Cranfield University

Space capabilities

At the centre of the global space economy

Space **capabilities** at **Cranfield**

Cranfield has world-leading capabilities in space research and education, with our researchers and academics working in collaboration with strategic partners, to solve some of the biggest challenges faced globally. With a UK space sector income of £16.5 billion in 2019/20, space activity across the UK, Europe and the world continues to push the frontiers of science and exploration - and Cranfield is leading the way.

Cranfield has a long history in space-related research, spanning the last 60 years. Our excellence in strategic and applied research has enabled us to make significant contributions to the world around us, addressing real life challenges of strategic and practical importance. With breakthroughs that are already delivering benefits, developing capabilities and building businesses globally, from sensor technologies, precision engineering, earth observation, autonomous vehicles, and spacecraft, satellite and missile design, Cranfield has cemented a central role in the research and problem solving in the emerging global space economy.

For many, space conjures up images of rockets, astronauts and inter-planetary missions. However, today space touches our everyday lives, from the technology that drives our mobile phones, to our satellite navigation systems, to the entertainment that appears on our screens at home. Space technology has the potential to achieve social good, enabling us to monitor food and water security, track climate change, and predict extreme weather events.

Whether you are a multinational company, a growing SME or a small start-up, the space sector is buoyant and ready for growth. Here at Cranfield, there are huge opportunities ahead, where we can make a real difference to you and your organisation through our technological advances and ground-breaking research.

Contents

Space situational awareness and space surveillance and tracking

The recent development and deployment of mega-constellations, together with the increase in the number of satellites in orbit, poses new challenges in terms of simultaneous tracking capability and readiness of current space situational awareness systems.

With the exponential increase of objects and launch of new spacecraft into orbit, the space research community must find effective solutions to evaluate and manage the population of space objects, to mitigate the probability of triggering cascade collisions that could compromise the future use of certain space regions.

Forecasting is a fundamental step to the long-term future – and safety – of the sector. It will enable autonomous space traffic management solutions capable of handling and mitigating multiple and frequent threats, to autonomously plan collision avoidance manoeuvres.

Our research explores ground-based and space-based technologies that seek to enhance the current space domain awareness capabilities.

Space debris and space traffic surveillance

Multiple fragments of past space endeavours are trapped in orbit around Earth, threatening our future in space. With the number, mass and area of the debris objects growing steadily, this increases the risk to functioning satellites.

- Covariance propagation methods and collision assessment,
- Debris detection and tracking sensors and algorithms for both optical and radar systems,
- Drag sails for end-of-life de-orbit, with a particular focus on small/low-cost satellites,
- Autonomous traffic management.

Space-based surveillance system

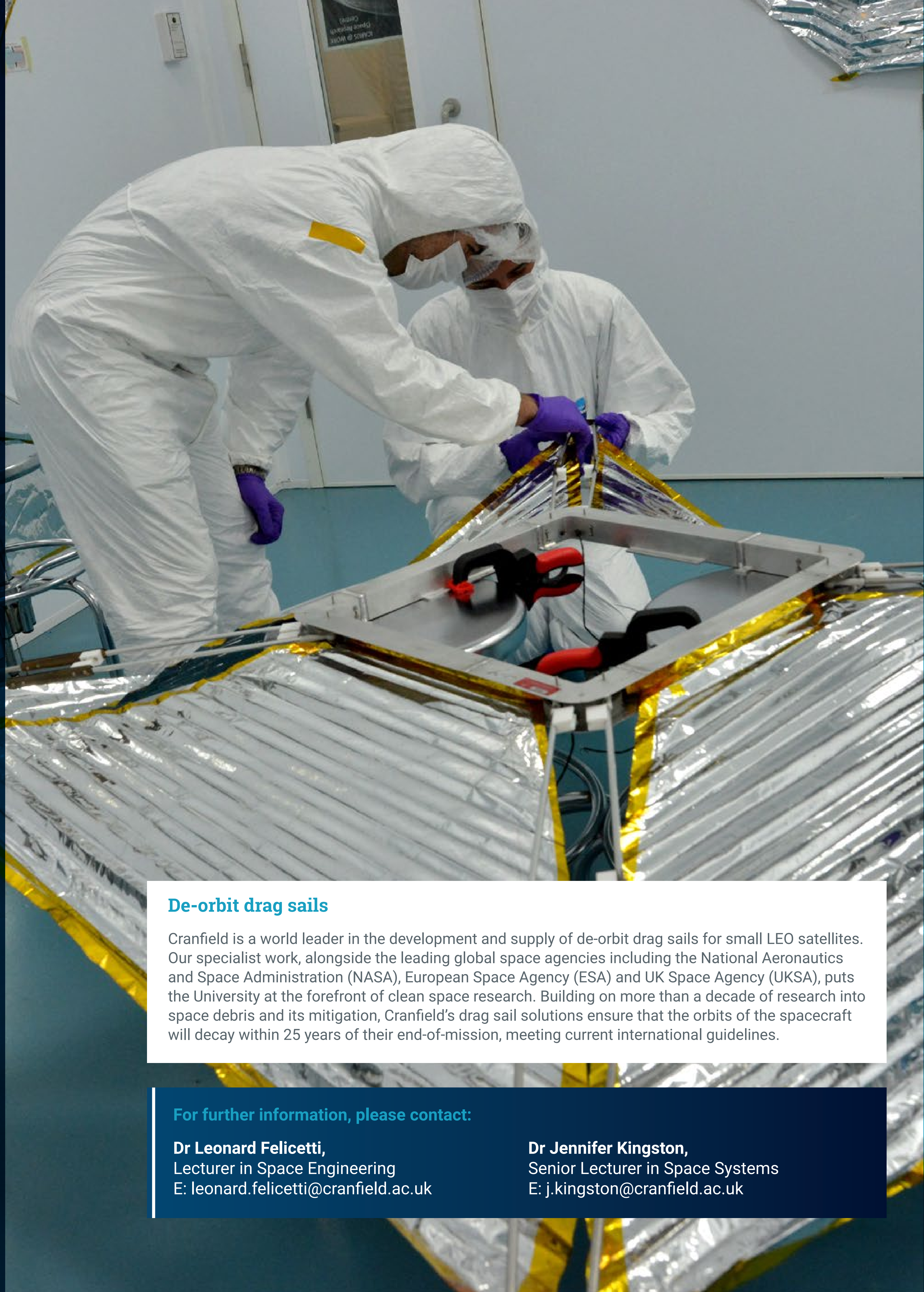
Space-based sensors are becoming key assets for enhancing the current and future capabilities of the space surveillance network. Cranfield is exploring the concept and the eventual benefits of having a network of space-based optical sensors distributed in a constellation of autonomous small-satellites (e.g. CubeSats - read more on page 8).

