University of Southampton

SPACE AT SOUTHAMPTON 2022

Our researchers and students are forging new partnerships, breaking new ground and pioneering world-leading space technologies and capabilities, to understand, explore and harness the potential of space in innovative ways

WELCOME TO SPACE AT SOUTHAMPTON 2022

We, at Northrop Grumman Space, are extremely proud to partner with the University of Southampton and engage with its Space Programme. The high-level of credibility and recognition that is associated with the Southampton space engineering courses is well-recognised across the space industry, with this based on the excellent facilities and experienced team that enable the programme's delivery.

Academia, with its ability to engage with business and generate innovation and enterprise, has never been in greater demand. The huge advances in space-based systems for sensing, geospatial monitoring and understanding Earth's climate are vital for meeting the goals that we must work towards to ensure a sustainable future. The topics covered in this issue are a great example of what we can achieve by working together on shared challenges across the commercial and academic space enterprise landscape.

Humankind has long been fascinated with space and the opportunities it offers, including exploring the universe, using space-based sensor systems to understand more about our Earth, returning to the lunar surface, and furthering human space flight endeavours. Currently the level of interest and investment in space from the UK, and internationally, is at an unparalleled high level, with governments, industry, academia, and individuals all playing their part in a vibrant and growing sector that offers a plethora of opportunities.

The level of innovation in the sector is absolutely amazing, with new technologies being developed constantly, including reusable rockets, on-orbit satellite servicing, and novel propulsion systems. These technologies are integrated and delivered by organisations that are working in new ways to provide their customers with the benefits of space at a faster pace and a lower cost. However, the innovation and business growth can't succeed without the most important part of the sector – our people. The space 'team' includes some of the most intelligent, dedicated, and talented people from across the globe, that work to combine their skills in space systems engineering, project management, business management, and a whole host of other specialisations to develop and grow our industry.

Space at Southampton **is created by Lucy Collie and Frances Clarke, Research and Innovation Services**

David Pile delivering the keynote at the University's Space at Southampton 2022 conference

Here at Northrop Grumman Space, one of the world's leading space companies, we work to solve our customers' most challenging problems with innovative, reliable and affordable space capabilities. We are immensely proud of our team that worked with NASA to deliver the James Webb Space Telescope, and we continue to provide a wide range of missions including resupplying the International Space Station with our Cygnus spacecraft and Antares launcher, and leading the development of on-orbit satellite servicing with our Mission Extension and Mission Robotic Vehicles.

I enjoyed the impressive Space at Southampton conference in September 2022 and was delighted to deliver the keynote. We look forward to more joint activities with the University of Southampton in the future.

David Pile
Regional Director (UK, Europe and MENA) of Northrop Grumman Space Systems

CONTENTS

Space-based solar power: Turning science fiction into fact 4 – 9
Going solar 7 – 9
Clever coatings 7
Innovating the future 8 – 9
Beaming the energy 9

Materials for space structures 10
School of Engineering Design Show 2022 10

Micro machines: Scientific instruments for space 11

Where is everyone: Space data for population mapping 12 – 15
Eradicating polio from Nigeria 14
Population mapping in Afghanistan 15

Mission (im)possible: Orbital mechanics and mission design 16 – 17

Introducing Southampton Geospatial 18

In the fast lane: The space potential of silicon photonics 19

Demystifying black holes 20 – 21

Out of this world: Britain's first astronaut visits Southampton 22 – 25
Reaching for the sky: Applying to be an astronaut 24 – 25

Student focus 26 – 29
Nanosat Design Competition finalists 26
In a spin: Southampton graduate's SPINternship 27
Debris hunting: Mapping space debris 28 – 29

The future of communications 30 – 31

Advising the UK Space Agency 31

TURNING SCIENCE FICTION INTO FACT

The concept of space-based solar power is no longer reserved only for science fiction – it's fast becoming a viable reality.

The once-wacky idea of space-based solar power (SBSP) was first described by science fiction writer Isaac Asimov in his 1941 short story, *Reason*. Back then, the idea of harvesting the sun's energy and beaming it back to Earth was for the imagination only.

Ever since the '70s, researchers have investigated different SBSP proposals – but the cost of the technology and launching it into space has always been far too high.

That is now changing – and research, including pioneering work happening here at Southampton, is set to make SBSP a reality within the next decade.

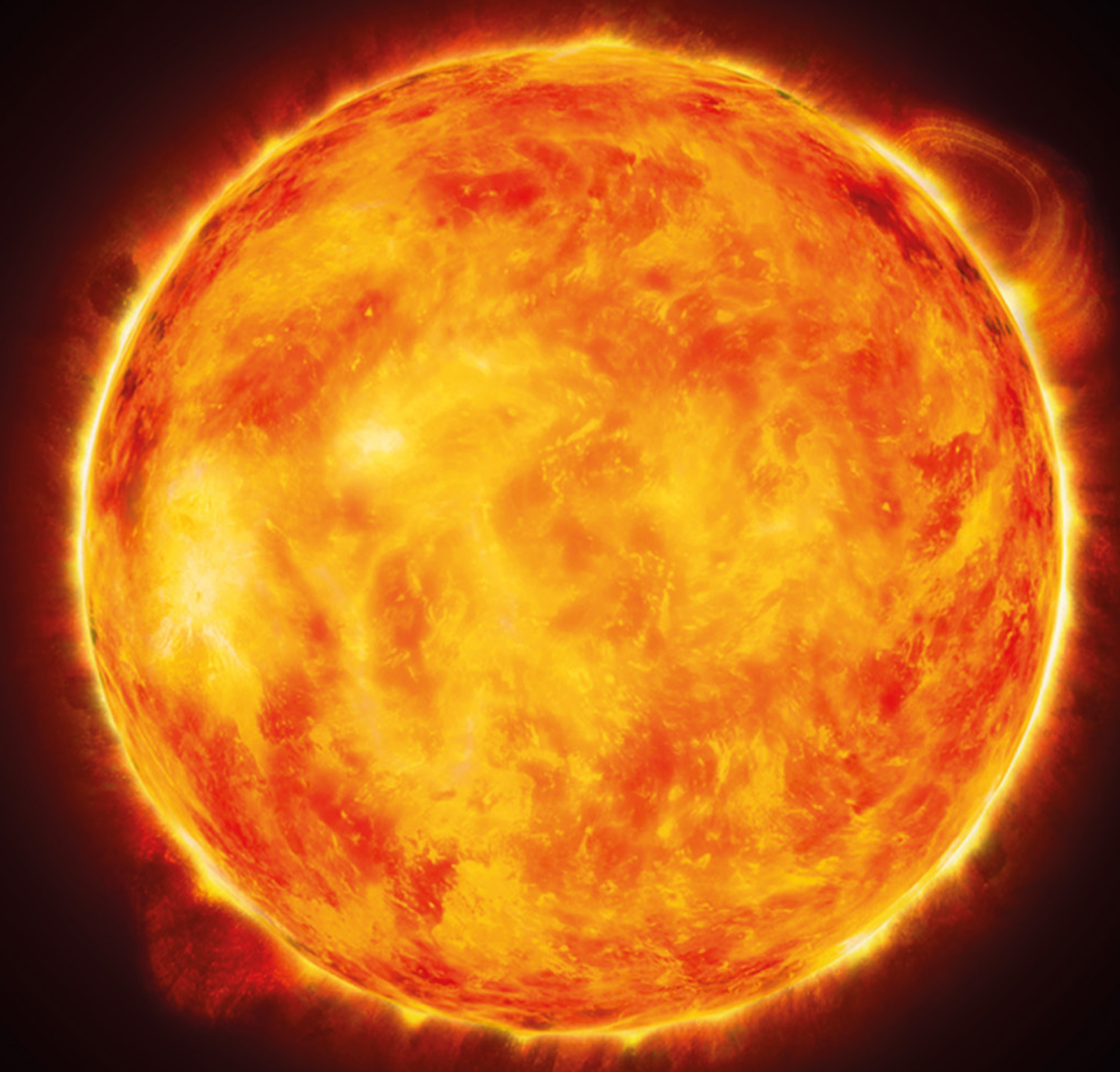
The University of Southampton is a member of the Space Energy Initiative (SEI) consortium, which is leading development of SBSP for the UK. The SEI brings together government, academic research and industry. Martin Soltau, Co-Chair of the SEI, gave an overview of SBSP at September's Space at Southampton conference at the University. He said: "The UK is turning science fiction into fact. The UK has been leading the thinking on this very futuristic idea. Our plans are to transform it from science fiction to reality within a decade."

What is SBSP?

SBSP is the concept of harvesting solar energy via an assembly of huge solar panels in high Earth orbit, converting it to RF (radio frequency) in the form of microwaves, and transmitting that down to Earth where it is reconverted back to DC (direct current) electricity and fed into the grid. The energy will be received by a rectenna (a rectifying antenna), most likely located offshore and potentially next to a wind farm where there are already connections to the grid.

The systems deployed into space to enable this would be huge – several kilometres in length, and by far the largest structure ever to have been built in space. But the system would be modular and would be assembled in-situ by autonomous robotic systems.

Martin explained: "It will be like building a huge Lego construction. The hyper-modularity adds resilience and also lowers the cost."



The time is now

SBSP would answer our ever-pressing need for new sources of clean energy.

"Affordable, reliable energy underpins quality of life for all of us on the planet," said Martin. "Energy consumption is expected to increase by 50 per cent and electricity demand two to three-fold by 2050. It's the abundance of energy in space that really makes the economics work. It's very scalable. This could power a substantial portion of our global electrical needs."

The cost of space launch is a big part of the capital cost, which has rendered SBSP unviable in the past. But that has changed and the cost of space launch is now about a tenth of what it was a few years ago, and that trend is continuing.

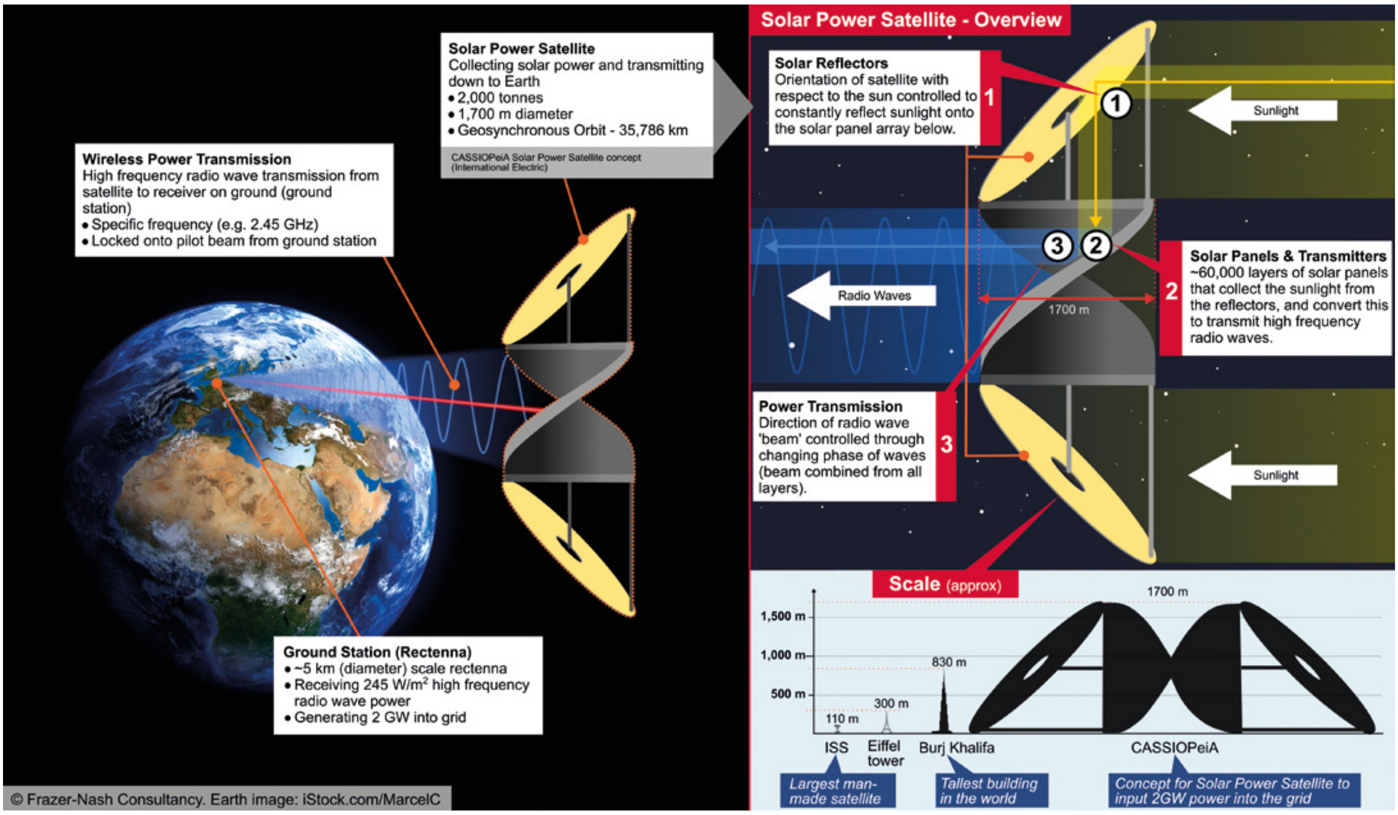
Martin said: "The cost of space hardware is also lowering, and autonomous systems and robotics are advancing at an incredible pace. Together with the imperative of decarbonising our economies, this is becoming viable – and urgent.

