2010

Achievements and Impacts of the UK's Mars Exploration Programme

BNSC
BRITISH NATIONAL SPACE CENTRE

Science & Technology Facilities Council

Introductions

Aurora is a European Space Agency (ESA) programme for long-term European involvement in the exploration of our Solar System. The Science and Technology Facilities Council (STFC) funds the scientists and institutions that are part of the UK Aurora programme and helps deliver a number of important benefits.


Credit: STFC

The UK's Aurora programme provides a strong cross-disciplinary science and technology base, develops a highly-skilled workforce and delivers economic impact through technology spin-outs. It also encourages partnerships between industry and academia and helps attract young people into science and engineering.

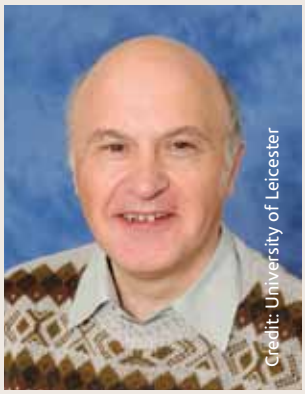
Initially focusing on the Moon and Mars, the first major element of Aurora will result in the ExoMars rover landing on Mars in January 2019.

Understanding the conditions that could have supported life on Mars is an important step towards addressing one of mankind's most fundamental questions: are we alone in the Universe? By answering this question, STFC can also deliver its vision "to maximise the impact of our knowledge, skills, facilities and resources for the benefit of the United Kingdom and its people."

This is the first report on the progress and outcomes of STFC's UK Aurora programme. The innovation and technology spin-outs already achieved at this early stage are impressive and STFC looks forward to this continuing into the future.

PROFESSOR KEITH MASON
CHIEF EXECUTIVE, STFC

The UK is taking a leading role in developing the European Mars exploration programme. It is the largest contributor to the Mars Robotic Exploration Preparatory (MREP) Programme, the second largest subscriber to ExoMars and currently chairs the International Mars Exploration Working Group.


Credit: University of Leicester

MREP supports technology studies and long-term development for future missions such as Mars Sample Return, which will be the first mission to return samples of Martian rock to Earth. The UK Aurora programme supports the UK's contribution to ExoMars' scientific payload as well as technology development to strategically position UK industry and academia, knowledge exchange, science exploitation and outreach.

The Aurora Advisory Committee (AurAC) was set up to advise STFC and the British National Space Centre (BNSC) on priorities within the programme. The committee contains representatives from industry and the broader scientific community including areas supported by other research councils. This range of expertise ensures that knowledge from other disciplines is brought into the programme and that outcomes feed back into all relevant fields.

During this initial phase the emphasis has been on successfully positioning the UK to take a leading role both technically and scientifically. Fostering industrial and academic partnerships at the start has developed a natural route for technology development and is already paying dividends.

PROFESSOR MARK SIMS
AurAC CHAIRMAN 2005-2010

From science on Mars to life on Earth

The discovery that life on Earth can survive under extreme environmental conditions has rekindled thoughts about the existence of life elsewhere in the Universe. Thanks to scientific and technological advances we can address this question by exploring our Solar System.

Mars may appear arid and lifeless but it is the most Earth-like planet in the Solar System. It is the most likely planet to have supported life at some time in its history as it shows substantial evidence of surface water in the past. Even today liquid water could still be present at depth beneath the surface.

The first billion years of Earth's history, during which life probably emerged, are not present in its geological record but Mars' geological record for the same period is preserved.

Discoveries in the last ten years have indicated that Mars is geologically dynamic and that conditions have existed to support the emergence of life. The detection of active methane emissions in 2003 raises the question of whether this is geological or biological in origin.

Past hydrothermal systems and areas of salts and clays have also been found and these will be targeted in the search for traces of past or present life. Studying Mars will also help us understand the early evolution of water-rich terrestrial planets similar to Earth and the development of habitable environments.

Mars is the most accessible planet from Earth and Aurora's long-term goal is for a Mars Sample Return (MSR) mission, a necessary forerunner for later manned missions. The International Mars Exploration Working Group (IMEWG), currently chaired by the UK, is co-ordinating worldwide plans for Mars' exploration and is developing implementation plans for MSR.

