University of
Southern
Queensland

Space and Defence Research

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Research at the University of Southern Queensland

The University of Southern Queensland is a dynamic, regional University that has established its position as a prominent teaching and research institution, providing education worldwide from three physical locations across South East Queensland (Toowoomba, Springfield, and Ipswich) with an extensive online presence. The University's mission is to drive economic and social development through higher education and research excellence.

University researchers are working directly with local communities, industry, and our international partners to form strong and enduring research partnerships that deliver tangible benefits and real impact. The University's world-class research institutes, centres and faculties are home to unique state-of-the-art facilities enabling our researchers to deliver a broad range of research outcomes across multiple disciplines.

The University's Flagship Research Areas

- Agriculture, including Climate Science, Drought Mitigation and Adaptation, Crop Health, Agricultural Technology and Environmental Science.
- Space and Defence, including Astrophysics, Hypersonics and Rocketry, and Materials Engineering.
- Regional Development, including Agribusiness, Economic Development and Cultural Heritage.
- Health, including Sport and Exercise Science, Mental Health and Allied Health.

Research Excellence

The global reach and world-class quality of the University's research is confirmed by International Rankings and the Australian Research Council's Excellence in Research for Australia (ERA) Report. In the 2018 ERA Report, the University's research was rated as 'world standard or better' in 30 areas of research and 18 fields of research were rated as 'well above world standard'.

The following 18 fields of research received the ultimate accolade of 'well above world standard'