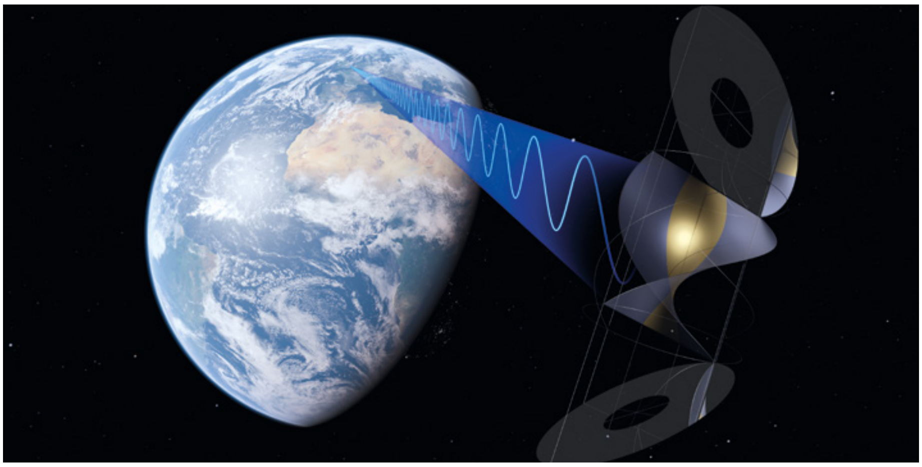
"Space-based solar power has a unique set of beneficial characteristics. It's really the ultimate renewable technology; it's safe and secure; it has a low environmental impact; and it has the unique ability to beam power to different nations, which makes it incredibly flexible for export. It could be a game changer to get us to Net Zero by 2050."

"Space-based solar power has a unique set of beneficial characteristics. It's really the ultimate renewable technology."

Martin Soltau

Continued on page 6





Above: Martin Soltau, Co-Chair of the Space Energy Initiative

Top: An overview of SBSP. Image courtesy of Frazer-Nash Consultancy

Right: An artist's impression of space-based solar panels beaming energy to the UK. Image courtesy of the Space Energy Initiative

Leading the way in the UK

The UK is in a leadership position for SBSP.

The Space Energy Initiative was launched in March 2022 to champion SBSP. It's a consortium that brings together researchers and commercial partners from different sectors, and raises awareness amongst energy policymakers and others. The consortium has Government support and SBSP is now included in the National Space Strategy.

Martin added: "We have set up a company called Space Solar Limited and we have a 12-year roadmap. We're working with the Government, raising finance to launch a development project. The aim is to be beaming commercial-scale power by year nine, and by year 12 to have a fully operational power station in space.

"It's an exciting vision and it's happening. We're developing something that's going to be completely game-changing for humanity."

For more information
spaceenergyinitiative.org.uk

GOING SOLAR

Now that space-based solar power is a viable energy source, research at Southampton is helping to contribute to the drive to make it a reality by collaborating to address the challenges, and advance the technologies beyond what was thought possible.

CLEVER COATINGS

We usually imagine it's cold in space. But it's also, of course, extremely hot under the sun's radiation. Researchers at Southampton are inventing new coatings to ensure space infrastructure, spacecraft and satellites maintain manageable temperatures.

The ability to effectively radiate heat is crucial for anything in space. And when it comes to space-based solar power, the ability of the solar panel array to absorb the sun's energy without burning up is critical.

Professor Otto Muskens and Dr Kai Sun, from the Integrated Nanophotonics Group, are developing metasurface thin film coatings for temperature control in space.

Professor Muskens explained: "It's a challenge to keep things cool in space. People think it's very cold in space, but it's also very isolated so once things get hot, by the sun shining on them, it's not easy to cool them down. They can only cool down by radiating the heat away, so it's absolutely important for things in space to be able to radiate heat very efficiently – either by panels optimised for radiation, or a coating on the outside of spacecraft – and have minimal absorption of the solar radiation, hence why spacecraft are generally white or shiny."

Having previously worked on coatings for spacecraft bodies, Professor Muskens and Dr Sun are now building on that work for space-based solar cells.

They use the University's state-of-the-art cleanrooms in the Zepler Institute to fabricate multi-layer thin film coatings that can be laid over a sheet of photonic cells to keep them from overheating when they are blasted by the sun.

"Space-based solar is about scale," said Professor Muskens. "You need to have very large areas of solar panels in order to get enough power to beam back to Earth, so we have to make things extremely lightweight, robust and durable. That's why we're using thin film technologies. Our materials can withstand temperatures of up to 180 degrees Celsius and down to -180 degrees Celsius."

Smart materials

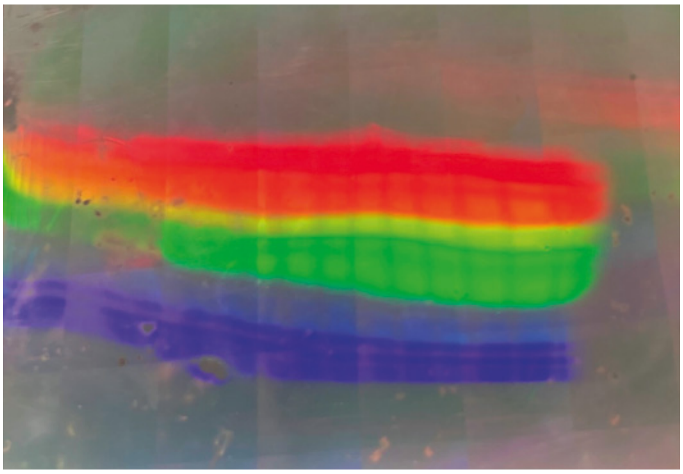
Professor Muskens and Dr Sun have developed a thin film coating that switches its cooling abilities on and off itself, depending on the temperature. For example, a satellite in the dark is in the cold, so its cooling capabilities can auto-switch off to save energy.

Dr Sun explained: "If a satellite is not facing the sun, it still consumes a lot of electric power to maintain its temperature. Our coating has the capability to switch on and off the cooling. When cooling is switched off, it saves energy, so if there is an on-board energy source like a battery it will last for longer."

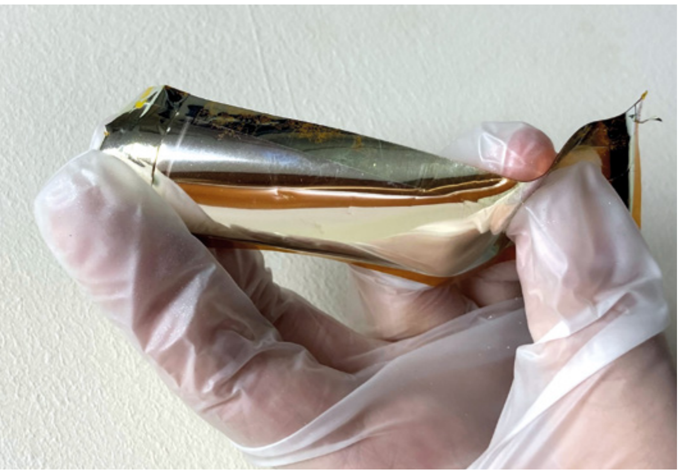
The application is called Smart Radiative Cooling. Without introducing mechanical components, the team has developed a phase-change material to achieve a passive radiative cooling control against the coating's temperature, which can be tuned from 70 degrees Celsius down to room temperature.

"The cooling is achieved by radiating the heat away by thermal infrared," explained Professor Muskens. "It's the glow of the material that gets hot that's radiating. You can make it glow more or less by having a material that changes its ability to emit radiation."

Professor Muskens and Dr Sun are investigating the potential use of their Smart Radiative Cooling coating for space-based solar power.



Optical solar reflectors fabricated on flexible substrates. These are the radiative cooling coatings for spacecraft or satellites



Demonstrating the flexibility of the thin film coating

MAKING IT HAPPEN

Turning ideas into reality for a sustainable future is the driving force of Dr Nina Vaidya's work. She is building on her work on optics, materials engineering, and space systems – bringing that expertise to her projects at the University of Southampton.

Dr Vaidya joined the University in 2021 from the California Institute of Technology (Caltech). "At Caltech, we took this seemingly impossible dream of sustainable energy and space technologies from a fiction novel idea to space-based solar power (SBSP) prototypes," she said.

Dr Vaidya, Lecturer/Assistant Professor in Astronautics and Spacecraft Engineering, explained: "The project went from feasibility studies, to designs, to inventing new things, drawing upon terrestrial engineering and scientific knowledge, and disruptively re-engineering it for ultralightweight and efficient space-based technologies."

That project is approaching the significant milestone of a test space launch in December 2022.

Addressing the challenges

There are three main challenges to SBSP that Dr Vaidya and her Caltech colleagues addressed, and which she continues to address here at Southampton.

The first is the collection and conversion of solar power into electricity, which is where the optical concentrators and the photovoltaic cells – the devices that convert light into electricity – come in. The second is the power beaming – the wireless transfer of power to the receivers, and the third is the structural design of the space installation.

"The concept is to have ultra-lightweight modular repeating units stowed for launch, which unfold in space creating a tiled sunlight-harvesting surface that collects, converts, and transfers the solar energy to Earth," explained Dr Vaidya.

"We had to innovate, because it would be too heavy and expensive to launch a SBSP installation with conventional solar arrays that also need space radiation shielding. We needed to engineer materials and devices that are compatible with the space environment – vacuum, radiation, and temperature cycling to name a few."

The Caltech team used a new material, developed from perovskite, to make ultra-lightweight space solar cells. "Perovskites are sensitive to air and moisture, which is tricky for terrestrial applications but not a problem in space," said Dr Vaidya.

Inventing a new space reflector

Dr Vaidya's role at Caltech included inventing a new type of space reflector for collecting the sun's energy.

"My job was to create space concentrators that are extremely efficient so they don't lose any light, but also ultra-lightweight, with materials that are space-compatible. I invented a completely new type of space reflector," she said.

Dr Vaidya's prior work at Stanford University on optical concentrators (called Axially Graded Index Lens, or AGILE) placed her in a unique position to innovate the space reflectors for the SBSP prototypes. AGILE was fabricated using 3D printing that created lightweight and design-flexible lenses arrays.

Renewable energy is the future

Dr Vaidya believes that SBSP is positioned to have a dramatic impact.