A number of missions will be required to develop and test the technology necessary for MSR. The UK hopes to become a major player in this endeavour and ExoMars is a first step towards achieving this aim.

Artist's view of the Mars Sample Return ascent module returning to Earth with Martian soil samples

Echus Chasma – one of the largest drainage channels on Mars

A Mars Express image of a crater in Mamers Valles, a long winding valley on Mars

ExoMars

ESA's ExoMars mission was originally conceived as a single-launch mission with one rover and a science station. In 2009 the mission was redefined as a larger-scale collaboration between ESA and NASA. The UK played an influential role during these negotiations, prompting and hosting discussions with NASA, ESA and the main European partners while allowing UK objectives to remain centre-stage.

The new ExoMars mission satisfied both space agencies' objectives and is compatible with the 1B€ European budget. It also provides an enhanced science return with the introduction of an orbiter. This will serve as a new high-performance data-relay satellite in Mars orbit for use in 2016, 2018 and subsequent missions. The mission has two elements:

Mars 2016

An ESA-led orbiter will study the origin and distribution of methane and other trace gases in the atmosphere. It will also carry a lander to demonstrate European capability in undertaking a controlled landing on Mars.

Mars 2018

The 2018 NASA mission will land the European ExoMars rover and a NASA rover. The European rover will carry out experiments to detect evidence of past and present life and to investigate the local environment. These experiments will be performed on soil samples taken from depths of up to two metres, where the chances of finding evidence of organic compounds that indicate past or present life are greatest.

Roving the red planet

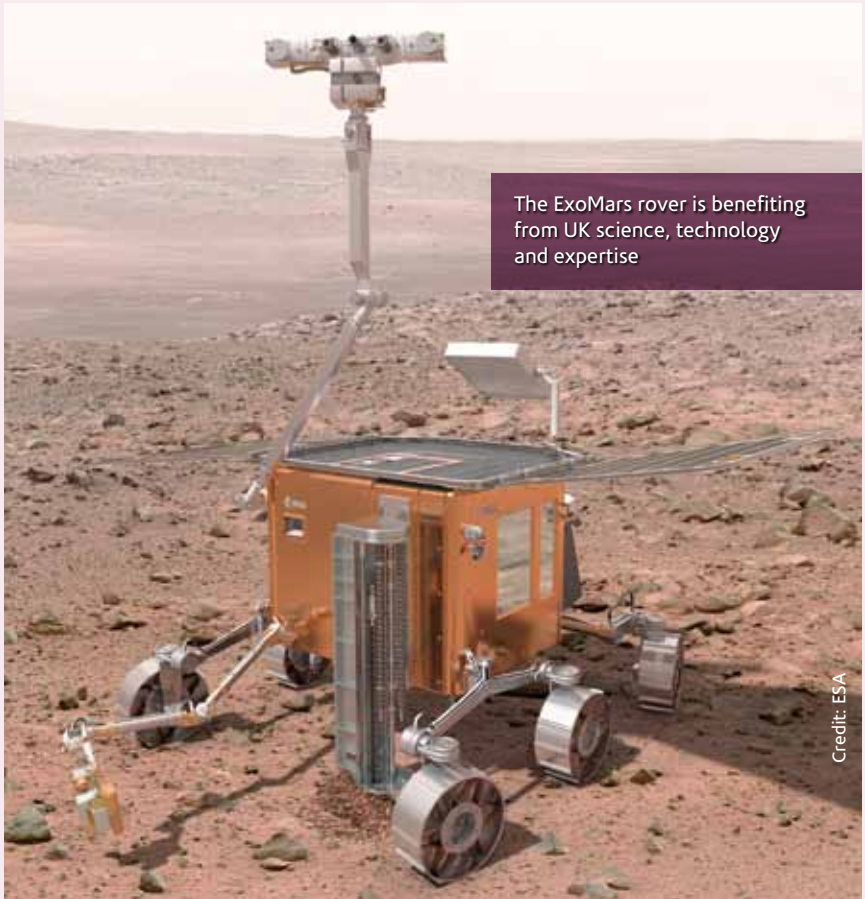
In 2019 two rovers from ESA and NASA will land on Mars. The lead company developing the European ExoMars rover is Astrium UK.

"Building a team to deliver the first European rover to land on Mars is more difficult than one would first imagine," says ExoMars Vehicle Project Manager Mark Roe, from Astrium UK in Stevenage.