Our research focuses on:

- mission and concept design,
- optical system design,
- image processing, streak detection and orbit estimation algorithm,
- spacecraft design.

Spacecraft collision avoidance using machine learning

Our research teams are working with the UK Space Agency (UKSA) and The Public Service Consultants (a digital agency) on testing and use cases for satellite monitoring and collision warning tools for UK satellite operators. We are also investigating the use of machine learning with the UKSA to identify and predict scenario outputs.



De-orbit drag sails

Cranfield is a world leader in the development and supply of de-orbit drag sails for small LEO satellites. Our specialist work, alongside the leading global space agencies including the National Aeronautics and Space Administration (NASA), European Space Agency (ESA) and UK Space Agency (UKSA), puts the University at the forefront of clean space research. Building on more than a decade of research into space debris and its mitigation, Cranfield's drag sail solutions ensure that the orbits of the spacecraft will decay within 25 years of their end-of-mission, meeting current international guidelines.

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Systems engineering for clean space

The ground-breaking technology required to develop drag sails is founded on excellent systems engineering. This includes initial mission design, requirements definition and technology development for the mitigation of space debris, through to the development of drag sails, clean space technologies and on-orbit operations, including servicing, manufacturing, assembly and recycling.

Model-Based Systems Engineering (MBSE) for planetary rover systems

MBSE methodologies in robotic system design are being used in the creation and modelling of a planetary rover system architecture. The system design and component selection is driven by system requirements identified in the initial phase of the project, with the architecture showing the detailed interaction between sub-systems and layers. This work is set to deliver a comprehensive illustration of the use of MBSE methodology during the conception and architecture phases of a project, using the planetary rover as a use case.

Human-robot system design and development

Human-robot interaction is inevitable in most robotics applications. However, capturing and modelling of human behaviours in human-robot interactive system design remains a challenge for MBSE. Our research explores ways to improve representation of human-robot interaction and collaboration in MBSE to deliver the system requirements at the appropriate level of performance. The human element is vital in the effective and efficient operation of these interactive systems, and as a result, its system representation must fully reflect the human functionalities and activities in the system.

Systems engineering and mission analysis and design

In today's competitive and international environment, we need to achieve the greatest efficiency while remaining on time and to budget. By providing facilitation, guidance and leadership, good systems engineering underpins the successful design and management of complex projects over the entire lifecycle. The goal; to provide a solution that meets the needs of all stakeholders, and is fit for the intended purpose in real-world operations.

Cranfield's reputation and track record in space systems engineering is widely renowned, and covers the following key research areas:

Space mission analysis and design

- Mission design, requirements definition and technology development for space missions,
- definition and implementation of a design, qualification, integration, and test, programmes for flight payloads to European Cooperation for Space Standardisation standards,
- tradespace exploration, multi-objective optimisation and trade-off analysis.

Systems engineering, product lifecycle management and Model-Based Systems Engineering (MBSE)

- MBSE methodologies applied to a wide range of space systems,
- analysis and critical assessment of MBSE methodologies for space systems development, and suggestions for potential improvements on existing frameworks,
- modelling and simulation of complex systems through their whole lifecycle.

Agile technology development

- Scrum methodology for agile development of space hardware,
- hybrid-agile product development process targeted to space technologies development.

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Guidance navigation and control of space systems

Guidance Navigation and Control (GNC) is a fundamental part of all space missions. Our research spans Attitude and Orbit Control Systems (AOCS), spacecraft formation flying, non-co-operative rendezvous and proximity operations and positioning, navigation and timing.

Attitude and orbit control

Attitude and orbit control is the process of controlling the orientation of a vehicle (in this case a satellite or solar sail) with respect to an inertial frame of reference or another entity such as the celestial sphere, certain fields, and nearby objects. At Cranfield, our research focuses on:

- AOCS for small satellites (CubeSats), with the development of ad-hoc control and estimation algorithms, exploiting limited onboard computational capabilities or actuation/sensing technologies,
- AOCS for fine pointing or dynamic slew manoeuvring for astronomy and earth observation missions,
- AOCS for solar sails, with the development of optimal steering laws maximising the exploitation of solar radiation for performing propellant-free manoeuvres,
- AOCS for large structures, space-tethered systems and space webs.

GNC for planetary rovers and aerobots

Cranfield's researchers are developing GNC algorithms for planetary exploration with both wheeled and aerial vehicles. Research includes:

- Visual/lidar-based navigation algorithms for limited onboard computational capabilities,
- sensor fusion and simultaneous localisation and mapping for planetary exploration,
- path planning and hazard avoidance algorithms.