She outlined: "There is almost nine times more solar energy in space than on Earth because of the day and night cycle, the atmosphere and the weather. Harnessing this power in space makes sense, either to beam it back to Earth or for space exploration. SBSP could provide a global supply of clean and affordable energy where and when it is needed, including in areas that currently do not have access to electricity.

"Abundant renewable power would create equality of energy access and energy independence from the present fossil fuel energy channels. Clean energy is a vital part of addressing the urgent climate and sustainability challenges, and we need to catalyse engineering solutions to make that a reality."

Above: Caltech SBSP vision. Image courtesy of Caltech

Top: Space Solar Power Project prototype with the space reflector arrays Dr Vaidya created – integrated with photovoltaics, power transfer circuitry and beam steering. Image courtesy of Nina Vaidya

Left: Dr Nina Vaidya measuring the experimental performance of optical concentrators under a solar simulator that acts as an artificial sun. Image courtesy of Nina Vaidya

For more information

Caltech SBSP project:
www.spacesolar.caltech.edu

Space reflectors:
ieeexplore.ieee.org/abstract/document/8366046

AGILE:
nature.com/articles/s41378-022-00377-z

3D printing:
nature.com/articles/s41378-018-0015-4

BEAMING THE ENERGY

The possibilities of wireless power transfer are being pushed to their current limits – and beyond – for space-based solar power (SBSP). The University's Next Generation Wireless research group is harnessing its expertise to support this.

The precise beaming of solar energy from space to Earth is crucial to the success of SBSP. All that energy from the sun must be sent wirelessly to a 'rectenna', or rectifying antenna, on Earth.

This is done by converting the harnessed energy into RF microwave radiation, which is beamed to the rectenna, converted into direct current electricity and fed into the grid.

But the accuracy required to ensure the beam lands in the right spot is critical, requiring a high-efficiency beam alignment for the wireless power transfer system, as well as target-detecting technology for high beam efficiency.

Dr Mohammed El-Hajjar, Associate Professor in the Next Generation Wireless research group, is involved with the Space Energy Initiative focusing on the beam steering aspect of SBSP. He said: "We need accurate beam alignment and tracking to maximise the transmitted energy."

Regular communication is necessary between the ground station and the base station, which is in geosynchronous equatorial orbit, 35,786 kilometres above the equator, to ensure beam accuracy.

"Efficient wireless communications are needed between the ground station and the SBSP station in order to maintain accurate energy transfer," explained Dr El-Hajjar. "There will be regular interaction between the ground station and base station."

The finer details of how this will work are still being researched. Watch this space!

MATERIALS FOR SPACE STRUCTURES

The material of anything that is destined for outer space is critical. It needs to be strong, it needs to be light and it needs to possess a range of vital physical characteristics. Researchers at Southampton are designing complex microstructures for a promising class of futuristic materials to fit the bill.

The use of lightweight multi-functional materials in structural applications has increased significantly in various domains of engineering – especially in space applications – in recent years.

Spacecraft, antennae, reconfigurable and deployable components, and sensor applications all benefit from these advanced engineered materials.

The increased demand has also propelled researchers from multi-disciplinary fields to come forward and contribute to different aspects of analysis, design, and manufacturing.

Dr Susmita Naskar, based at the University of Southampton's Boldrewood Innovation Campus, leads the Engineered Materials and Structures Laboratory (EMSL). EMSL is focusing on functional material and structural systems where multiple materials and components are micro-architected to enhance the mechanical performances required for modern space systems.

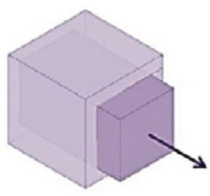
Dr Naskar said: "The main objective of our work is to design and develop new advanced materials and structures for space applications. The EMSL group at Southampton works on the multi-physical mechanics of such advanced engineered

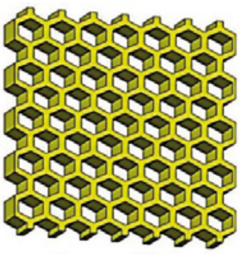
Dr Susmita Naskar

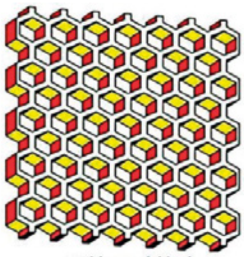
material and structures, and further tests their strength, stiffness and flexibility through 3D printing, along with several static and dynamic experiments, to achieve the desired mechanical properties for complicated aerospace applications."

Dr Naskar has recently investigated how multi-material micro-architected lattices affect the mechanical properties of metamaterials for multi-functional structural designs. This work was done in collaboration with the Indian Institute of Technology Kanpur and Swansea University.

The results of this research are useful in expanding the scope of 3D printing metamaterials with desired mechanical properties along different directions.



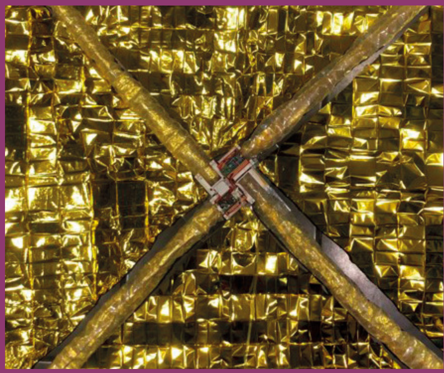




Left: Macroscopic view of forces or deformations that materials are subjected to

Middle: Microscopic view of lattice structures of a material with one intrinsic material

Right: Microscopic view of lattice structures with multiple intrinsic materials



SCHOOL OF ENGINEERING DESIGN SHOW 2022

A Group Design project from the EMSL group scooped the Environment Award at this year's University of Southampton School of Engineering Design Show.

A team of five students – Thomas Doughty, William Oldman, Robert Oxford Pope, Ceris Brown and Nathan Marsh – investigated and designed an ultralight drag sail, based on an origami structure with the use of environmentally-friendly polymer films.

By deploying a sail at the end of a satellite's life, a small amount of drag can be generated by the atmosphere present in Low Earth Orbit. This can therefore provide a functional scope in terms of time for the satellite to de-orbit into the Earth's atmosphere.

The students designed and built small-scale structural models to demonstrate the design concept through extensive computational simulations and several experimental tests at the University's Testing and Structures Research Laboratory.

Above: Robert Oxford Pope and William Oldman receiving the Environment Award from Professor David Richards, Head of the School of Engineering

Top: The origami spacecraft structure designed by the Environment Award-winning PhD students

MICRO MACHINES

Terrestrial equipment isn't, of course, designed to work in space. There are many challenges to designing instruments that will work on other planets – not least size and weight.

Scientific instruments, like microscopes, wind sensors, seismometers and radiometers, need to be designed and built for purpose if they are going to work on planets other than Earth.

This is at the core of Dr Hanna Sykulska-Lawrence's work. A highlight of her career so far was helping to design and fabricate a microscope that was used for NASA's Phoenix mission to Mars in 2008.

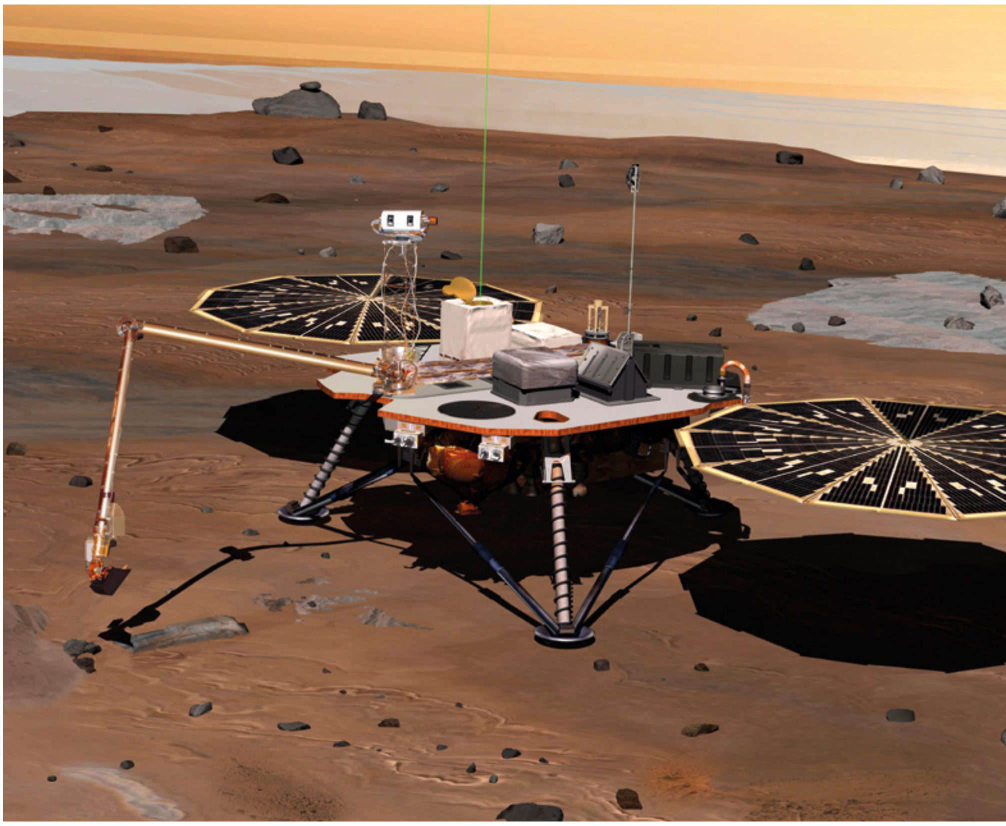
The microscope she worked on was smaller than the size of a matchbox and sat inside the MECA (Microscopy, Electrochemistry and Conductivity Analyser) chamber.

Dr Sykulska-Lawrence, from the University's Aeronautics and Astronautics Group, was working at Imperial College London at the time. She said: "We designed and fabricated parts of the instrument, and then controlled it on the surface of Mars, and analysed the data at the end.

"We were able to look at the Martian 'soil' with unprecedented resolution and, from this, deduce how dry Mars really is."

Dr Sykulska-Lawrence's work on miniaturising instrumentation for space has also seen her involved in designing other miniaturised instruments to explore the surface of Mars, and now she is moving on to designing instruments for different planets.

Her current projects at Southampton include developing a miniature radiometer to explore the atmosphere of Venus, and also a Raman spectrometer for the surface of Europa, one of Jupiter's moons. The Raman spectrometer project was the focus of Aria Vitkova's PhD (outlined on page 24), which Dr Sykulska-Lawrence supervised.



Above: Dr Hanna Sykulska-Lawrence

Top: The Delta II rocket launching from Cape Canaveral Air Force Station in Florida, USA, carrying the Phoenix spacecraft for the first leg of its journey to Mars, in August 2007. Image courtesy of NASA

Right: Artist's depiction of NASA's Phoenix Mars Lander monitoring the atmosphere overhead and the soil below. Image courtesy of NASA

> “The data have led to five million more children in Afghanistan receiving a set of vaccines against diseases such as polio, measles, mumps and rubella. In northern Nigeria, our data estimates were used in the successful elimination of polio from the country.”
>
> **Professor Andy Tatem**

Every five years, between 35 and 40 million people migrate. Keeping track of where people are is vital for social welfare, crisis response, development, and top-level decision-making. Space data is critical to this.

WHERE IS EVERYONE?

The interdisciplinary WorldPop research group at the University of Southampton is highly-skilled in population mapping – and a key international player in the field. The group relies on data from satellites to inform its work.

WorldPop Director Andy Tatem, Professor of Spatial Demography and Epidemiology, outlined: "Our core work is around supporting governments with population mapping and estimations. There is a whole set of countries that have not done a census in 20 to 30 years, and there are also lots of countries that were supposed to do a census in 2020 or 2021 but couldn't because COVID-19 led to their budget being removed, or prevented them from going knocking door-to-door.