Astronomical and Space Sciences

Materials Engineering

Mechanical Engineering

Numerical and Computational Mathematics

Environmental Science and Management

Agriculture, Land and Farm Management

Crop and Pasture Production

Physical Sciences

Medical and Health Sciences

Human Movement and Sports Science

Clinical Sciences

Psychology

Nutrition and Dietetics

Public Health and Health Services

Chemical Sciences

Inorganic Chemistry

Macromolecular and Materials Chemistry

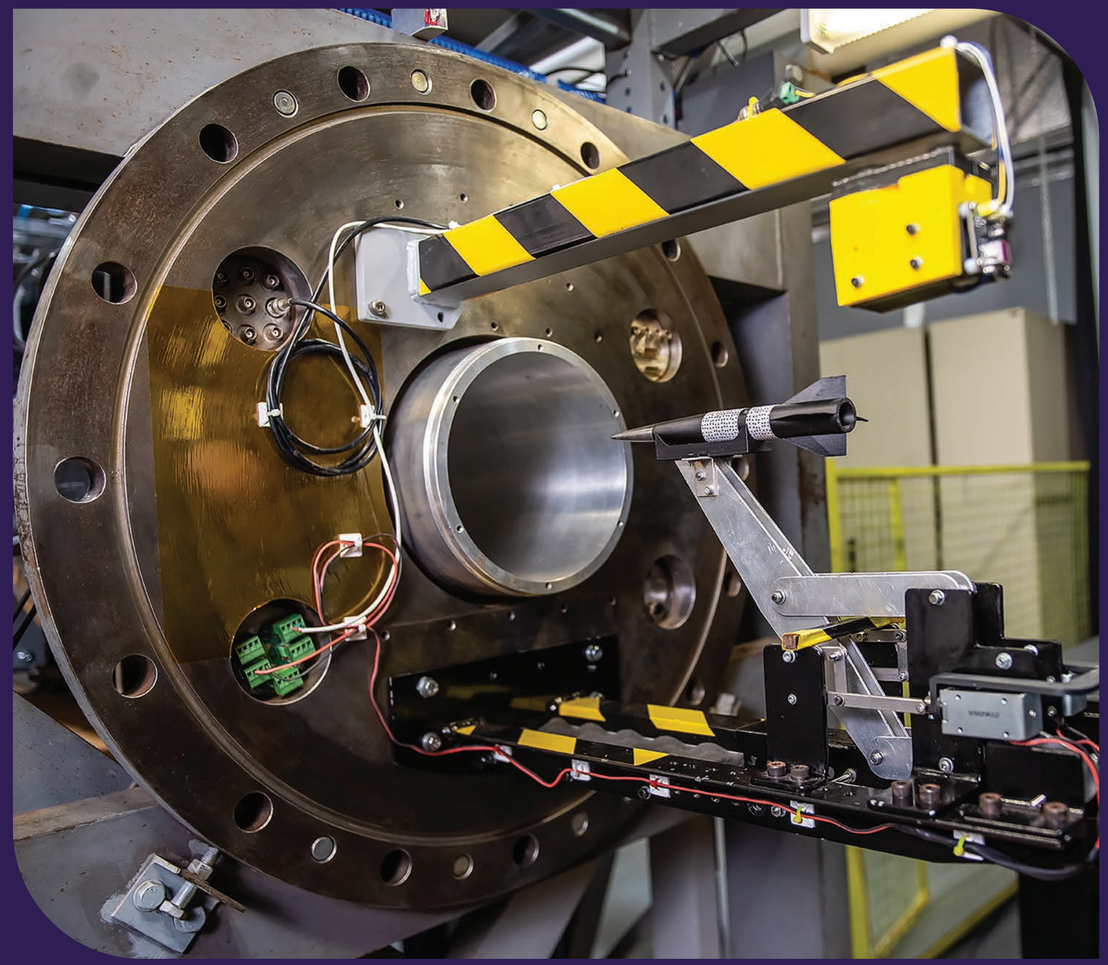
Microbiology

In the Times Higher Education World Rankings, the University of Southern Queensland is ranked in the 301 - 350 band and is in the 151 - 175 band for Engineering.

In the Times Higher Education Young University Rankings, the University of Southern Queensland is ranked 86 in the world.

The University of Southern Queensland's Space and Defence Research Portfolio

The hypersonic wind tunnel facility at the University of Southern Queensland 'TUSQ' is used in a wide variety of national and international research projects investigating aerodynamics and heat transfer on aerospace vehicles.



Space and Defence Research

The University's Institute for Advanced Engineering and Space Sciences is focused on delivering space and defence related research, with strengths in developing hypersonic propulsion systems, advanced materials, and astrophysics. The Institute is home to world-class infrastructure and equipment, including the Mount Kent Astronomical Observatory, a long duration hypersonic wind tunnel and a rocket laboratory, as well as one of Australia's largest dedicated composite materials manufacturing and testing facilities.

The University's global partnerships with NASA, the US Airforce, Boeing and BAE Systems are helping build commercial pathways and deliver impact in our communities. We are working to ensure our graduates and researchers with space capabilities are attaining high-growth, knowledge-rich jobs in the space sector.

Our unique geographical location supports our space research programs and industry interactions. The University's Toowoomba campus is the ideal home for ground-based observations and the strategic location of our rocket laboratory, and wind tunnel. All three University campuses are in close proximity to the strong defence presence in the Ipswich region, enabling the University to leverage its space expertise to boost Australia's sovereign defence capability.

The University's Mount Kent Astronomical Observatory is Queensland's only professional research and teaching observatory for astronomical and space sciences.

Astronomical and Space Sciences Research

Research at the Centre for Astrophysics is advancing our understanding of the shared evolution of stars and their planetary systems, and the implications for planetary habitability. Through the Centre for Astrophysics, the University operates the Mount Kent Astronomical Observatory, Queensland's only professional research and teaching observatory in astronomical and space sciences.

Research Capabilities

- Stellar Astrophysics: Studying stellar activity by imaging stars and their magnetic fields using spectra observed in polarised light to understand the magnetic activity of stars and the Sun over time to provide insights into how 'space weather' might impact orbiting planets.
- Exoplanetary Science: The discovery, monitoring, characterisation and modelling of exoplanets orbiting stars other than the Sun.
- Computational Astrophysics: Modelling of the orbital dynamics of planetary systems, using the University's High-Performance Computing Cluster.
- Astronomical Instrumentation: Collaborating on major national and international stellar surveys, instrument development, space debris and meteor tracking, space telescope missions and on space industry applications of astronomy.

The Centre for Astrophysics' research was independently given the highest accolade - 'well above world standard' by the Australian Research Council's 2018 ERA assessment rating.

Infrastructure and Key Projects

MINERVA-Australis

Mount Kent Astronomical Observatory is the only facility in the Southern Hemisphere providing a key support role for NASA's Transiting Exoplanet Survey Satellite (TESS) mission, which is using transit photometry to detect Earth-like exoplanets near our Solar system. The University has established MINERVA-Australis; an innovative array of 0.7m CDK700 telescopes that can observe multiple targets at once, providing TESS with the ground-based follow-up radial velocity spectroscopy required to confirm and characterise these worlds. MINERVA-Australis is therefore a vital piece of the puzzle – without it many of the planets TESS finds would remain unconfirmed and uncharacterised. The facility has already played a pivotal role in the universal hunt, assisting in the discovery of hundreds of new planets orbiting distant stars.

SMARTNet

Mount Kent Astronomical Observatory hosts the Australian space debris optical tracking station of the DLR German Aerospace Centre Small Aperture Robotic Telescope network (SMARTNet) program. Space debris is a significant 'space situational awareness' problem for the industry. SMARTNeT monitors the geostationary ring of debris in low Earth orbit and requires a network of stations to monitor all the longitudes of the night sky.