Near-asteroid and comet proximity operations

Cranfield's GNC capabilities are also applied to near-asteroid and comet scenarios. Our research in this area includes:

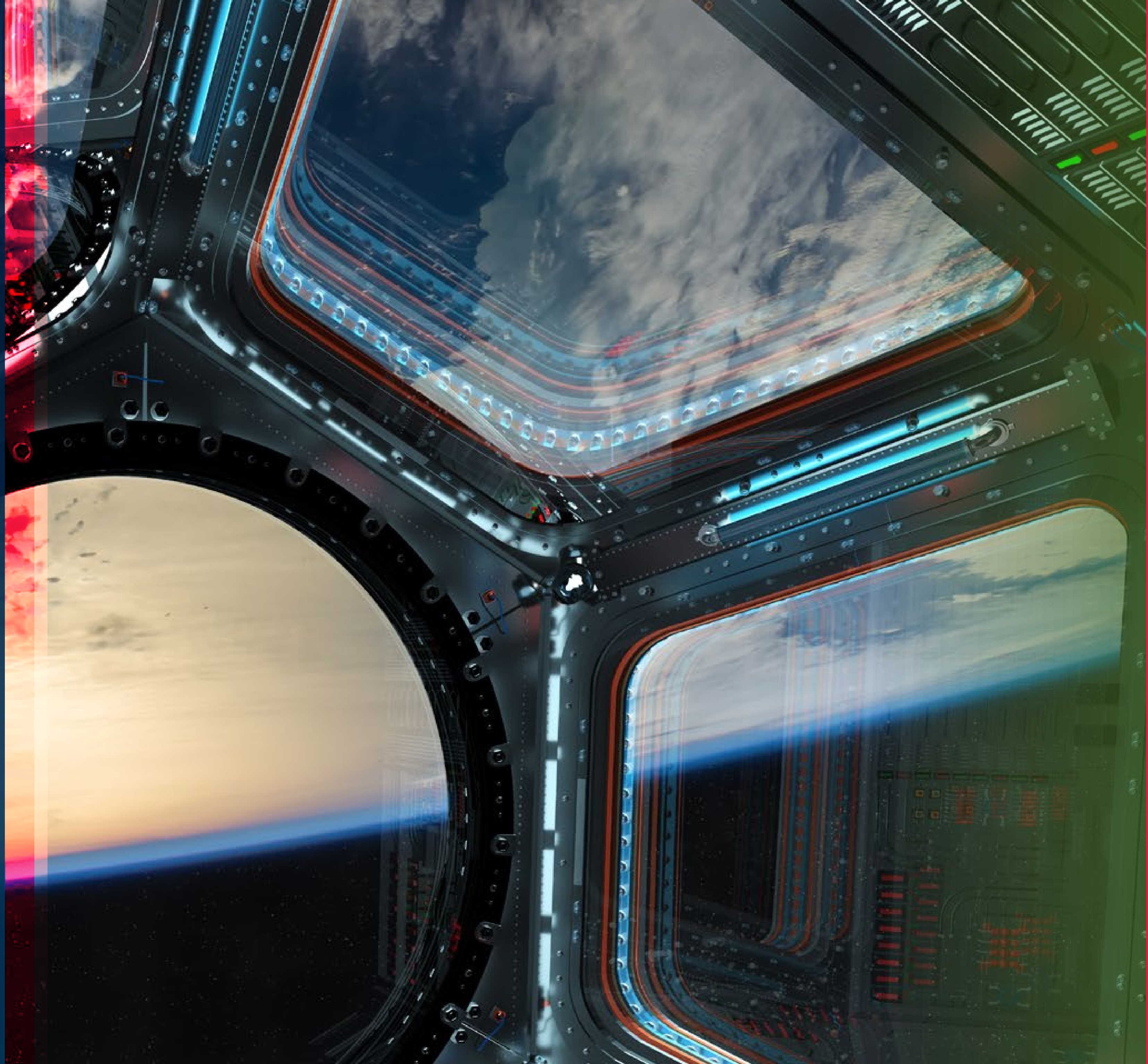
- Image-based navigation for near-asteroid operations and characterisation,
- dust impact and attitude analysis during fly-bys of comets,
- mission analysis and design.

Non-cooperative rendezvous and proximity operations

On-orbit applications, such as active debris removal, satellite refuelling, maintenance and satellite health diagnosis require the ability for spacecraft to closely inspect other orbital objects in a non-cooperative manner. In this kind of mission, the relative navigation process becomes critically important to ensure safe and collision-free proximity operations and manoeuvres.

Cranfield's key research areas include:

- Image-based, lidar-based, or radar-based relative navigation,
- Sensor data fusion and AI-based algorithms for inspection and relative navigation,
- Model-predictive, control–based rendezvous.



Spacecraft formation flying

The focus of formation flying is to maintain a targeted orbit configuration of various spacecraft. Cranfield's research seeks to look at how the autonomous formation flying of multiple spacecraft can act as enabling technology for many future missions. Our aim is to solve key technical challenges such as multi-objective attitude and orbit coordination among platforms, centimetre-level relative navigation accuracy required for precise observations, and the development of new optimal control techniques enabling efficient formation reconfigurations and target observation campaigns.

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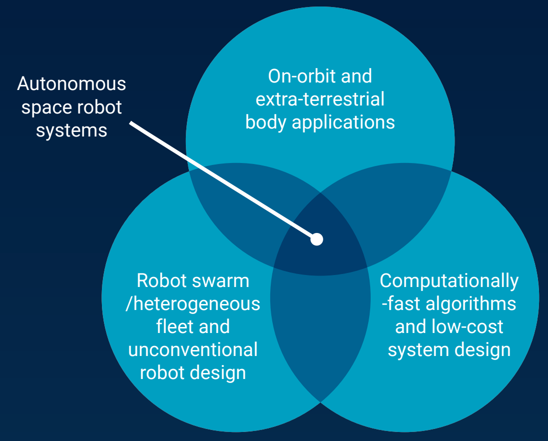
Autonomous systems

The market for unmanned and autonomous vehicles continues to grow, with existing and potential applications posing exciting opportunities for the space industry.

Over the last 30 years, Cranfield has honed a reputation in autonomous systems, with many groups across the University involved in the research, development and engineering of control systems.

Specialisms for airborne and space systems include robot autonomy and Artificial Intelligence (AI), and its application to space robotics (on-orbit and extra-terrestrial bodies). We have expertise in the planning and control of dynamically constrained robots, as well as in developing computationally fast and robust solutions for agile and high-speed mobile robots working in extreme and uncertain environments.