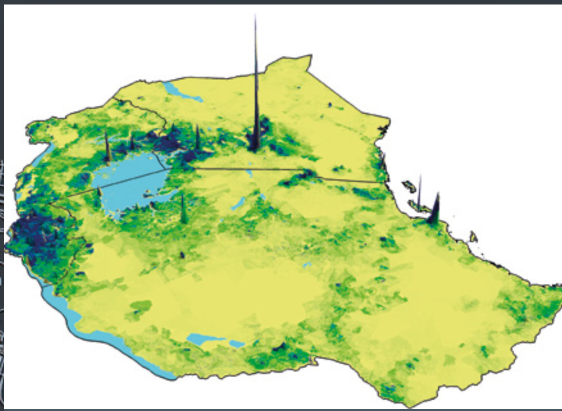
"A lot of our work at the moment is working with UN agencies and national governments on developing ways to produce population estimates. That involves many datasets that have been built from satellite imagery."

WorldPop was initiated in 2013, combining population projects across Africa, Asia and the Americas. Since then, the group's work has informed the recommendations and actions of governments around the world.

Professor Tatem said: "The data have led to, for instance, five million more children in Afghanistan receiving a set of vaccines against diseases such as polio, measles, mumps and rubella. In northern Nigeria, our data estimates were used in the successful elimination of polio from the country.

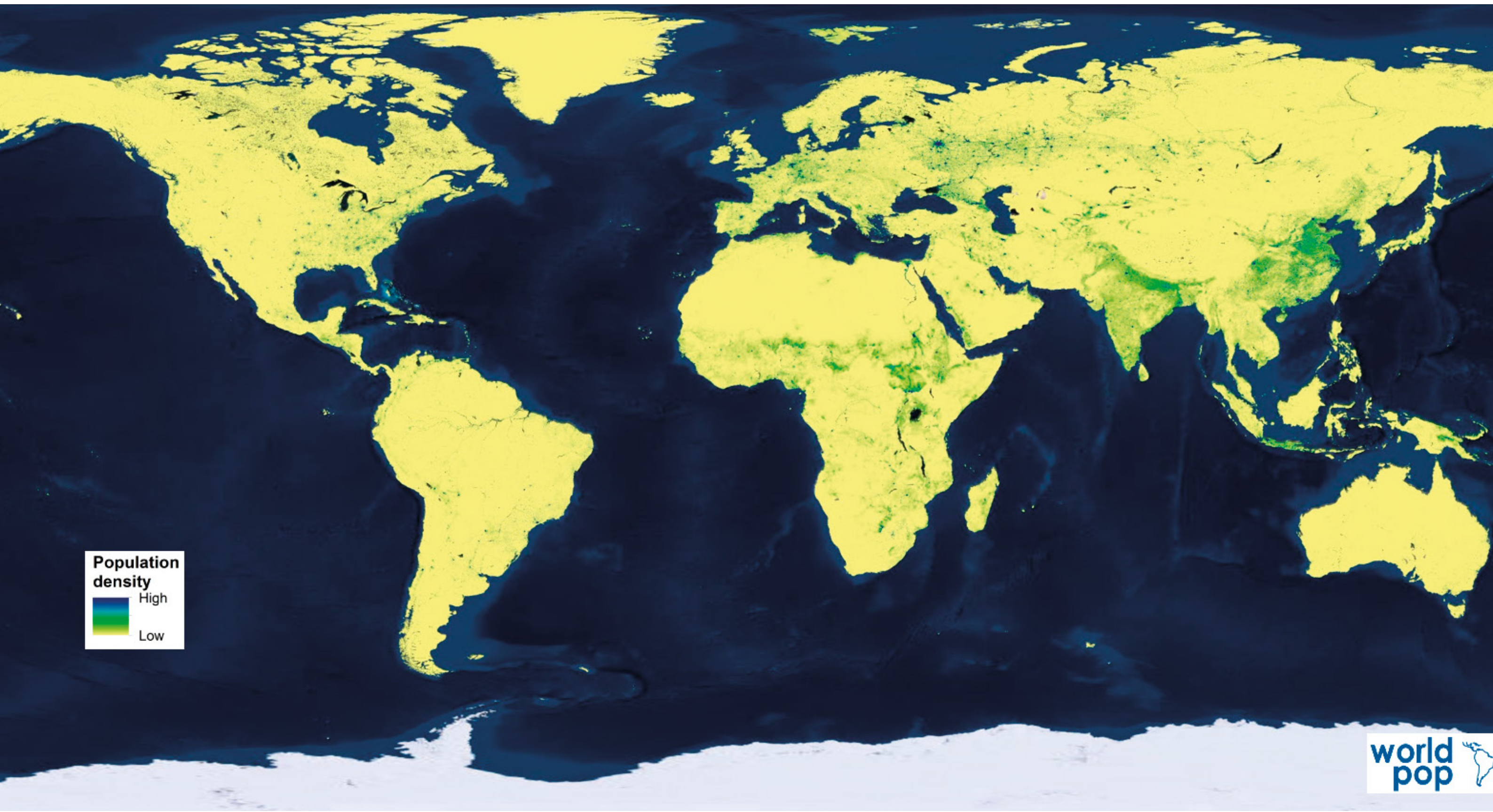
"In a few countries, estimates from WorldPop have been used to fill gaps where a census has been conducted, but certain areas couldn't be included because they were inaccessible due to conflict or gang control. We have been able to provide them with a way to fill those data gaps, and this information is used as official statistics to allocate aid, resources and representation in parliament."

Professor Andy Tatem



A 3D population map for East Africa

Continued on page 14



Above: WorldPop's global population map

Right: An example close-up predicted population map from an area of Cameroon

POPULATION MAPPING IN AFGHANISTAN

Decades of conflict and instability meant resource allocation, aid delivery and development planning was under threat in Afghanistan due to hugely outdated population statistics.

It has not been possible to conduct a national population and housing census since 1979, so government population statistics were based on simple projections from a 40-year-old baseline that did not account for any of the major demographic changes that had occurred subnationally in the intervening period.

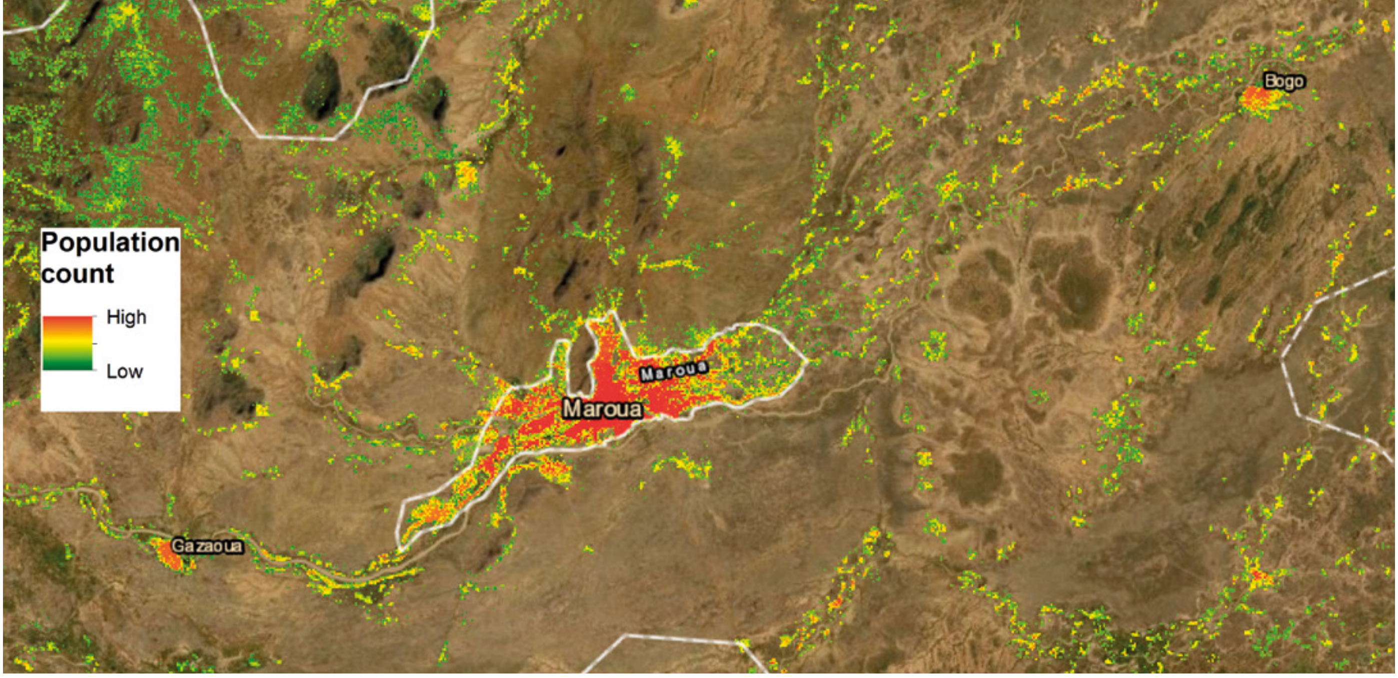
Following a presentation to the Afghan government, WorldPop researchers worked with the Afghanistan national statistical office to integrate satellite-based mapping of residential buildings with other geospatial datasets in a spatial statistical modelling framework.

This enabled new population estimates to be calculated at national and local levels – down to 100m grid cells. A validation exercise then demonstrated that the predictive ability was strong, including at local levels.

The population estimates have since been used in a range of applications in Afghanistan, including polio elimination efforts.

Professor Tatem said: "The work we were able to do in Afghanistan provided an accurate picture of the population, enabling aid delivery, government planning and resource allocation to all be done with accuracy."

For more information
worldpop.org



Layers of data

Layer upon layer of data from satellites and on-the-ground sources provide WorldPop researchers with intricate information to build estimations and maps of population numbers.

"The main approach we use to map populations at small area scales is to take data that has been collected, perhaps from surveys, and then in areas where we have such population data, we look at how those population densities relate to things we can measure from satellites," explained Professor Tatem.

"We can map buildings including their heights, we can use satellite images of the Earth at night, plus satellite-derived data about topography, land use, land cover and the amount of vegetation. We end up with up to 50 layers of data that we can map at high resolution across an entire country that provides a detailed picture of environments, infrastructure and geography, which can be strongly related to how populations distribute themselves on landscapes.

"In the locations where we have sample population counts, we can then establish statistical relationships with the satellite-derived datasets and use these relationships to predict population numbers for areas where we do not have ground-collected population counts."

The WorldPop team works with an array of satellite image providers, governments, UN agencies and donors, including the Bill & Melinda Gates Foundation and Maxar Technologies, a company that has mapped every building across sub-Saharan Africa. The team also collaborates with Google, Facebook and Microsoft on mapping buildings and population dynamics.

ERADICATING POLIO FROM NIGERIA

The battle against polio in Nigeria had waged for decades. In 2010, victory looked imminent, but then the disease spiked again in 2011 (62 cases) and 2012 (99 cases).

The spikes puzzled health officials, as by then vaccination rates were above 90 per cent for children under the age of five. But it then became clear that the maps being used by vaccination teams to show where under-fives lived were relying on projections from 2006 and were, therefore, inaccurate in many areas.

"To eliminate polio, it was necessary for almost all under-fives to receive the vaccine," explained Professor Tatem. "To achieve this, accurate and recent data on numbers of under-fives and where they lived was critical to enable calculations for vaccine planning and delivery."

In the absence of census data, WorldPop collaborated with the Bill & Melinda Gates Foundation and Oak Ridge National Laboratories to use innovative new approaches to estimate population numbers and distribution. They used detailed satellite imagery to map all settlements in Nigeria, then classified them and then visited some of them to measure population densities in each type. Geostatistical methods were then used to construct models of population distributions. These models were integrated with similar models for estimating population age structures in order to estimate where under-fives were.

As a result, polio outbreaks disappeared entirely and have remained that way.

Professor Tatem added: "Space data – the images we used from satellites – were absolutely critical in achieving this polio eradication. Without them, we would not have been able to take the first steps of mapping and classifying settlements in Nigeria."

MISSION (IM)POSSIBLE

Calculating the most economical and ecological routes through space – making the most of the 'downhills' to enable previously impossible missions – is the focus of a specialised team at the University of Southampton.