"The rover is in many ways like a spacecraft but also unlike it, as so many of the existing tools and products are not immediately applicable," he states. "Within the UK, however, we have a solid foundation of capability to draw upon."

The ExoMars rover has been through several transformations with the latest model being tested at the Astrium Mars Yard in Stevenage, Hertfordshire. Early testing with the rover's unique drill, which can retrieve samples from up to two metres below the surface, is being performed in Italy while in the UK the focus is on understanding the software-driven navigation controls and improving mechanical performance over terrains similar to those present on Mars.

The wider rover vehicle team has drawn on expertise from many institutions including Aberystwyth University, Dundee University, Surrey Space Centre, and the UK companies Roke Manor Research, in Hampshire, and ABSL Space Products in Oxfordshire. This combination of UK science, technology and engineering talent is helping to deliver this challenging mission to Mars.



The ExoMars rover is benefiting from UK science, technology and expertise

Credit: ESA

Instruments for success

The eyes of Mars

The Panoramic Camera (PanCam) on the ExoMars rover acts as its science eyes on the ground. A pair of wide-angle cameras (WACs) provide a 3D panoramic view of the nearby terrain while a high-resolution camera (HRC) allows close-up capability. All three cameras, sited on the rover's mast, will picture the Martian terrain in unprecedented detail and help plan which areas the rover will explore next.

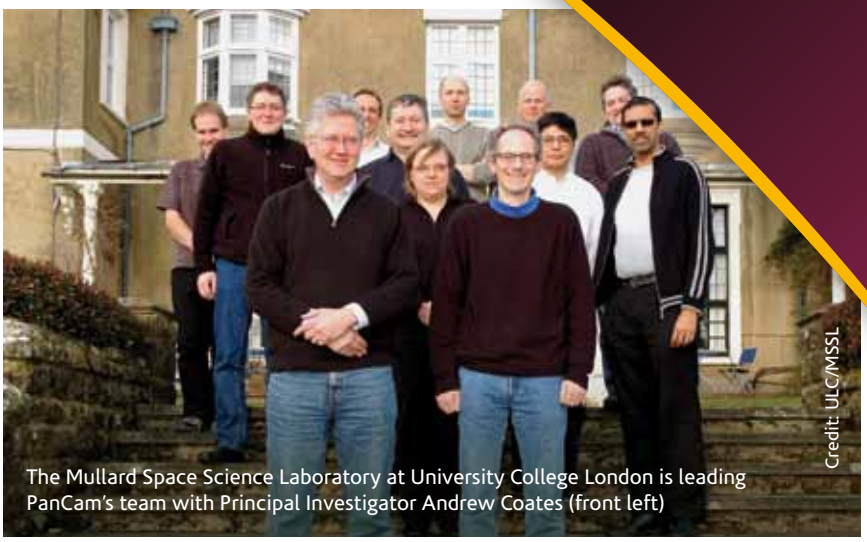
Researcher Claire Cousins examines a PanCam filter wheel

Credit: UCL/MSSL

The Mullard Space Science Laboratory at University College London leads the international PanCam team and the main elements have been successfully tested in Norway (AMASE, the Arctic Mars Analog Svalbard Expedition) and Bedfordshire.

Mars rocks

The ExoMars mission will analyse any soil samples collected by the rover and the Mars-XRD instrument – an X-ray diffractometer – will measure the composition of samples and determine their mineral content. The project is led by Italy with the UK responsible for the detector assembly. This will detect the X-rays diffracted by the Martian samples and provide the data necessary for scientific analysis.



The Mullard Space Science Laboratory at University College London is leading PanCam's team with Principal Investigator Andrew Coates (front left)

Credit: ULC/MSSL

Mars-XRD relies on the partnership of a young dynamic team from the University of Leicester and e2v Technologies (UK) Ltd for delivery of the detector assembly. Designing such a small instrument will have additional benefits ranging from pharmaceutical to archaeological applications.

Martian forensics

Raman spectroscopy is a non-destructive, analytical technique often used in forensic science. The Raman Laser Spectrometer on ExoMars will use a laser and digital camera system, supplied by the UK, to analyse samples drilled from the planet's subsurface for the composition and structure of minerals and organic compounds.