Autonomous space robot systems

Integrated Vehicle Health Management

Cranfield is conducting research into creating a 'conscious aircraft' which is is self-monitoring and has self-learning systems, capable of monitoring health, automatically reconfiguring to optimise performance for airborne and space systems.

Projects include:

- Prognostics health management - a novel approach for adaptive power management considering prognostics health indicators for electrical power generator and distribution systems,
- reliable power electronics for airborne and space systems - power electronics will increasingly be placed in harsher environments for weight and cost savings,
- hardware Trojan detection - developing a design for prognostics and security in field programmable gate arrays. This uses kernel-based machine learning and path-delay based hardware, Trojan detection and ageing methods.

Our facilities include the autonomous vehicles laboratory which is equipped with a netted area for flight tests and a variety of sensors, used for testing guidance, navigation, control and surveillance, with computational capabilities powered by the University's high performance computing facility.

Our researchers are working on developing low-cost autonomous robotic systems for space applications (on-orbit servicing and manufacturing, in-situ resource utilisation, and exploration) using:

- Novel locomotion robots design and autonomy,
- computationally-fast autonomy algorithm design for existing space robots with less resources,
- heterogeneous robot fleet/swarm operation.

Some of our latest innovations include the creation of computationally-fast planning tools for dynamically-constrained mobile robots traversing rugged and obstacle-cluttered environments. The proposed tools are capable of generating thousands of solutions in a fraction of a second on a low-cost embedded computer. Traversability analysis is also being conducted for the use of hopping robots on rugged moon and martial terrains.

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Cybersecurity of space infrastructure

Data is the most valuable asset in the world and has become increasingly significant to the space economy as the number of satellites in orbit increases.

Data collected and shared by satellites in orbit is crucial to the provision of services back on Earth. It is paramount to develop mechanisms to prevent and defend the space infrastructure from cyber threats which can potentially deny, disrupt or deceive satellite data.

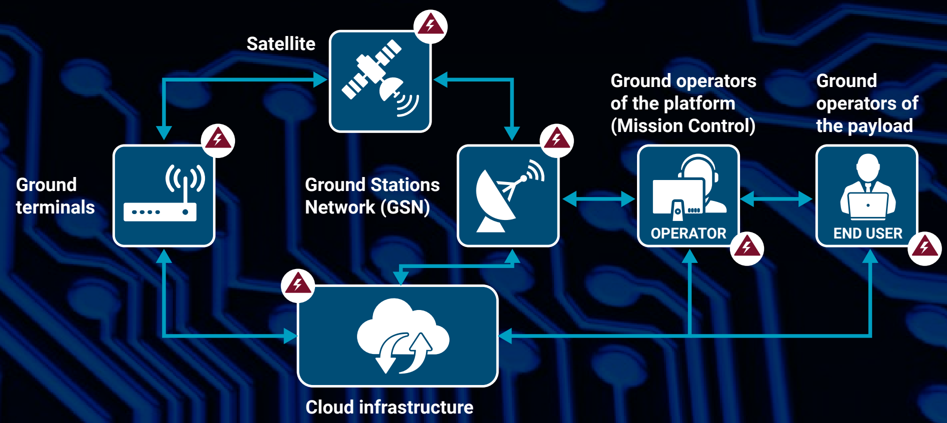
Cranfield is addressing cybersecurity concerns across multiple perspectives, from the policies required to facilitate international cooperation, through to attack detection and system recovery technology.

Policies and international cooperation

Collectively there is a need to foster cooperation between the many international stakeholders involved in the space ecosystem, including the North Atlantic Treaty Organisation (NATO), the European Union and the UK. Cranfield is working to identify and articulate what can be done at an international level to foster greater collaboration, providing a set of recommendations and good practices targeted at improving the cybersecurity of space assets, and reducing the risk associated with cyber threats.

Attack detections and system recovery

Modern-day businesses and organisations rely on the Internet of Things (IoT) to enable millions of intelligent data conversations, helping them track, monitor and manage assets, ensure the safety of their workers, and improve remote operations. As we enter a new era of Satellite IoT, Cranfield academics are conducting a vulnerability analysis study, in order to maintain the confidentiality, integrity and availability of the data being shared among different space systems when this architecture goes online.



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Sensors, systems and weapons integration

Sensors

Electro-optical and infrared laboratories:

- Broadband to hyperspectral,
- ultra violet to infrared,
- 2D, 3D and machine learning algorithms for target classification,
- image-based position, navigation and guidance,
- countermeasure techniques including stealth materials.

Radio frequency (RF) laboratories

- Radar cross-section prediction and measurement,
- doppler and micro-doppler target classification and guidance,
- RF antenna modelling and protyping,
- mmWave Imagin,
- ground-based synthetic aperture radar communications,
- RF/wireless communications and communications electronic warfare research and development.

Weapons integration

We have more than 20 years of experience investigating the flow physics and aeroacoustics of single and tandem aircraft weapons bays, both with and without ordnance. This work has been conducted at varying scales and at representative flight speeds. They have included detailed geometric features, such as leading and trailing edge modifications, doors and palliative devices. Through this experience, we assist with weapons bay design and the mitigation of aeroacoustic phenomena.