Shared Skies Partnership

The Shared Skies Partnership is a longstanding live remote observing partnership between the University of Southern Queensland and the University of Louisville (Kentucky, USA). With Mount Kent Astronomical Observatory covering the Southern Hemisphere with three eastern longitude telescopes, and the Northern Hemisphere watched over by telescopes in Arizona and Kentucky, all of the night sky is visible though the project.

The telescopes are primarily used for the NASA TESS mission, and support student research, training, education, and outreach.

The SMARTNet program at Mount Kent Astronomical Observatory will continue for at least the next decade, with University researchers working remotely with scientists from the DLR German Aerospace Centre to maintain operations.

Leading Australia in a Universal Quest

Of the thousands of planetary systems discovered to date, our Solar System is exceptional. The Solar System hosts a diverse set of planets ranging from gas giants to rocky celestial bodies. Only a small handful of the thousands of other exoplanetary systems are known to host similar sets of planets. University Research Fellow Dr Chelsea Huang has received a Discovery Early Career Research Award from the Australian Research Council for her research, which is advancing our understanding of the formation of the Solar System by exploring the characteristics of different types of planetary systems.

Dr Huang's project makes use of cutting-edge technologies and images of the sky from the TESS Space Telescope, providing access to an array of interesting planetary candidates that is giving the project an Australian advantage amongst this global effort.

SONG

Mount Kent Astronomical Observatory hosts the Australian node of the global Stellar Observations Network Group (SONG) telescope network, an Australian collaboration with Danish astronomers. SONG observations enable seismology of stellar interiors, complementing the work of MINERVA-Australis to deliver new knowledge of the physics and evolution of stars and their exoplanets.

Dr Chelsea Huang is exploring the uniqueness of our Solar System using the world-class facilities at the University's Mount Kent Astronomical Observatory.

Space Agriculture

Researchers from the Centre for Agricultural Engineering are working with NASA to extend fresh food options for astronauts during space missions by developing launch-ready software that will use machine vision to detect early stress in plants being grown on board space flights. Robotic vision systems requiring minimal or no crew interaction will monitor plants for signs of stress and will ultimately provide increased food safety and nutrition options. This work transfers the University's existing expertise in the development of new machine algorithms for plant monitoring in broadacre cropping environments and at remote farm locations to space.

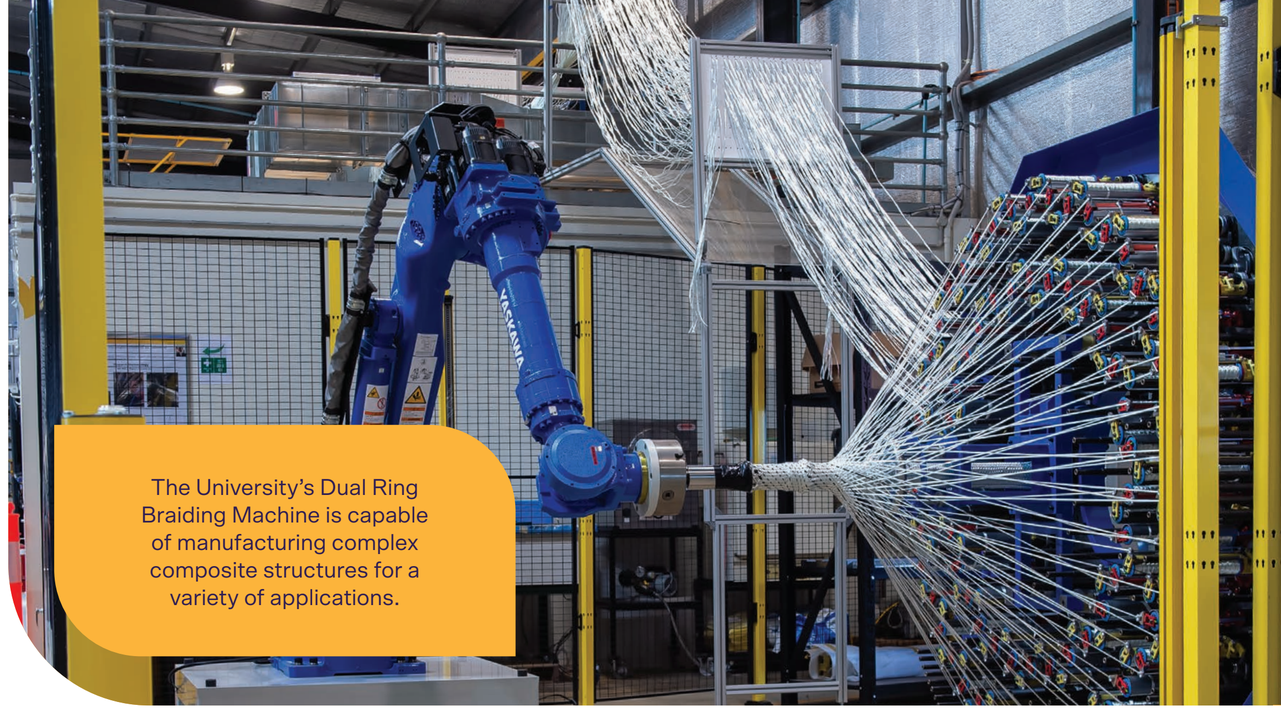
Advanced Composites Manufacturing Research