The spectrometer will search for characteristic 'life-detection signatures' produced by organisms that can survive in extremely hostile environments. Such organisms, or extremophiles, are believed to be the most likely form of Martian life, if present. The instrument will also be able to identify minerals that have been altered by the presence of past life or water.

Markers for life

The Life Marker Chip (LMC) instrument on ExoMars will detect organic molecules from crushed samples obtained by the rover's drill. Mixing the sample with solvents will remove the organics from the mineral and will detect them using molecular receptors (antibody fragments). The readout is made via a fluorescent label, which glows when illuminated by a red laser. The resulting pattern of glowing spots indicates which molecules are present.

The LMC aims to detect organic molecules that might have been associated with past life on Mars and also current life, which could still be present below the surface. It can also detect organic molecules arising from non-biological processes. The University of Leicester leads the instrument with major contributions from Cranfield University and Imperial College London in the UK, the Netherlands, Germany, Italy, and science involvement from USA, Norway and Sweden.

Members of the Mars-XRD team at the University of Leicester including Technical Lead Richard Ambrosi (second left) and co-principal Investigator Ian Hutchinson (third left)

Credit: University of Leicester

CREST for success

Technology development

The UK, by participating in Aurora, is building its technical capability for exploring the Solar System and also hopes to maximise any economic impact resulting from this technology.

After wide consultation in 2004, the UK's priorities were identified as science instrumentation, autonomous vehicles and robust descent systems. These then informed STFC's priorities for industrial return on ExoMars: to lead rover vehicle development and to secure niche roles in the entry, descent and landing systems.

STFC set up its Collaborative Research in Exploration Systems and Technology (CREST) initiative to support Aurora's scientific and technological goals. CREST aimed to build long-term knowledge exchange partnerships, facilitate technology spin-outs and position industry and academia for future work from ESA – particularly for ExoMars.

STFC funded nine CREST projects to a value of £1.7m. These included the development of novel autonomous software to enhance the scientific productivity of rovers. The ability to rapidly react to and avoid obstacles without the use of complex image processing, for example, reduced travelling time between scientific targets. Software was also developed to automatically identify rocks that would warrant further investigation. These advances have helped position Astrium UK to lead the ExoMars rover vehicle with support from other UK companies.

Supersonic flow

Another CREST project studied the supersonic flow of air around spacecraft parachutes to improve the design, performance and prevent mission-threatening instabilities during the descent phase. This work has positioned UK company Vorticity Ltd for an important role in the early design phase of the ExoMars descent system.

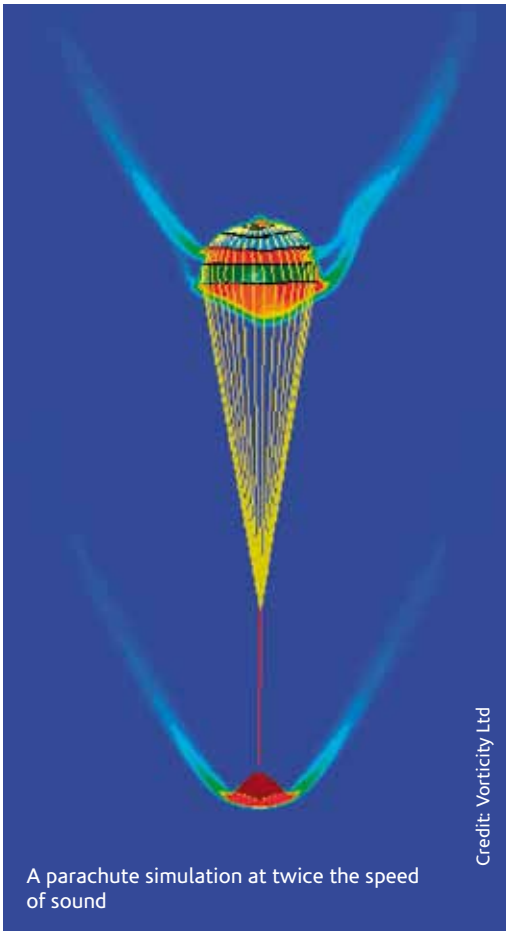
The research can also be applied to terrestrial parachute systems requiring supersonic flow performance, such as aircraft escape systems, and the analytical techniques developed can be used on a broad range of engineering design problems.