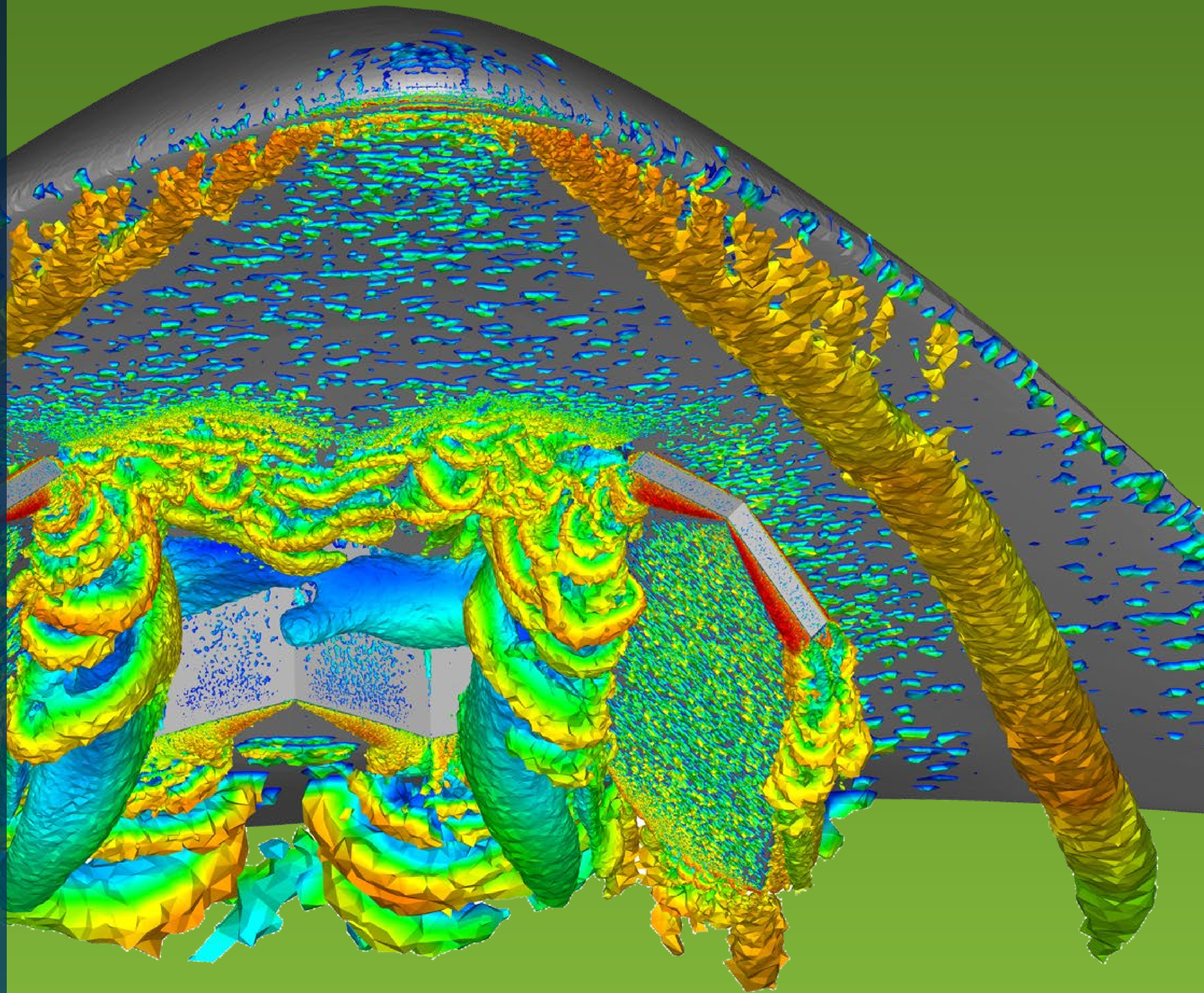
Our experimental facilities include transonic ($0.2<M<0.9$) and supersonic ($1.7<M<2.6$) wind tunnels for weapons bays of up to 300mm in length, with high-speed pressure measurement, particle-image velocimetry (PIV), and surface flow visualisation techniques available. We also have access to Cranfield's high-performance computing facility, using improved delayed detached eddy simulation methods for full aircraft models. Post-processing techniques use Matlab to obtain line integral convolution, fast Fourier transform, spectrogram, and wavelet analysis results.

Manufacture of rocket propellant

Cranfield has the explosive licence to remotely manufacture solid, liquid and hybrid rocket propellant. We carry out compatibility, safety and performance tests on our explosives range at Cranfield Ordnance Test and Evaluation Centre (COTEC) and at our laboratories at Shrivenham. The facilities, which are ISO 9001 accredited, are also used to manufacture gas generating devices using pyrotechnics.

The explosive licence enables us to undertake research into new green tuneable rocket propellant using continuous flow nitration. With the latest resonant acoustic mixer for manufacturing the new propellant compositions, our team of researchers use a purpose-built facility for remote explosive mixing and pressing. This facility also has a fully conducting cell where sensitive pyrotechnics compositions can be manufactured for gas generating devices.

In order to carry out all activities safely, our test house has the capability to undertake energetic materials hazard tests, for example, impact, friction, electrostatic spark, and ignition. The facilities at COTEC can carry out the large-scale insensitive munitions tests, including fragment impact, bonfire tests, slow and fast cook off. Our large bore gas guns are used to determine the effect of high velocity shock loading on the propellant.



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Cranfield Air and Space Propulsion Institute

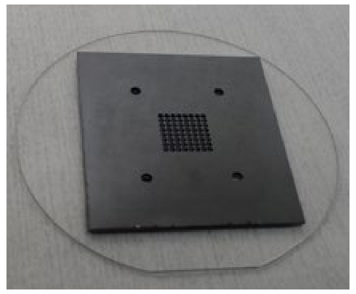
Launched in Spring 2022, Cranfield Air and Space Propulsion Institute (CASPI) sits right at the core of Cranfield's research and technology, providing an interdisciplinary approach to deliver integrated, sustainable air and space technologies for the future.

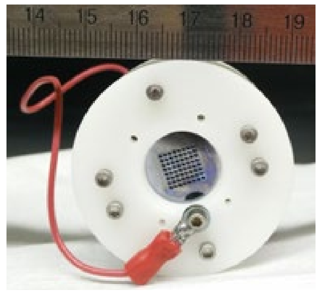
CASPI was set up as a virtual, pan-university institute to help accelerate developments in aerospace towards a more sustainable future. With research that spans a wide range of disciplines and sectors. It seeks to accelerate the inception and development of new, revolutionary technologies for use in a range of air and space applications.