Space exploration is limited by fuel. When missions set off from Earth, they must carry all the fuel they require. That can often amount to over 90 per cent of their total weight, severely limiting the amount of scientific and exploratory equipment that can be carried.

Scientists within the Astronautics Research Group are addressing this challenge. By calculating and following natural dynamics in space, missions can be designed to require significantly less fuel.

Dr Alexander Wittig, Associate Professor in Astronautics, is an expert in orbital mechanics, and mission design and analysis. His work on theoretical mission designs demonstrates the possibilities of space travel.

"We figure out the manoeuvres a spacecraft has to perform in space to go to where it needs to go – a bit like providing a sat nav for a spacecraft," he explained. "When we design these missions, we try to find a way to use as little fuel as possible. Sustainability is crucial, not just for ecological reasons, but simply to make space missions possible. Because there are no gas stations in space, spacecraft have to carry all their fuel with them. The more fuel you need, the less of everything else, such as cameras and sensors, you can take. It's a problem that can easily make some interesting missions impossible."

Natural dynamics

Space travel is much more complicated than driving on a 2D surface, as on Earth.

"We try to design missions that use the natural dynamics of how things move in space – a bit like when you roll a car down a hill, it's making use of the natural flow," said Dr Wittig. "In space, that can involve flying very close to other planets because then you get a slingshot effect as the planet deflects the spacecraft, changing its course without any fuel being used."

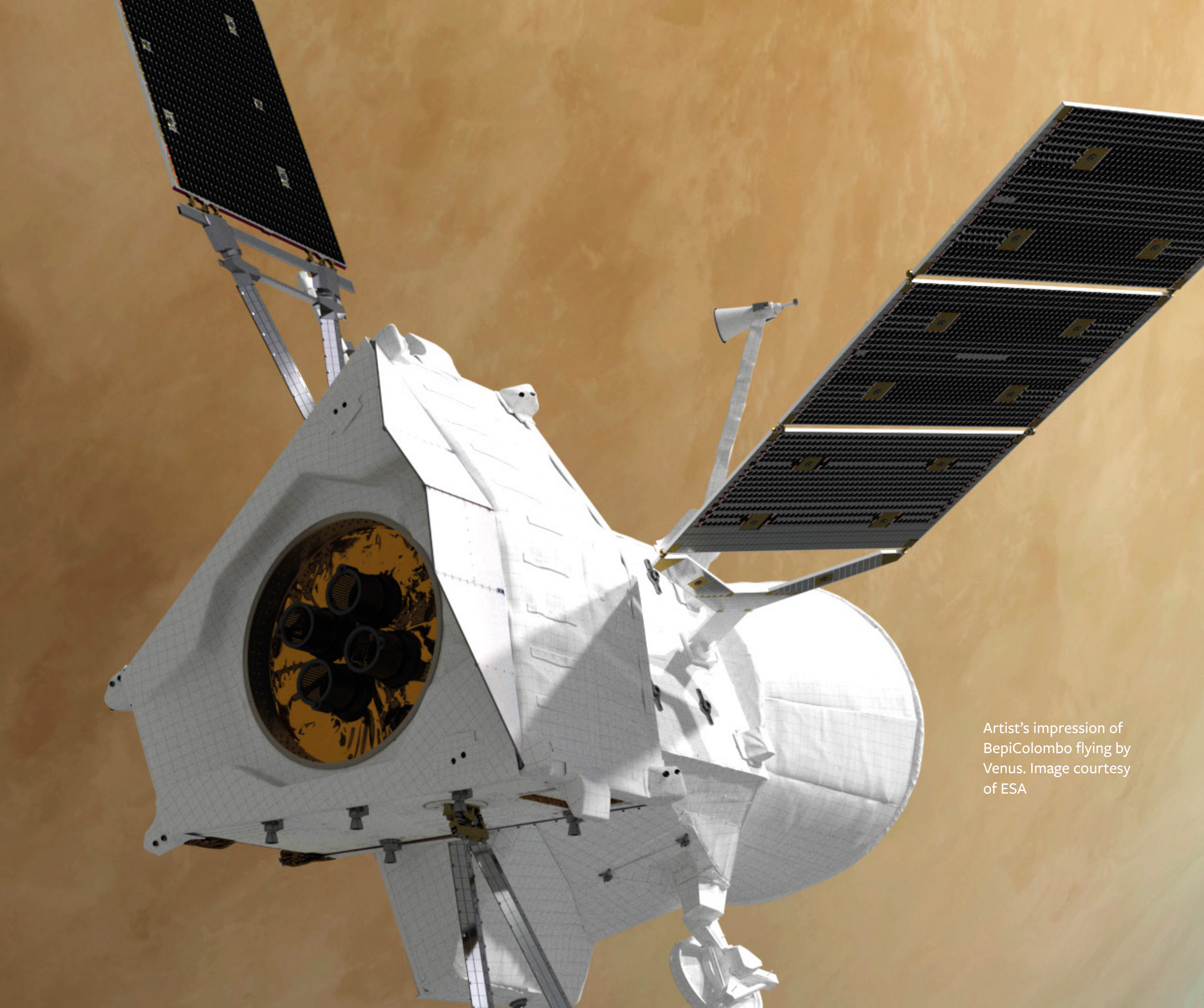
Dr Alexander Wittig

For example, the BepiColombo mission – a seven-year European Space Agency and Japan Aerospace Exploration Agency mission to Mercury, which launched in 2018 – is using this concept of bouncing around different planets in order to reach its destination.

Dr Wittig and his team use mathematical concepts from Dynamical Systems Theory to calculate where 'interplanetary highways' are. They are developing a method to automatically classify which trajectories are useful for mission planning.

He outlined: "If you flew to Venus, for example, you would first need to do a huge manoeuvre near the Earth, requiring a lot of energy, to overcome its gravity. Then upon arrival you'd have to get rid of all that momentum by putting the brakes on, or you will just shoot on past Venus – this requires almost the same amount of energy again. We're working on finding a trajectory where that's not necessary. It's called ballistic capture, where you make clever use of the intricate effect of the Sun to achieve a temporarily captured orbit around another planet via natural dynamics. We're developing the mathematical description and tools underpinning this process."

This work will enable cheaper and more feasible space missions in the future, as much less fuel will need to be carried.



Artist's impression of BepiColombo flying by Venus. Image courtesy of ESA

Deorbiting safely

Dr Wittig's research is already being put to practical use through a collaboration with Dr Minkwan Kim, also Associate Professor in Astronautics, on a project called Cube de ALPS (CubeSat de-orbit ALI-printed Propulsion System).

Dr Kim has designed and built a deorbiting propulsion system for CubeSats (miniature satellites that are used for space research). The system – known as a 'vacuum arc thruster' – provides a tiny amount of thrust, equivalent to the weight of a feather, but over long periods of time. Together with the right mission design, this enables the safe and controlled removal of CubeSats from busy orbits.

"We're working on simulating how to use that tiny thrust to deorbit satellites, and also to stop them from spinning so fast, which could result in them breaking up or damaging other satellites," said Dr Wittig. "We have an upcoming mission ready to launch in December 2022, where we will put one of these vacuum arc thrusters on a satellite and study how it affects the satellite. This allows us to confirm and calibrate our simulations and adjust the mission profile accordingly."

Once completed, the deorbiting propulsion system will reduce the deorbiting timescale of CubeSats flying 800 kilometres above Earth's surface from over 100 years to about two years.

Dr Wittig added: "We are working on developing the system to be like a foil sticker that can go on the side of a satellite. It's innovative from a manufacturing perspective because we're printing many of the electronic components onto a flexible substrate. That makes the system cheap and easy to produce and customise based on specific satellite design needs."

INTRODUCING SOUTHAMPTON GEOSPATIAL

A new cross-University initiative, Southampton Geospatial, is bringing together expertise in geospatial science applications to create new opportunities.

"So many global challenges are geospatial – environmental change, energy use and health inequality – we need novel interdisciplinary ideas that bring geospatial data together for targeted solutions."

Professor David Martin

Geospatial science focuses on using different forms of location-based data and analytics to understand people, places and processes that affect the Earth's surface. Such scientific methods use large datasets from, for example, the European Space Agency's Sentinel satellite programme, in conjunction with artificial intelligence , to undertake spatio-temporal analyses.

Professor David Martin, a founder of Southampton Geospatial and Professor of Geography, said: "So many global challenges are geospatial – environmental change, energy use and health inequality – we need novel interdisciplinary ideas that bring geospatial data together for targeted solutions."

The University of Southampton is a leader in the geospatial field.

Professor Steve Darby, Associate Dean (Research) in the Faculty of Environmental and Life Sciences and Professor of Physical Geography, said: "As a University, we have world-class experts in the geospatial arena, especially around data and analytics. In the UK, and particularly within our region, there is huge commercial and entrepreneurial potential here as well – there is a large concentration of geospatial firms in the south and southwest."

Professor Jadu Dash, a founder of Southampton Geospatial and Professor of Remote Sensing, outlined: "We launched Southampton Geospatial in October 2022 to provide a collaborative hub to bring together multidisciplinary experts in data science to address important environmental and social challenges. It will showcase the University's unique capabilities in various forms of geospatial data and software tools, to create new opportunities for collaboration."

Professor Darby added: "A key goal is to build a community of scientists – our experts, but also reaching out to partner organisations, for example Ordnance Survey and our collaborators within Space South Central. We aim to build deeper relationships with external stakeholders and industry partners. The initiative will also set up a training and development programme for early career researchers and bid for graduate and postgraduate training."

For more information, contact
geospatial@soton.ac.uk

or visit
southampton.ac.uk/research/institutes-centres/southampton-geospatial

IN THE FAST LANE

Trailblazing silicon photonics research at the University of Southampton is opening up possibilities for more secure and speedy communications than ever before – bringing space into the picture.

Southampton is a world leader in silicon photonics. It's all about making optical circuits on silicon chips, principally for communications but also for LiDAR remote sensing technology.

Professor Graham Reed and the Silicon Photonics Group, within the Optoelectronics Research Centre, are at the forefront of this technology. Their research published in November 2020 won the world record for how fast a silicon modulator can encode data into light, ready to send via an optical fibre, where it is decoded by a device at the receiving end.

Outlining the technology, Dr Milos Nedeljkovic, Senior Research Fellow in the Silicon Photonics Group, explained: "Telecommunications today uses optical fibres for sending light long distances, and there is equipment at either end – a laser and devices that encode information into the light at one end, and a detector and devices for decoding the information at the other end. We work on modulators that are at either end of that."

The modulators, made of silicon, are only a few tens of microns wide and a couple of millimeters long. The amount of light transmitted through a modulator is controlled by applying electrical signals to it.

The space potential

The Silicon Photonics Group's work has huge potential in space.

"There is a lot of interest in the potential for making laser communications between satellites and also from satellites back down to Earth," said Dr Nedeljkovic. "The idea would be to shine a laser beam carrying data from one satellite to another. There have been several demonstrations of these kinds of optical communications systems in space, but they have been done using fibre optics. Instead, we would use chip-scale optics components that are much lighter and less power-hungry. That's where what we're working on can have a clear advantage compared to what's being delivered at the moment."

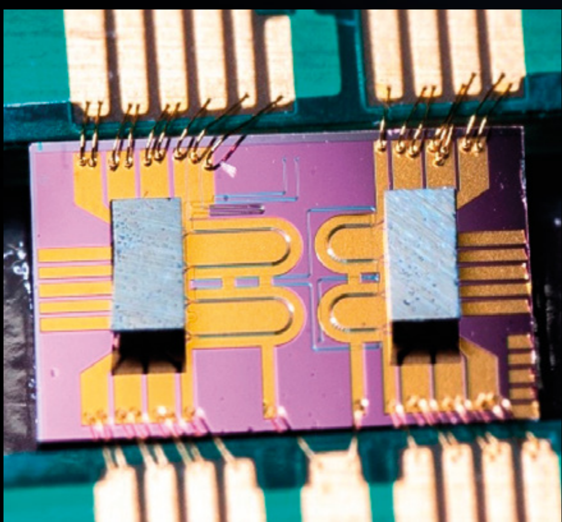
The technology enables communication at the speed of light – whether sending data from one point to another, sending secure communications, or sending enormous volumes of data.