ExoMars instruments

All the CREST-funded instruments, including the rover, were included on the original ExoMars mission scheduled for launch in 2013 – a testament to the programme's success. Four instruments, plus the rover, are now on the reconfigured ExoMars rover mission which will be launched in 2018.

An STFC review of CREST, in 2009, found that the programme had been extremely successful in meeting its aims and objectives, both enabling and increasing collaborative partnerships between industry and academia. The review recommended that similar programmes should be operated by STFC in the future.

Respondents to a questionnaire that formed part of the review described a wide range of outcomes including direct benefits to science, industry, engineering, technology, outreach and education. Support for the programme was universal and enthusiastic with all respondents stating that they would reapply for funding if it became available. CREST finished in 2007 after a period of 18 months but it is now hoped that a CREST 2 programme will be launched in 2010.



A parachute simulation at twice the speed of sound

Credit: Vorticity Ltd

Expanding the science community

Aurora research has resulted in patents, commercial applications and unforeseen benefits. Listed below are just a few examples of the programme's successful spin-outs in fields ranging from human mobility to environmental resources.

Clean and green

Technology developed for ExoMars is helping to clean and extract oil deposits in less time – and using less water – than current methods.

Two-thirds of the Earth's petroleum lies in deposits such as oil sands which are difficult to retrieve. They are usually mined and extracted using a hot water and flotation step but the process leaves substantial amounts of water, contaminated by organic compounds, sitting in settling pools for years.

ExoMars scientists at Imperial College London came up with an innovative solution. State-of-the-art components for detecting organic matter on Mars require water-based solvents to extract 'molecular fossils' from rocks. The extraction uses an advanced surfactant technology that is readily transferable to terrestrial applications and can reduce the time needed for the water recycling process to days or weeks.

These surfactants also scavenge organic compounds from water and are so environmentally benign they are actually edible.

Detecting drugs and diseases

The Life Marker Chip (LMC) instrument is designed to detect trace levels of multiple organic molecular targets – biomarkers of life – in samples of Martian rock and soil while, at the same time, operating in extreme environments.

Developed for ExoMars by scientists at the University of Leicester and Cranfield University, the LMC uses advanced medical diagnostics technology that can detect the presence of diseases and antibodies. The LMC can also detect molecular pollutants, leading to a number of possible uses within the environmental sector, as well as security applications through detecting illicit drugs and chemical or biological agents.

Yes we can!

Magna Parva Ltd, based in Leicester, is applying engineering know-how gained from ExoMars to a number of different challenges. These include modifying the design of beverage cans so that less material is used during manufacture.

The company's work with a global beverage can maker has allowed raw material costs to be reduced by 12% – a huge potential impact since the global consumption of canned beverages alone is around 270 billion units each year. Apart from possible annual savings of around £100 million in ten years time, the innovation also benefits the environment. Magna Parva was shortlisted for the Lord Stafford Award for Innovation in Development in 2009.

Flying high with robotic technology

Robotic technology intended for Mars could soon be helping to transport passengers and goods at airport terminals on Earth.

A consortium of academics and industry, led by Wiltshire-based company SciSys, successfully demonstrated an autonomous Mars rover prototype and adapted the system for use in airports. It will allow people with reduced mobility to use smart devices to remotely request transportation.

The underlying control software was the result of STFC-funded work and a prototype has been developed, courtesy of the EU sponsored FP6 programme. This was demonstrated in a live trial in December 2009 at Portugal's Faro Airport.

Credit: Magna Parva

Aurora Fellowships

STFC funds a number of fellowships as part of the Aurora programme. These three-year awards are targeted at active young researchers – the potential science leaders of the future – in the fields of planetary science and astrobiology.

The fellowships are also aimed at enabling established academics in other science areas to transfer between disciplines and apply their skills to astrobiology.

"The first discovery of water vapour, methane and carbon dioxide in the atmosphere of an extrasolar planet with space and ground-based telescopes was accomplished with collaborators as part of my Aurora project. This was a boost to my career and eventually led to a permanent position at University College London."

Giovanna Tinetti, University College London

"During my fellowship I started projects related to Mars, the Moon, outer planets and general habitability. I am preparing for future missions and instruments and analysing data using methods from engineering, maths and sometimes just sheer speculation. The fellowship has certainly helped me to broaden my scientific horizon."