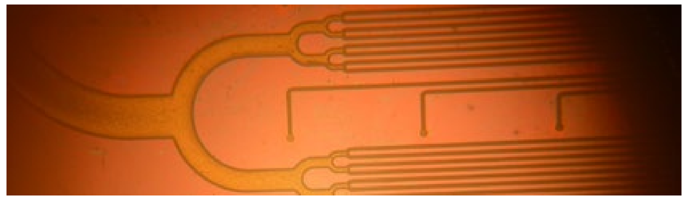
CASPI, in collaboration with its industry and academic partners, seeks to develop new solutions in a number of 'traversal' technology areas, such as sustainable fuels, combustion, materials, controls, electrification, fundamental aerodynamics, thermal management, systems integration, and others. These are expected to have a wide impact across a number of aerospace sectors, with particular focus on space flight, hypersonic sub-orbital flight, supersonic and subsonic flight, and urban air mobility.

Cranfield Ordnance Test and Evaluation Centre

Cranfield Ordnance Test and Evaluation Centre (COTEC) performs independent tests and evaluations on high-power rocket engines, munitions, weapon systems, pyrotechnic and explosive stores, and conducts disposals and demilitarisation. In November 2021 academics involved in CASPI, working closely with industry partner, Pulsar Fusion, facilitated a successful chemical rocket engine propulsion test at COTEC.







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Space propulsion

Cranfield has been at the forefront of space propulsion for many years. Our unique set of capabilities has been developed through long-term collaboration with industry including the Cranfield Rolls-Royce University Technology Centre, Siemens, Hitachi, Samsung, easyJet, NASA, Defence Science and Technology Laboratory (DSTL), Ministry of Defence (MoD), EU Clean Sky, Engineering and Physical Sciences Research Council (EPSRC), Aerospace Technology Institute (ATI), and Innovate UK.

Our research considers performance evaluation, design space assessment and optimisation, component and prototype R&D, mission assessment, powerplant integration, and diagnostics.

High precision space electric propulsion

Spacecraft electric propulsion uses electrostatic or electromagnetic fields to accelerate mass to high speeds, generating thrust to modify the velocity of a spacecraft in orbit. Electric thrusters typically use much less propellant than chemical rockets due to their higher exhaust speed.

Here at Cranfield, research is focused on the fabrication of arrays of electrospray sources for satellite propulsion (colloid thrusters). Electrospray is a highly efficient method to atomise a liquid into a beam of charged particles accelerated by an electrostatic field. If ejected at high speeds from a space electric thruster, the thrust is delivered efficiently in terms of propellant and power consumption, unlike traditional electric thrusters, even at extremely low power levels.

While the natural thrust of a single electrospray source has been too low for any mission, our research has found that this can be overcome by multiplexing the number of sources; combining micro-electromechanical system (MEMS) development, experimentation of the thruster array and physical modelling, to optimise the performance and geometry of the thrusters.

We have successfully developed large arrays of micro-fabricated electrospray sources tested to Technology Readiness Level (TRL) 5. The tested arrays provide accurate and throttleable thrust at low power and with high precision, creating a viable option as the main propulsion engine of SmallSats or attitude and orbit control system (AOCS) where high pointing precision is required. The current goal is to raise the TRL level of the thruster to TRL 8.

Hollow rotating detonation engines

Major UK defence assets rely on combustion in the form of gas turbines, jet engines and rocket engines for propulsion, with the fuel burn being significant operating cost. We are looking at ways to increase the efficiency of these engines by designing, building and testing a modular hollow rotating detonation engine (RDE) technology demonstrator, that will replace existing combusters, reducing current fuel costs and their associated environmental impact. The success of this project would make the UK a world leader in RDE technology.

Space robotics

Space robotics is a key enabling technology for developing a flexible, sustainable, and reusable space infrastructure, reducing the cost associated with operating and maintaining space assets and relieving humans from dangerous tasks.

On-orbit servicing and active debris removal

The ongoing development of on-orbit servicing and active debris removal missions will require performing a wide range of robotic operations, which might involve complex grasping and manipulation tasks as well as high levels of autonomy, reliability, efficiency, and safety during the operations. Cranfield's recent activities and key results in this area include:

- Evaluation of system design concepts and use scenarios for on-orbit servicing of commercial GEO satellites and LEO mega-constellations,
- examination of financial considerations for viability, technology state-of-the-art, and requirements for co-development between servicer and client vehicles,
- development of in-orbit scavenging and recycling concepts for building a sustainable space ecosystem,
- development of control algorithms and autonomous systems performing on-orbit operations using robotic manipulators and other capture technologies,
- development of visual based perception for ground, aerial, and on orbit scene understanding and navigation.

On-orbit manufacturing and assembling

New ambitious mission concepts include the construction of huge structures in space (very large antenna systems, space-based solar power, or new space stations). The deployment of such structures in orbit will require autonomous robotic assembly and manufacturing capabilities.

Cranfield's researchers are active in developing key technology and algorithms for:
- Mission concept exploration for construction, operations, disposal of such large structures,
- robotic technology and algorithms enabling assembly of large space structures, which might involve multiple specialised and autonomous robotic systems,
- dynamics and control of ultra-flexible large space structures.

Robotics for planetary exploration and resource utilisation

Cranfield's main research activities in this area include:
- Locomotion of planetary rovers,
- autonomous navigation for planetary exploration,
- multi-body dynamics and space manipulators for in-situ resource utilisation,
- system design of next-generation Martian aerobots.

Autonomy laboratory

A 200 m² space equipped with:
- motion capture system,
- multiple sensors,
- visible, thermal cameras,
- light detection and ranging,
- aerial and ground vehicles,
- unmanned aerial vehicles,
- four-wheeled robotic platforms.

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Manufacturing capabilities for space applications

Modern industries depend on advanced manufacturing technologies to precisely tailor the surface chemical, physical and mechanical properties of components.