"The possibilities for optical communications include being able to send data from one side of Earth to the other and not having to go through fibres, so not having to rely on built infrastructure," explained Dr Nedeljkovic. "For example, in rural areas it's hard to get internet at the moment, but it would be easy from a satellite.

"It also enables truly secure communications, as data is not sent through the internet but through a satellite network. Plus it could enable a faster and more secure internet."

It could also support satellites that are used for Earth observation. "More and more data is gathered in space that needs to be sent back to Earth," said Dr Nedeljkovic. "The kinds of communications used at the moment do not work at high enough speeds."

For more information
siliconphotonics.co.uk



A modulator chip

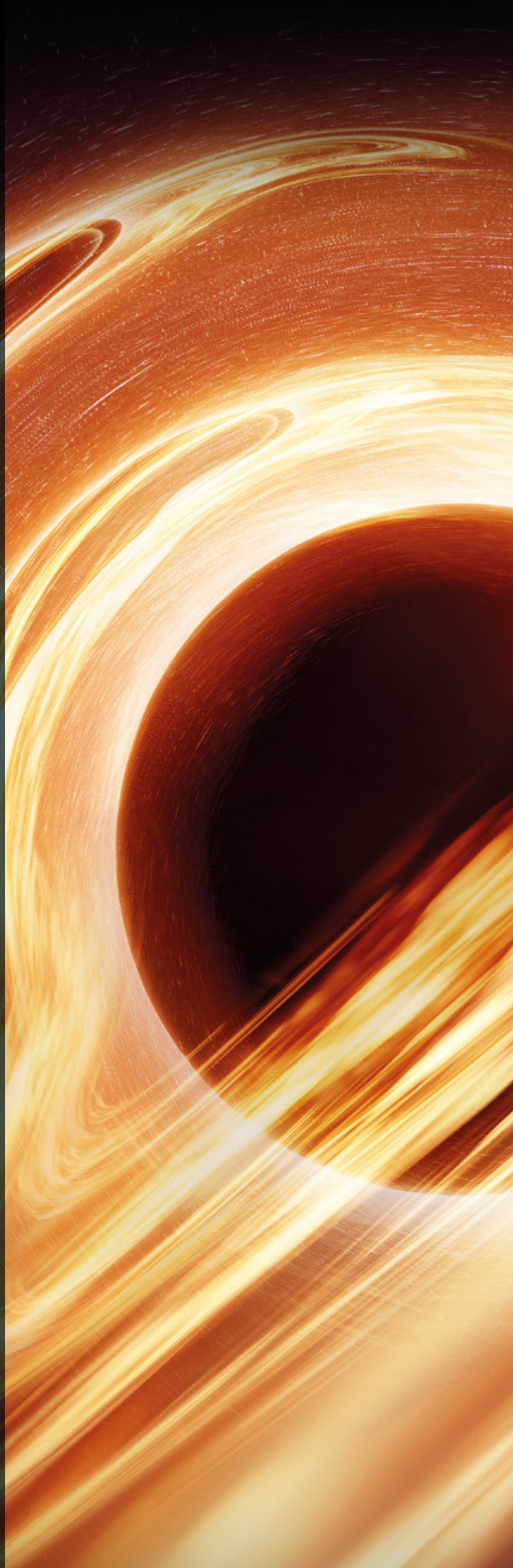
Dr Milos Nedeljkovic

"There is a lot of interest in the potential for making laser communications between satellites and also from satellites back down to Earth. The idea would be to shine a laser beam carrying data from one satellite to another."

Dr Milos Nedeljkovic

Einstein's theory of General Relativity revolutionised our understanding of the big stuff: space, time, gravity and the universe. It also famously predicted the existence of black holes. Physicists at Southampton have leading roles in a space mission that is set to discover more about these mysterious objects – as well as putting Einstein's theory to the test.

DEMYSTIFYING BLACK HOLES

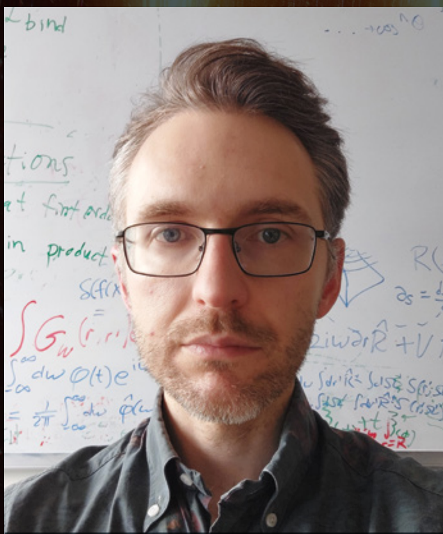


Gravitational waves are almost inconceivably tiny ripples in spacetime travelling at the speed of light. The first direct detection of these minute waves was celebrated with a Nobel Prize in 2016 and, since then, these waves have unveiled a universe teeming with dark objects – black holes – and dramatic events that were invisible to traditional technologies.

The Laser Interferometer Space Antenna (LISA) mission is seen by many scientists as the next big step in this transformation of astronomy. One of three flagship missions in the European Space Agency's Cosmic Vision programme, LISA will be the first gravitational wave detector to operate in space.

Southampton physicist Dr Adam Pound has a leadership role in the LISA Consortium, the large international collaboration focused on the LISA mission. His work is on theoretically modelling the collisions of black holes.

Dr Pound, a Royal Society University Research Fellow in Southampton's Applied Mathematics and Theoretical Physics research group, explained: "In order to detect and interpret gravitational waves, detectors such as LISA require high-precision models of the waves, and the systems that generate them. The strongest sources of gravitational waves are binary systems in which two very dense objects – black holes or neutron stars – orbit around each other, gradually spiral inward, and eventually merge, creating ripples in spacetime, just like how two boats moving around one another would create ripples in a pond. I work primarily on modelling a subset of those systems: binaries in which one of the objects is much heavier than the other."

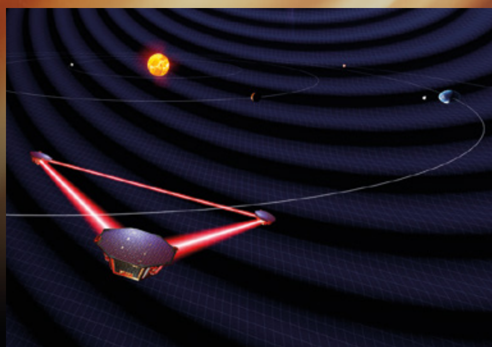


Dr Adam Pound

LISA will target the most extreme examples of these systems, by observing the slow inspiral of black holes, roughly as heavy as our Sun, into massive black holes that are millions of times larger.

Such 'extreme-mass-ratio inspirals' (EMRIs) have never been observed but are believed to occur at the centres of many galaxies, where massive black holes reside.

"We're pretty confident that each galaxy has a massive black hole at its core, and galactic cores are busy environments," said Dr Pound. "So, we expect LISA to see quite a few of these EMRIs. Because the orbit of the smaller black hole, and the emitted waveform, is very long-lived and intricate, these systems are expected to provide unparalleled tests of Einstein's theory of General Relativity and its theoretical description of black holes."



An artist's rendition of LISA orbiting the Sun. Credit: Simon Barke

Explaining black holes

Black holes are places in space where gravity's pull is so strong that not even light can escape.

"A black hole forms when a star collapses, which happens after a supernova," explained Dr Pound, who came to Southampton from Canada in 2011. "They are incredibly dense objects. For example, a black hole as heavy as our sun would be only three kilometres in diameter, compared to the sun's 1.39 million kilometres. The black hole at the centre of our own galaxy is physically the size of the sun, but it is four million times heavier."

Remarkably, Einstein's theory predicts that no matter how these strange objects were created or what has fallen into them, they all take the same, simple form: the only difference between them is how big they are and how fast they spin.

One of the goals of the LISA mission is to test that prediction by studying the gravitational waves created by EMRIs. Any violation of the prediction would tell us either that General Relativity isn't quite correct, or that the dark, dense objects in galactic centres aren't quite what we think.

Dr Pound said: "One way the General Relativity prediction might fail is that quantum physics might take over very near the surface of the black hole. If that is true, as some physicists believe, it would make the entire black hole into an enormous quantum object. Quantum effects around a massive black hole could then affect the motion of the smaller black hole in an EMRI and that could leave a signature in the gravitational wave. Our calculations will help test such ideas."

Finding black holes

Despite their often immense size and – we now know – great abundance, black holes are tricky to detect, precisely because they are 'black', which means that our traditional electromagnetic observatories can only get very limited information about them and can't see systems like EMRIs at all.

Therefore, the best way for scientists to discover more about the nature of black holes is by hunting for the gravitational waves they emit. Current gravitational wave detectors observe about one signal per week, the vast majority of them from black holes. This number is bound to grow dramatically as the sensitivity of the detectors improves.

Dr Pound said: "All gravitational waves we have detected so far are created by black holes or neutron stars orbiting each other in remote galaxies. By the time the waves reach us, they are tiny, as we are so far away from the systems that create them."

Depicting the creation of a gravitational wave by two orbiting black holes.
Image courtesy of T. Pyle/LIGO

To detect these ripples, in addition to using an incredibly sensitive detector, physicists use theoretical calculations of the predicted waveforms, or templates.

"We have two goals," explained Dr Pound. "One is to provide the templates that will make it possible to dig the gravitational waves out of the noisy detector data. The second is to be able to interpret the waves and trace their features back to the physical properties of the systems that created them. For example, what is the shape of the orbit of the two objects around each other? How big is each one? How fast do they spin? Understanding that gives us a lot of information about what is out there in the universe and about the fundamental laws of physics governing it all."

Modelling for LISA

Once in operation, LISA will orbit around the sun. It will comprise three spacecraft forming a triangular shape, with each side of the triangle being about 2.5 million kilometres long. The current target date for launch is 2034.

Operating in space will bring a lot of advantages. Present-day gravitational-wave detectors are limited in what signals they can 'hear'. Being on Earth, they are susceptible to the gravitational noise created by everyday activity on, and inside, the planet. This noise prevents them from observing especially large systems, such as EMRIs. They primarily see the mergers of black holes that are a few times (or a few tens of times) as massive as our sun. Located in space, LISA will escape the noise of Earth and be able to observe a whole zoo of other, much bigger events.

In addition to EMRIs, LISA will detect many binary systems within our own galaxy, the Milky Way – tens of thousands of them at any given time.

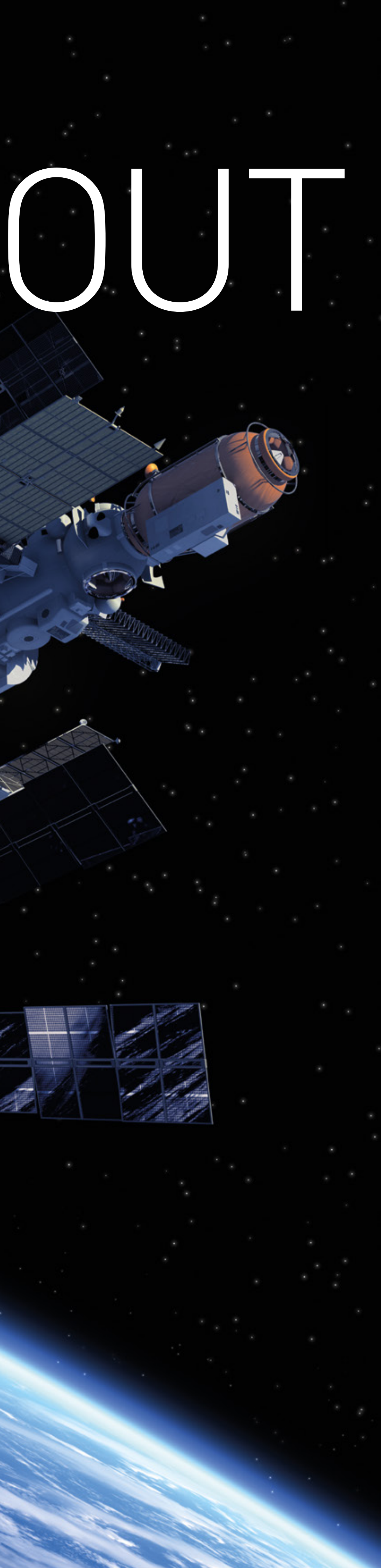
Scientists hope that LISA will also detect gravitational waves generated by the merger of two supermassive black holes at the centres of colliding galaxies. These are incredibly loud, dramatic and violent events: they release millions of times more power in gravitational waves than the light of the entire visible universe.