Axel Hagermann, Open University

"Outreach, such as school talks and visits, has been an important part of the fellowship helping to inspire the next generation of young planetary scientists. I hope the UK continues its investment in establishing planetary sciences through fellowships and world-leading participation in missions dedicated to the search for life within our Solar System and the study of our planetary neighbours."

Manish Patel, Open University

"Multidisciplinary research of this kind has often fallen between funding agencies but the STFC Aurora fellowship has allowed me to pursue my goals and set up growing collaborations in the UK and overseas. My next step is to help the UK become a world-leader in planetary science and space exploration."

Peter Grindrod, University College London

"The Aurora programme is about curiosity. It combines exploration and science and my own research focuses on exploring and understanding the planet Mars. In 2009 I was invited to be president of the Geology Section of the British Science Association and I've also given radio interviews and classroom 'skypechats' about Mars and the search for life."

Matt Balme, Open University

"Life as we know it would not exist without phosphorus. Understanding how nature came to use and develop this element into some of the complex molecules of life, such as DNA, will help us piece together how water-based biology emerged on Earth and in turn how such a transformation might occur on non-terrestrial bodies."

Terence Kee, University of Leeds

"I am focused on the evolution of volatile elements, from their origin and through the formation of the earliest building blocks of the Solar System, to the present state of the terrestrial planets, asteroids and comets. I also help to teach various aspects of planetary science at the University and in the public arena."

Henner Busemann, University of Manchester

Aurora Studentships

STFC is funding four Aurora studentships in autumn 2010 leading to PhDs in the fields of planetary science and astrobiology. As a result four young graduates will start their academic careers at the universities of Aberdeen, St Andrews and the Open University.

Astrobiology summer school

The second STFC astrobiology summer school was held at the University of Kent in September 2009. Organised by Professor Mark Burchell, chairman of the UK Astrobiology Society, the summer school was attended by 26 research students from backgrounds including astronomy, planetary science, geology, physics, biology, chemistry and space science.

The wide-ranging programme included lectures by both internal and external speakers, practical sessions, project workgroups and a field trip. Participants also gave a short presentation on their own research. Feedback was excellent with organisation and content being graded either 4 or 5 on a scale of 1-5.

Aurora workshops

The Open University hosted a workshop on habitability and landing sites on Mars in June 2009. Sponsored by STFC, this was the first in a series of two-day workshops and was attended by 33 scientists from the UK, who discussed priorities for selecting landing sites on Mars and the best uses of UK science and technology strengths.

The resulting document, published in the Royal Astronomical Society's journal *Astronomy & Geophysics*, confirmed the UK's expertise in several key areas including remote sensing, landing and surface operations, instrumentation, astrobiology and cosmochemistry. A second workshop on space robotics in future Mars lander missions took place on March 17-18, 2010.

UK Aurora Meeting

The first 'UK in the Aurora Programme' meeting was held in December 2008 at the Royal Astronomical Society (RAS) in London. The aim was to bring together researchers within the planetary science community interested in this ESA space programme. Over 20 UK institutions were represented with 14 talks and 22 poster presentations. At least six major areas of active research within the Aurora programme were evident: scientific instrumentation for ExoMars and other landers, technology for robotic missions, remote sensing of the Moon and Mars, meteorite analysis, noble gas analysis and exobiology. The next UK Aurora meeting at the RAS is planned for 2010.

Inside the 100km-wide Nicholson Crater is a raised hill 55km long and approximately 3.5m high. No one knows how it was formed

The 10km-wide valley arm merging into Ares Vallis is believed to have formed billions of years ago. Surface features suggest it was carved into the Martian landscape by large water flows

Science outreach: spreading the word

Credit: Cranfield University

Dave Cullen talks about life on Mars to Cranfield Lower School children

Credit: Astrium

Astrium scientist Ben Boyes with Bridget and the Blue Peter team

The Mars rover TV star

Astrium's ExoMars rover prototype, fondly known as 'Bridget', is a key tool in the company's UK outreach activities. Over the past two years the rover has travelled the length and breadth of the country to inspire future generations about science and engineering opportunities within the space industry.