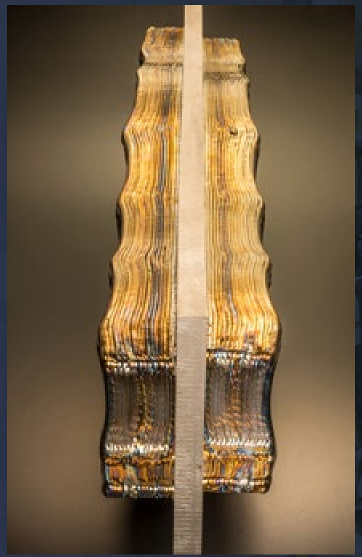
Cranfield's Surface Engineering and Precision Centre has specific expertise in advanced functional materials, thin film deposition, nanotechnology and precision device manufacturing, coatings and surface treatments, and ultra-precision machining and associated metrology. This enables us to progress our research from simple design to full manufacturing process integration.

Research facilities include clean rooms, laboratories and test/fabrication services through to prototype component manufacture, with extensive analysis, modelling, synthesis, and characterisation capability, including:

- Physical vapour deposition, chemical vapour deposition, sol-gel coating and printing,
- specialism in piezoelectric, pyroelectric, thermoelectric, catalytic, radiation detectors and biosensors,
- design, testing and analysis of coating systems,
- surface treatments for components subjected to extreme conditions,
- corrosion, wear and fatigue performance of coatings,
- ultra-precision machining of fine features over large areas,
- extensive materials and geometrical characterisation techniques.

Wire + Arc Additive Manufacturing

Cranfield is developing pioneering hardware and software to enable the industrial implementation of a large-scale printing process known as Wire + Arc Additive Manufacturing (WAAM). WAAM has huge potential to make a reduction in the cost of parts by reducing material wastage and time to market, as well as increasing freedom of design and part complexity, and customisation.



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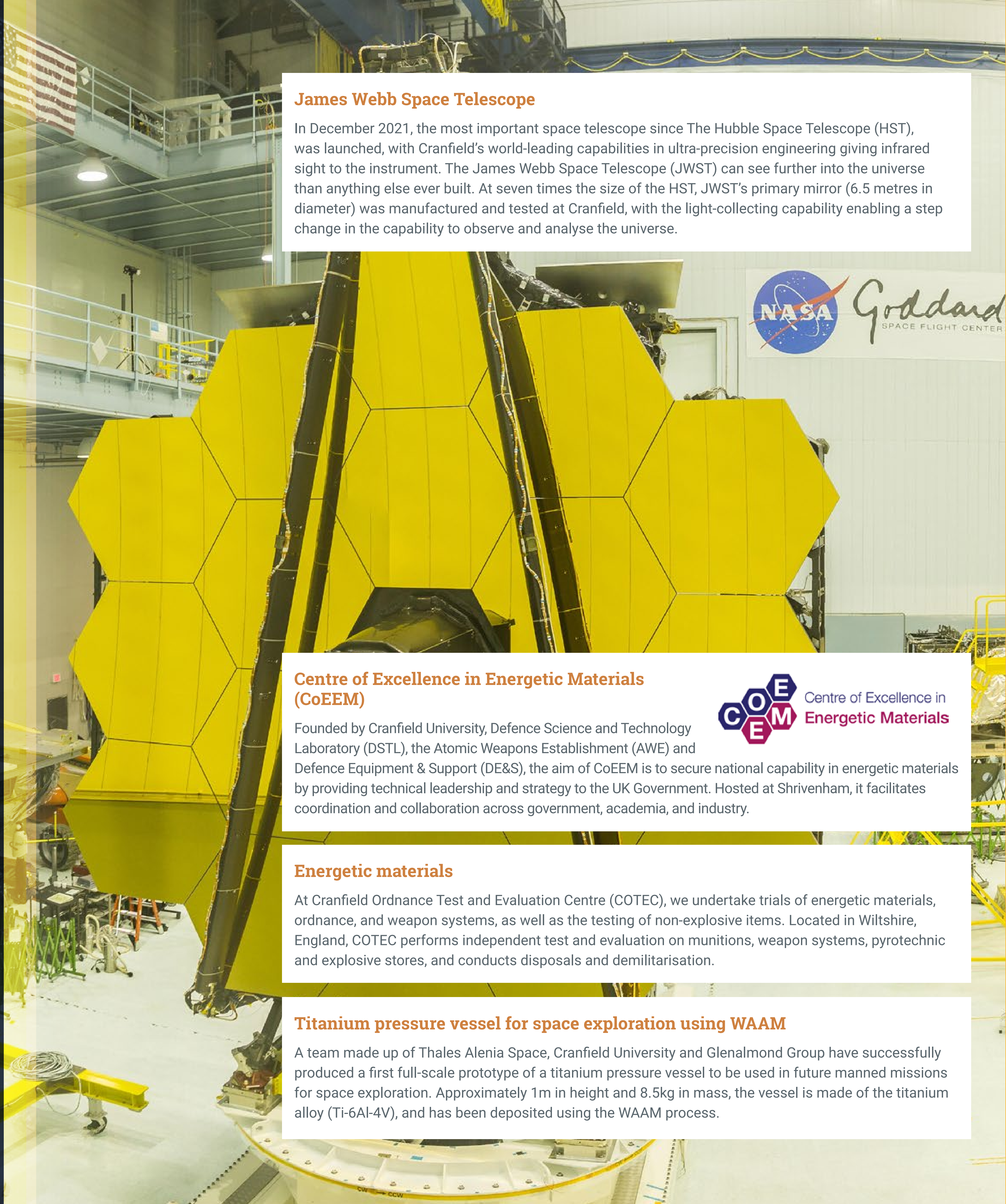

James Webb Space Telescope

In December 2021, the most important space telescope since The Hubble Space Telescope (HST), was launched, with Cranfield's world-leading capabilities in ultra-precision engineering giving infrared sight to the instrument. The James Webb Space Telescope (JWST) can see further into the universe than anything else ever built. At seven times the size of the HST, JWST's primary mirror (6.5 metres in diameter) was manufactured and tested at Cranfield, with the light-collecting capability enabling a step change in the capability to observe and analyse the universe.