Modelling all these systems represents a huge theoretical challenge. EMRIs are especially difficult because the signals they produce are especially complicated.

LISA's launch in 2034 may seem like a long way off, but scientists like Dr Pound are already feeling the urgency of their work. "I see it a bit like climbing a mountain," he said. "We can see the peak we're trying to get to, but it's a long climb up. Now we need to try not to fall too many times along the way."

CGI recreation of Mir, with two Soyez capsules attached

Helen Sharman with Professor Mark Spearing, Vice President (Research and Enterprise), and Lorna Colquhoun, Director of Research and Innovation Services



OUT OF THIS WORLD

Britain's first astronaut visits Southampton.

Did you know it takes just 530 seconds – less than nine minutes – to reach space in a rocket?

Helen Sharman, Britain's first astronaut, shared fascinating insights into her experiences as a space explorer in a captivating speech at the University of Southampton.

From developing ice creams to venturing into outer space, Helen's career path took a surprising turn when she heard the call for astronauts – 'no experience necessary' – on the radio. She told the University audience about her experiences of astronaut training, and what it's really like to be in space.

"I never expected to be an astronaut," she said. "I was a shy teenager, I kept my head down, and I didn't know what I wanted to do as a career."

Helen studied chemistry to "keep my options open" and embarked on a career in manufacturing, landing a job at Mars Confectionary, where she was part of the team that invented the Mars Ice Cream bar.

Hearing a radio advert inviting applications to be an astronaut, Helen responded, thinking that the selection process might be fun. This included medical and psychological tests, and being whizzed around in a centrifuge to test g-force tolerance. Helen passed these tests and went to Star City, north of Moscow, for 18 months of astronaut training, first learning to speak fluent Russian, as the entire mission was conducted in Russian. She learned about the technology of the rocket, ballistics and astro-navigation, and spent three days at sea in a simulator to practice escaping should the return trip end in the ocean. She trained in a spinning chair to build motion sickness tolerance, and experienced parabolic flights to replicate zero-gravity conditions.

On 18 May 1991, Helen and her fellow cosmonauts, Anatoly Artebartsky and Sergei Krikalyov, boarded the Soyuz capsule which would take them to the Mir space station. In just 530 seconds, they were 400km above the Earth, in space.

Helen and her team spent six days on Mir, conducting medical and agricultural experiments.

Tackling the debris

Reflecting on advances made since her expedition, and today's challenges, Helen said: "One of the biggest problems is the huge amount of space debris. It's a problem to humans in space, and it's a problem to all the space equipment that monitors what's happening on Earth."

Experts such as Professor Hugh Lewis, of the University's Astronautics Research Group, are leading the way on tackling space debris. Professor Lewis said: "Space provides us with data services that we could not do without now, but the legacy of 60 years of space flight has left a lot of debris – it's a harsh reminder of how humans have treated their environment.

"There are millions of man-made objects in space and only a small fraction of those are operational space craft. If we consider the Earth's environment to be at risk and we are doing something about it, we should be doing the same for the space environment."

Helen Sharman shared her story at the *Space at Southampton* event in February 2022.

REACHING FOR THE SKY

In 2021, when the European Space Agency (ESA) put a call out for would-be astronauts, two Southampton academics put themselves forward – and were successful through the initial stages.

Senior Research Fellow and Veterinary Surgeon Dr Karen Marshall and Spacecraft Engineering PhD student Aria Vitkova both made it through the first two stages of selection, gaining a first-hand insight into what it takes to become an astronaut.

More than 23,000 people from across Europe responded to ESA's first call since 2008 for a new cohort of astronauts. Of those, 1,391 – including Karen and Aria – were selected to travel to Hamburg in October 2021 for psychometric testing.

The next stage would have been to go to ESA's European Astronaut Centre in Cologne, Germany, for thorough psychological assessments, followed by a full medical examination and panel interviews. The successful cohort of astronauts is expected to be announced at the end of 2022.

Opposite page: Astronaut Helen Sharman (centre) with Dr Karen Marshall (left) and Aria Vitkova

Dr Karen Marshall

Veterinary Surgeon and Senior Research Fellow, Bone and Joint Research group

Karen is a veterinary surgeon, previously specialising in large animal medicine and surgery, who is now working on the UK Regenerative Medicine Platform II project and completing a PhD in bone tissue engineering. Having graduated from the University of Glasgow in 2010, she moved to Southampton to join the University's Bone and Joint Research group in 2019.

She said: "I have always loved everything about space and have been fascinated by it since primary school. I saw the ESA call on Twitter only a couple of days before the deadline, and I managed to get a last-minute health test signed off by a doctor and I applied."

Karen made it through the initial application stage and was invited by ESA to travel to Hamburg to take part in tests. She said: "Before going to Hamburg, I took a week off work and crammed GCSE physics and maths. I also took Russian language classes at the Avenue Campus via Lifelong Learning courses available at the University, and did swimming training at the Jubilee Sports Centre in preparation, and I contacted Dr Andrea Da Ronch and PhD students in the Faculty of Engineering and Physical Sciences to request training in their fantastic new flight simulator at Boldrewood."

About her experience in Hamburg, Karen said: "It was a great experience, and I met some really interesting people. I didn't get through the programme beyond Hamburg, but I was really pleased to have got through to 1,400 out of the original 23,000 applicants. It has opened up opportunities, from using different facilities at the University I would never have used otherwise, to making new contacts from around the world, and discovering new opportunities for my research. For example, off the back of this I went to an Animal Health and Space Sandpit at the University of Surrey, where I presented my bone tissue research."

Aria Vitkova

Instrument Engineer and Southampton PhD student

Aria, originally from the Czech Republic, studied her Master's and PhD – submitted in September 2022 – at Southampton.

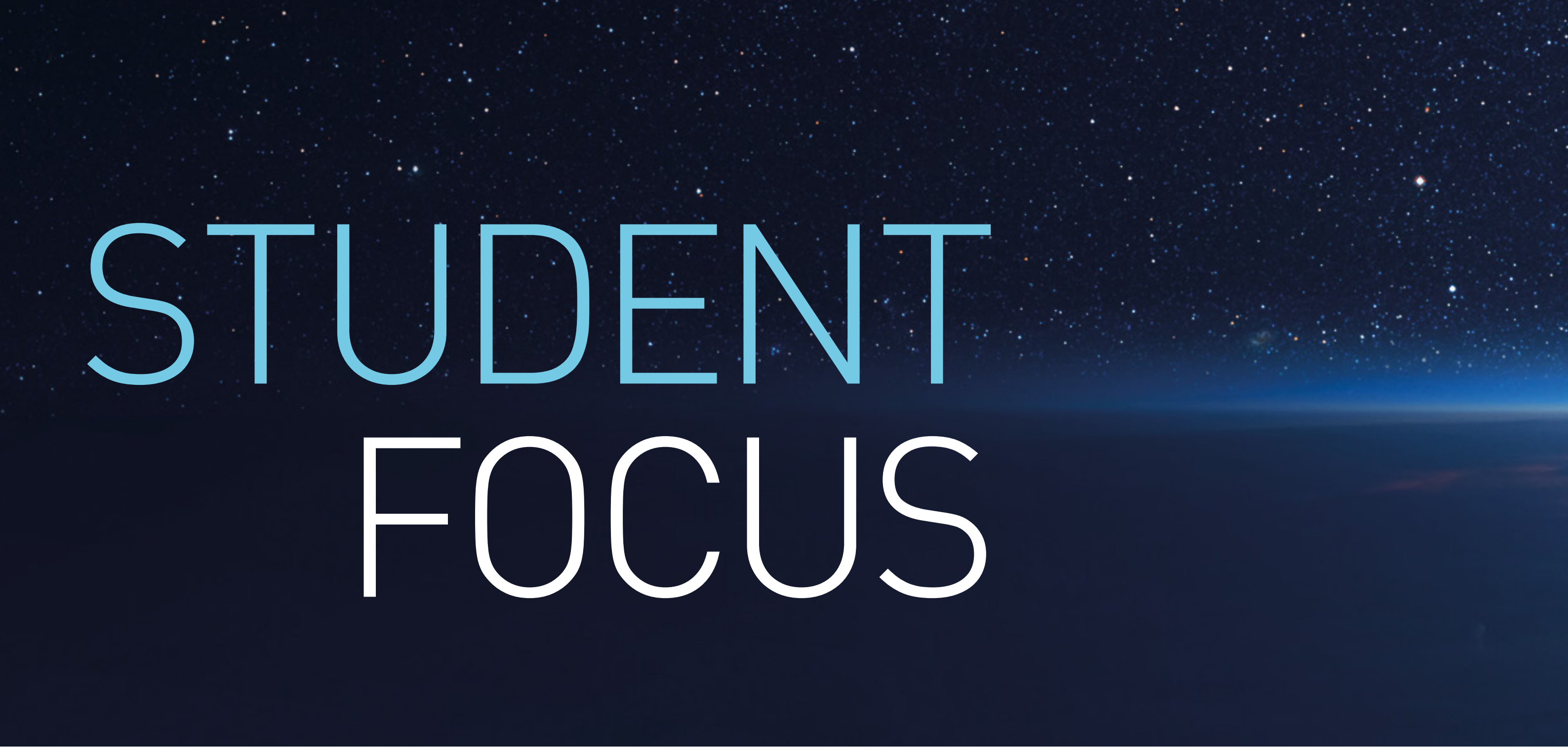
Her PhD focused on designing instruments that could detect life on Europa, one of Jupiter's moons. "It's one of the most likely sites in the solar system to have life, as it has large deposits of water under its ice," explained Aria. "Most exploratory instruments have been designed for Mars, but Europa is a very different environment. If there is life there, it's possibly some form of bacteria. It would be very exciting if this is the case, because life there would be very different from what we know."

Aria, who is now working at Imperial College London's Space Magnetometer Laboratory, said: "I have never had a burning desire to be an astronaut. The role of an astronaut was so far-fetched that I never considered it. But during the COVID-19 pandemic, I wanted to find out if I could be a pilot, so I applied – and passed – the aeromedical exam. It was just after this that ESA published the announcement it would be recruiting astronauts so, since I had just passed the required aeromedical exam I decided to apply."

Aria passed the first stage and, like Karen, was among the 1,400 applicants selected to travel to Hamburg for further tests.

"I couldn't believe it, especially when they said more than 23,000 people had applied," she said. "It was a very different and interesting experience in Hamburg. I loved the opportunity to meet others that applied and were selected – they were all incredibly interesting, experienced and talented and the experience was very humbling."


SPACE AT
AMPTON
HAVE
OFF



STUDENT FOCUS

NANOSAT FINALISTS

A team of five Southampton students reached the finals of the UK's Nanosat Design Competition 2022 with their innovative soil monitoring satellite invention.

They were one of five teams, from almost 50, to reach the final.