Thanks to Astrium's STEM (Science, Technology, Engineering and Mathematics) ambassadors, the rover is a regular visitor to schools, colleges and exhibitions. Young people can directly interact with the technology, understand how it works and even have a go at driving it themselves. No stranger to the media spotlight, Bridget has made a number of appearances on television programmes such as Blue Peter and CBBC's Whizz Whizz Bang Bang.

RALPH CORDEY
ASTRIUM UK

Life on Mars?

The possibility of life elsewhere in our Solar System, especially on Mars, has always captured society's imagination. The Life Marker Chip (LMC) will search for past and present life on Mars and, of all the experiments onboard ExoMars, probably has the greatest potential for public engagement because it is based on commonly-used medical diagnostic technology.

UK academics involved with the LMC have established a public engagement programme, aimed at primary school children in particular, incorporating visits and a significant presence at schools activities associated with the UK Space Conference 2010.

I am giving hands-on interactive lectures on 'Mars, Life on Mars and How to Detect It' to children at the space conference and similar lectures to Bedford Modern Junior School during National Science and Engineering Week. LMC work will also feature in a temporary exhibition at Bedford Museum.

DAVID CULLEN
CRANFIELD UNIVERSITY

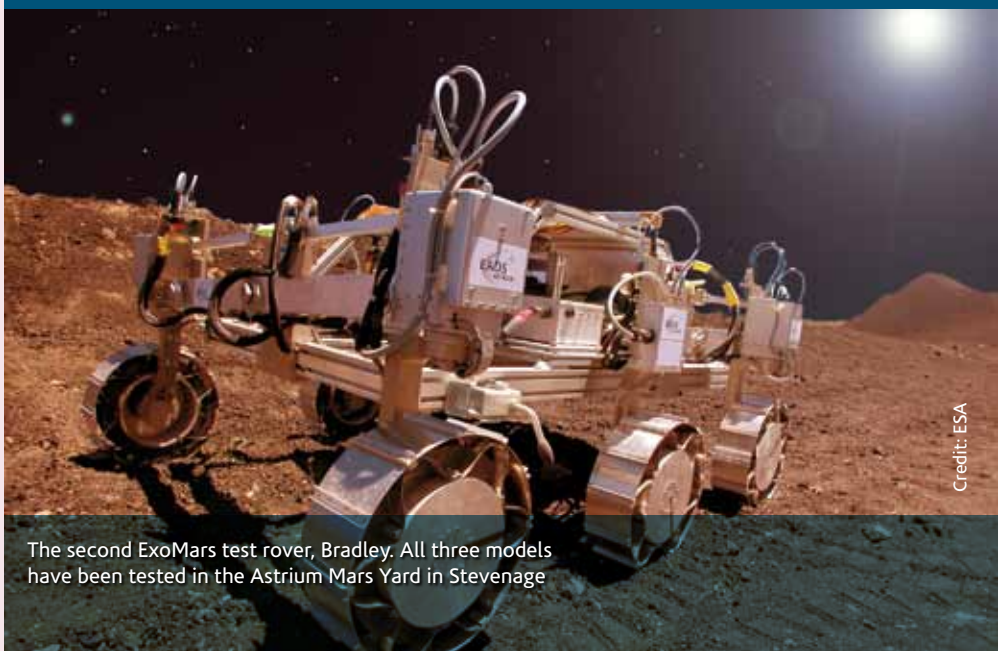
Reaching out to the next generation's scientists

Lewis Dartnell

ExoMars certainly fires up people's interest in space exploration. I give frequent talks about astrobiology and space exploration at schools and science festivals and feel that events about planetary science and the Aurora programme inspire students who may then go on to pursue a career in science or technology.

In January 2010, at the Association for Science Educators conference, I delivered the STFC keynote lecture on astrobiology as well as running hands-on sessions discussing with teachers how space exploration topics can be woven into lesson plans.

LEWIS DARTNELL
UNIVERSITY COLLEGE LONDON

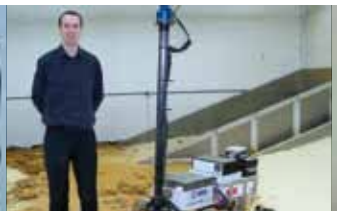


Credit: ESA

The second ExoMars test rover, Bradley. All three models have been tested in the Astrium Mars Yard in Stevenage

Scientists of the future


Claire Cousins


Paul Meacham


Maria North


Ben Boyes

I am an astrobiology PhD student and my research explores environments that are similar to Mars. Much of this work was conducted in Iceland as it has Mars-like terrain. The research has been highly interdisciplinary, crossing the boundaries between geology, biology and planetary science. I was lucky enough to be involved in the NASA/ESA-funded Arctic Mars Analogue Svalbard Expedition (AMASE) which brought together scientists and engineers to test rover instrumentation destined for Mars.