Centre of Excellence in Energetic Materials (CoEEM)

Centre of Excellence in Energetic Materials

Founded by Cranfield University, Defence Science and Technology Laboratory (DSTL), the Atomic Weapons Establishment (AWE) and Defence Equipment & Support (DE&S), the aim of CoEEM is to secure national capability in energetic materials by providing technical leadership and strategy to the UK Government. Hosted at Shrivenham, it facilitates coordination and collaboration across government, academia, and industry.

Energetic materials

At Cranfield Ordnance Test and Evaluation Centre (COTEC), we undertake trials of energetic materials, ordnance, and weapon systems, as well as the testing of non-explosive items. Located in Wiltshire, England, COTEC performs independent test and evaluation on munitions, weapon systems, pyrotechnic and explosive stores, and conducts disposals and demilitarisation.

Titanium pressure vessel for space exploration using WAAM

A team made up of Thales Alenia Space, Cranfield University and Glenalmond Group have successfully produced a first full-scale prototype of a titanium pressure vessel to be used in future manned missions for space exploration. Approximately 1m in height and 8.5kg in mass, the vessel is made of the titanium alloy (Ti-6Al-4V), and has been deposited using the WAAM process.

Human-machine intelligence

As society becomes increasingly inter-connected, human and machine intelligence is more closely related than ever. With networked society facing serious challenges from the human and natural world, our research is centred on connected intelligence systems, comprised machine learning, communication networks, and engineering.

Working in socio-cyber-physical ecosystems, we look at how artificial intelligence (AI) and informatics can be designed for specific challenging environments or tasks, while integrating human domain knowledge. This extends to human-machine intelligence transfer and mutual understanding, social and geo informatics, and securing autonomous assets against multi-vector cyber and human attacks.

Current research focus areas, primarily funded at low TRL (1-3), include:

- **Cybersecurity and Autonomy** - trustworthy and secure autonomy; understanding the cyber and human adversarial risk posed to new forms of AI used in transport; and communication networks, including human-machine teamworking. These are supported by multiple Engineering and Physical Sciences Research Council and defence projects.
- **Sustainability** - creating sustainable autonomy; and green AI for sustainability (supported by the EU's Horizon 2020 project), focused on understanding the techniques required to make AI sustainable, especially to reduce the global carbon footprint and enabling edge operations.
- **Data Intelligence** - graph signal analysis to exploit spatial patterns - modelling complex patterns as graph signals to predict global events, such as geomagnetic storms or the spread of contamination in water systems.

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Communications

In this interconnected world, telecommunication technologies represent a strategic asset. At Cranfield we are investigating the some of the world's most significant communications networks of the future.

Internet of things network

The integration of multidimensional networks such as space, air and ground are the future trend of the internet of things (IoT). At Cranfield, we have introduced the space-air-to-ground IoT network paradigm, including its composition and network architecture. Satellite-terrestrial networks (STN) use the spacious coverage and low transmission latency of the low earth orbit constellation to transfer requested content for subscribers, especially in remote areas.

With the development of storage and computing capacity of satellite onboard equipment, it was initially considered possible to leverage in-network caching technology on satellite-terrestrial networks to improve content distribution efficiency. However, traditional caching and distribution schemes are not suitable in STN, when considering the dynamic satellite propagation links and time-varying topology, with uneven user distribution lowering the quality of experience.

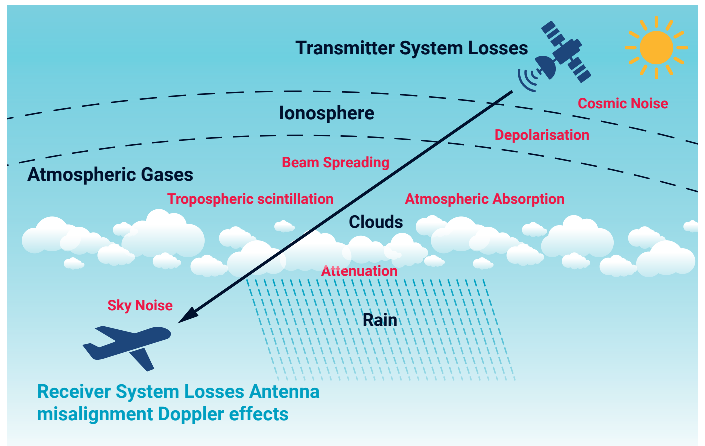
To address these challenges, Cranfield researchers proposed a density-based IoT network division algorithm, with the STN divided into a series of blocks with different sizes to amortise the data delivery costs. We analysed the link connectivity and proposed an approximate minimum coverage vertex set algorithm in order to deploy the caching satellites. Simulation results demonstrated that the proposed user-oriented STN content distribution scheme can reduce the average propagation delay and network load under different network conditions, offering greater stability and self-adaptability under continuous time variation.

5G-Satellite

Connecting people and machines to everything, everywhere and at all times through 5G networks is set to transform society. People need to be able to access information and services developed to meet their immediate needs and effectively contribute to the digital economy. In order for this to happen seamlessly, we need to utilise both satellite and terrestrial networks. With an increasing dependence on digital systems to support commerce, infrastructure management, and community services such as healthcare, there is a widening digital divide between urban and rural communities. To combat this, Cranfield is exploring the use of Beyond Visual Line-of-Sight (BVLOS) operation of drones, currently used for commercial purposes, for wider economic, societal, and environmental benefits.

Air-space networks

Cranfield researchers worked with Inmarsat, the world leader in global, mobile satellite communications, on the benefits of using satellites for air-space networks. The main target of the research was to provide an initial assessment and review of communication and data link analysis relating to the C-130, GX-5 satellite link, providing a high-fidelity link budget assessment and focusing on path propagation between the Inmarsat GX constellation and commercial aircraft.



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