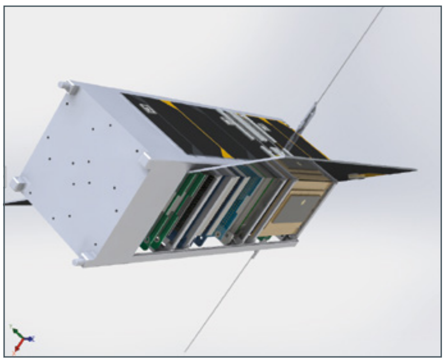
The aim of the competition, run by UK spaceflight programme Launch UK, was to design and build a nanosat (small satellite) that can be used to inform or provide innovative solutions to support the UK's climate change or decarbonisation efforts.

The Southampton team designed a nanosat that uses reflected signals from other satellites to estimate soil moisture content. It could be used for peatland conservation, gathering soil moisture data, and for flood, drought and wildfire risk mapping.

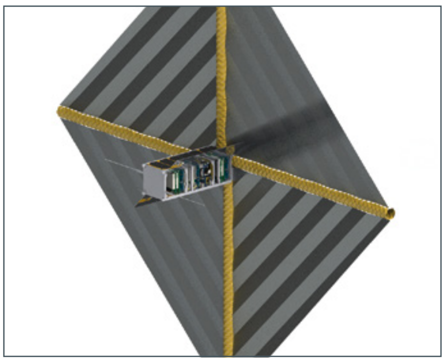
The team comprised Engineering PhD student Hazel Mitchell, Aeronautical and Astronautical Engineering with Spacecraft Engineering students Robert Oxford Pope and Ceris Brown, Aeronautical and Astronautical Engineering student Harvey James O'Sullivan Ryder, and Physics and Astronomy student Ethan Tregidga.

The competition concluded at the Farnborough Air Show in July 2022, where the five teams were invited to present and demonstrate their designs. The winners were a team from the University of Glasgow who designed a nanosat to analyse shorelines and coastal vegetation to understand the impact of climate change on coastal regions.

The Southampton nanosat competition team



The Southampton team's nanosat design



The nanosat with a drag sail for deorbiting

IN A SPIN

Using ‘Internet of Things’ (IoT) devices and radio communications to improve agricultural practices was at the heart of Southampton graduate Harold Hancock’s SPINternship.

Harold, who graduated from Southampton in 2022 with a BEng in Aerospace Electronic Engineering, secured a prestigious summer SPINternship (Space Placement in Industry internship) with the Satellite Applications Catapult Agri Living Lab. He was based at the Westcott Innovation Centre, Aylesbury, and at Harwell Science and Innovation Campus near Oxford.

The internship, funded by the UK Space Agency, saw Harold programme IoT (technologies that connect and exchange data over the internet) nodes to gather sensor data for agricultural applications such as soil monitoring for crop growth optimisation, gas monitoring to control the release of greenhouse gases from farms, and monitoring solar panel outputs to ensure they are optimally positioned. He also assisted on setting up a database and data visualisation tools for performance analysis.

Harold said: “The experience was very useful since I learned a lot in software development within a professional team, and it supported my career progression goals within the space and aerospace industries.”

Since the internship, Harold has joined Thales as a Graduate Systems Engineer in the company’s Avionics division.

Right: Harold Hancock

DEBRIS HUNTING

Millions of fragments of space debris are orbiting the Earth. They are the remnants of satellites, machinery and mission-related debris. It's a form of pollution – and a problem – that is growing fast.


Dr Mekhi Dhesi

Space debris – or space junk – will threaten future spaceflight around Earth if it is not cleaned up.

As of January 2021, the US Space Surveillance Network reported 21,901 artificial objects in orbit around the Earth, including almost 4,500 functioning satellites. But these are just the objects large enough to be tracked. More than 128 million pieces of debris smaller than 1cm, more than 900,000 pieces measuring 1cm to 10cm, and 34,000 pieces larger than 10cm are estimated to be 'out there' too.

It's a growing problem that former Southampton PhD student Mekhi Dhesi is looking to help tackle in her new role at Astroscale, in their Space Situational Awareness team.

Astroscale was set up in Japan in 2013 with the mission of reducing orbital debris and supporting the long-term, sustainable use of space.

Mekhi is working at Astroscale's UK offices at the Harwell Science and Innovation Campus near Oxford. She said: "Astroscale is the first private company with a vision for the safe and sustainable development of space. They are developing, innovating and pioneering technologies to remove and reduce orbital debris.

"It's really important because the orbital debris problem is spiralling out of control. Debris can crash into other debris, and poses a serious hazard to operational satellites. There are implications for GPS, and many other space-based technologies that we now heavily rely on, here on Earth."

Examining exoplanets

Mekhi has worked for a space mission before – the Twinkle space mission. This seven-year mission, due to launch into low Earth orbit in the coming years, will be sending a telescope to look at the atmosphere of exoplanets (planets outside of our solar system).

"If we can analyse the atmospheres of exoplanets, we can work out what they are made from, and even if there are signs of life," explained Mekhi, who worked on the mission from 2016 to 2019. "All planets orbit a star, so the telescope will look at the light that comes from host stars and, when planets pass in front of the host star, there will be a dip in light. This dip can then be analysed to determine what chemicals planets are made from."

Black holes

Investigating the cosmological history of black holes was at the heart of Mekhi's PhD, which she submitted in September 2022.

A black hole is formed when a star collapses (explained in more detail in 'Demystifying black holes' on page 20). Mekhi focused on analysing and understanding pairs of black holes that orbit each other and eventually merge, where one is 1,000 times smaller than the other.

Her work involved combining numerical and analytical techniques to model the gravitational waves emitted when two such black holes collide. Such models are necessary to extract signals from gravitational wave detector data.

"It's interesting because observing black hole mergers teaches us a lot about astrophysical environments that we do not know much about yet," she explained. "From analysing the gravitational waves emitted during mergers we can better understand how black holes come to exist, and how do you go from smaller black holes to bigger ones. Ultimately, it's about enabling us to learn about what's out there in space, and the structure of the universe."

"Debris can crash into other debris, and poses a serious hazard to operational satellites. There are implications for GPS, and many other space-based technologies that we now heavily rely on, here on Earth."

Dr Mekhi Dhesi

THE FUTURE OF COMMUNICATIONS

New ways of using satellites are likely to play a leading role in the future of our day-to-day mobile communications, as experts look ahead to 6G.

Right:
Dr Mohammed El-Hajjar

As we progress from 4G to 5G and on to 6G, the future lies in non-terrestrial networks.

5G – the fifth generation of broadband cellular network technology – succeeds 4G and began to be deployed worldwide in 2019. It is predicted that by 2025, 5G networks will account for 25 per cent of the world's mobile technology market.

The future, however, lies beyond this – and 6G is already being investigated.

Dr Mohammed El-Hajjar, Associate Professor in the Next Generation Wireless research group at the University of Southampton, outlined: "There are some places in the UK, and lots of places around the world, where communications signals are very bad. We want to enable good communications coverage everywhere, and in the Next Generation Wireless research group we are focusing on this challenge – so we are now looking at non-terrestrial networks."

Terrestrial networks feature base stations to cover specific areas. Potential alternatives are balloons/High Altitude Platforms (HAPs), drones, aeroplanes or satellites carrying base stations.

"Planes, for example, cover most of the Earth and are travelling everywhere, so could be potential base stations," said Dr El-Hajjar. "Similarly, so could satellites. Using these, together with the terrestrial base stations, would make good communications coverage global."

Making connections

But, with both terrestrial and non-terrestrial networks come many challenges around who and what communicates with what, and where.

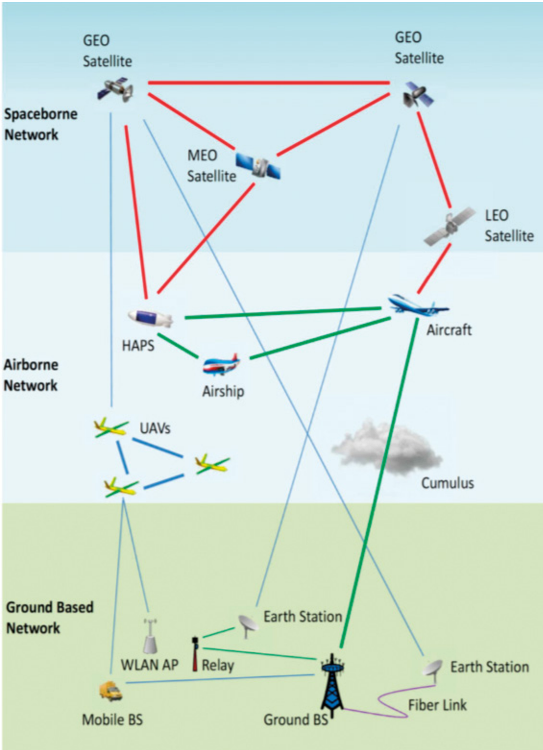
"If there are base stations on the ground, on satellites, on planes, on drones, and so on – which is the best for me to connect with, or is it better to communicate with a multitude of these?," asks Dr El-Hajjar. "For different areas and in different scenarios, the requirements are different. For example, for emergency services you don't want to go through satellites because there is a delay. In a disaster scenario, where ground infrastructure is destroyed, an air-based system would be beneficial."

Research at Southampton

Academics in the Next Generation Wireless research group are concentrating on several aspects of 6G communications.

One is user association – determining which users are associated with which transmitters. Another focus is the design of the transceiver to achieve the most efficient communications.

Southampton researchers are also investigating caching, as Dr El-Hajjar explained: "For example, if there is a football match on in Southampton and large numbers of people want to watch it, there is a lot of traffic across the network for this specific topic, which causes network delays. With caching, you would get the specific information – in this case the screening of the match – into the base station and automatically send it, via artificial intelligence, to the users who are interested in it."



"We want to enable good communications coverage everywhere, and in the Next Generation Wireless research group we are focusing on this challenge – so we are now looking at non-terrestrial networks."

Dr Mohammed El-Hajjar

ADVISING THE UK SPACE AGENCY

A broad range of cross-disciplinary research on space-related technologies has seen Dr Minkwan Kim selected to join the UK Space Agency's Space Exploration Advisory Committee (SEAC).

The committee's role is to advise the UK Space Agency on matters relating to robotic and human space exploration programmes, and on UK participation in European exploration programmes – including Mars exploration and the International Space Station.

Dr Kim, Associate Professor in Astronautics, joined the SEAC in February 2022 for a two-year term. His research expertise in in-situ resource utilisation, life support systems, planetary protection (cleaning and sterilising spacecraft), atmospheric entry technologies (thermal protection and radio blackout), and space propulsion, will be called upon.

He said: "I was so excited when I was informed that I was selected as a member of SEAC. The University of Southampton is one of only a few universities that has an active space-related research and teaching programme. However, as a University, we did not have a voice at the Agency to speak for the University's research activities and desired future space missions and programmes. Becoming an SEAC member will give us a chance to contribute ideas and suggestions on space exploration."

Outlining his aims during his two-year term on the SEAC, Dr Kim added: "I want to help enable more opportunities for academia to participate in European Space Agency and UK Space Agency exploration programmes. In addition, I want to encourage the UK Space Agency to consider University-led space missions, which often occur at universities in the United States. Finally, I want to contribute to the Agency's awareness of the importance of sustainable space development."

Dr Minkwan Kim

In addition to Dr Kim, the SEAC has nine members, who are:

- Head of Collections, Natural History Museum
- Professor of Planetary Science, University of Oxford
- Honorary Associate Professor of Physics and Astronomy, University College London
- Associate Professor in Sport and Health Sciences, University of Exeter
- Lecturer in Planetary Science, University of Glasgow
- Director of Astrobiology, The Open University
- Chancellor at Edinburgh Napier University and Chair of Seraphim Space Investment Trust PLC
- Technical Director, Reliance Precision Limited
- Head of Science, Airbus UK

Find out more:
www.southampton.ac.uk

business@soton.ac.uk

Space at Southampton is produced by Research and Innovation Services (RIS).

RIS facilitates academic collaborations, research funding bids, industrial interactions and knowledge exchange activities, including commercialisation and business acceleration. RIS also supports research ethics and integrity, research contracting, research and enterprise communications, and the REF.

Please recycle this publication
when you have finished with it.