CLAIRE COUSINS
UNIVERSITY COLLEGE LONDON

My role on ExoMars is to look after one of our prototype Mars rovers, the Locomotion Performance Model (LPM) – affectionately known as Bruno. I am responsible for maintaining Bruno, integrating new hardware and software and supporting various test campaigns. Recently, we have been testing Trajectory Control, where we give the rover a path to follow and it drives itself along it, correcting for slippage and any undesired motion on its way. This is the first step in the development of a fully autonomous rover.

PAUL MEACHAM
EADS ASTRIUM, STEVENAGE

I've been helping to develop software that allows a rover to determine its location from its cameras. It is very exciting to work on a project that helps to advance our vision-processing technologies and which will eventually assist the ExoMars rover in its exploration of Mars.

MARIA NORTH
ROKE MANOR RESEARCH

One of my recent tasks was to analyse and define the core functional 'needs' of the rover to deliver a successful mission. The rover design team is international and I am currently working with an engineering team in Sweden to see if they can provide electronic circuits that will survive minus 125 degrees C. We have a large sand pit to simulate Mars and often spend days there driving test rovers over the rocky slopes. It's great fun.

BEN BOYES
EADS ASTRIUM, STEVENAGE

In conclusion…

Having recently taken on the chairmanship of the Aurora Advisory Committee (AurAC), I am delighted to see the progress that has been made and how the UK has carved itself an important role in the international arena of Mars exploration.

Over the last five years several key ideas have been developed and these novel concepts have been proven to work. The ExoMars mission has gone through a number of designs and has delivered a robust, scientifically exciting and important mission. The strong partnership between NASA and ESA bodes well for future exploration of the Solar System.

I am also impressed by the way STFC, industry and academia have worked closely together to ensure that the UK has secured its goal on ExoMars, leading the rover development and two key instruments, the Panoramic Camera and the Life Marker Chip.

PPARC (the Particle Physics and Astronomy Research Council), now part of STFC, decided to join the Aurora programme, not just for the important science but because it provided a strategic opportunity to enlarge and broaden a strong cross-disciplinary science and technology base and deliver economic impact through technology spin-outs. A challenge over the coming few years will be to secure key science roles on the orbiter experiments.

Within STFC, taking a holistic view of technology development and building industrial-academic partnerships has paid dividends right from the start, as demonstrated in this report. There is now exploitation of innovation throughout every stage of the programme bringing economic benefits and scientific impacts to the UK.

The changing configuration and schedule of ExoMars means replanning other elements of the programme. The outreach programme should be expanded not only to cover the science but also to showcase our talented scientists and engineers, inspiring the next and future generations to tackle future technical challenges. We need to ensure that there is a strong academic community ready to exploit the data from ExoMars and to continue to maximise the economic impact of the government's investment in this programme.

PROFESSOR JAN-PETER MULLER
UNIVERSITY COLLEGE LONDON
AurAC CHAIRMAN

The UK involvement in ExoMars is funded by the Science and Technology Facilities Council, a partner of the British National Space Centre, which currently co-ordinates the UK's civil space activities.

Further information about Aurora, ExoMars and UK space science can be found on the following websites:

STFC **www.scitech.ac.uk**

STFC Aurora **www.scitech.ac.uk/SciProg/Aurora/auroraHome.aspx**

BNSC **www.bnsc.gov.uk**

ESA **www.esa.int**

Astrobiology Society of Britain **www.astrobiologysociety.org**

UK Planetary Forum **www.ukplanetaryforum.org**

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Establishments at: Rutherford Appleton Laboratory, Oxfordshire; Daresbury Laboratory, Cheshire: UK Astronomy Centre, Edinburgh; Chilbolton Observatory, Hampshire: Isaac Newton Group, La Palma: Joint Astronomy Centre, Hawaii.

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