The Centre for Future Materials' Advanced Composites Manufacturing Research Team provide novel design, manufacture and testing for aerospace, space, and defence industries. Expertise in liquid moulding technologies, automated fibre placement, pultrusion and filament winding capabilities with advanced process modelling tools provide a unique opportunity to develop structures that are lightweight, repeatable and financially sustainable. The University provides partners such as Defence Science and Technology (Australia), the US Airforce, US Navy, Boeing and BAE Systems with one of Australia's largest dedicated composite materials, manufacturing and testing capability services.

Research Capabilities

- **Advanced Composites Manufacturing** including industry scale automated manufacturing cells such as filament winding, braiding and pultrusion; testing of fibre reinforcement permeability; composites repair to enhance the reliability of aerospace grade structures; and high-production rate resin infusion processing for the aerospace, space and defence sectors.
- **Functional Materials** including investigating thermoelectric nanostructures as a 'green' and sustainable energy alternative; shape memory composites for smart engineering structural applications; and composites sensing and prediction.
- **Civil Composites** with a focus on internal reinforcement to concrete structures; composite railway sleepers and transoms; composite jackets for bridge pillar structural repairs; and improving structural performance of reinforced composite slabs with pultruded hollow composite bars.
- **Geopolymers and Concrete** including the development of fire-resistant, high-temperature geopolymer from waste streams such as fly ash; and the development of commercially viable, stable and highly durable geopolymer products.
- **Manufacture of rocket casings and fuel tanks**, and associated components via filament winding. Lightweighting of liquid hydrogen fuel tanks and components by robotic filament winding process.
- **Waste and Materials sustainable systems design and processing** for the development of future manufacturing and product development. Applicable to a range of industries including construction, food, energy and advanced materials.

The Centre for Future Materials operates a dedicated industry testing service specialising in materials characterisation, polymer analysis, mechanical testing and large-scale structural testing.



The University's Dual Ring Braiding Machine is capable of manufacturing complex composite structures for a variety of applications.

Infrastructure

- **Filament winding facility:** Australia's most advanced 8-axis filament winder to support pressure tank research and ultra-high temperature oxide processing.
- **Dual layer robotic braiding facility:** Capable of manufacturing high performance complex tubular composite structures for defence and space applications.
- **Resin infusion composite manufacturing:** Aerospace grade composite manufacturing and characterisation equipment for processing certified aerospace composite materials.
- **Process and in-service sensing systems** including the only system in the world for 16,000 node pressure sensor mats for monitoring pressure evolution in vacuum and autoclave processing (0 to 12 bar). A Dielectric Analysis to monitor internal laminate cure progression and a full field digital image correlation strain mapping system.
- **Fire/thermal performance** including a full fire testing and analysis suite with a blast furnace which reaches 3500° to simulate harsh rocket exhaust environments.
- **Ultra-high temperature Ceramic Matrix Composite (CMC):** Developing Australian sovereign capability in manufacturing low- cost oxide ceramic composite components, for aerospace, defence and space industries.

Resin infusion delivers manufacturing efficiencies through reduced time and labour and will provide an economic advantage to the 40,000 aircraft that are expected to be manufactured in the next 20 years.

Research Projects

Next Generation Composites Repair

Researchers from the Centre for Future Materials have partnered with the Defence Science and Technology Group's Aerospace Division to develop next generation out-of-autoclave repairs for composite aircraft structures. Traditional repair processes involve removing the damaged part of the aircraft to conduct repairs using an autoclave. University researchers have developed an automated method of controlling the curing process that enables repairs to be performed on the aircraft. This novel approach will reduce the cost of undertaking repairs and will minimise the time required to ground aircraft, enabling modern defence forces to meet the critical requirement of being able to deploy and operate aircraft for extended periods.

Faster cycle time in composite aerostructure manufacturing

University researchers are working with Boeing Aerostructures Australia to design advanced composite aerostructure components for commercial aircraft. This project is investigating the use of resin infusion processes to accelerate the production of trailing edge structures that contribute to the aerodynamic functions of aircraft. Resin infusion does not require an autoclave and can instead be cured in ovens to produce high-strength composite components with the intricate geometrics required in aerospace applications.

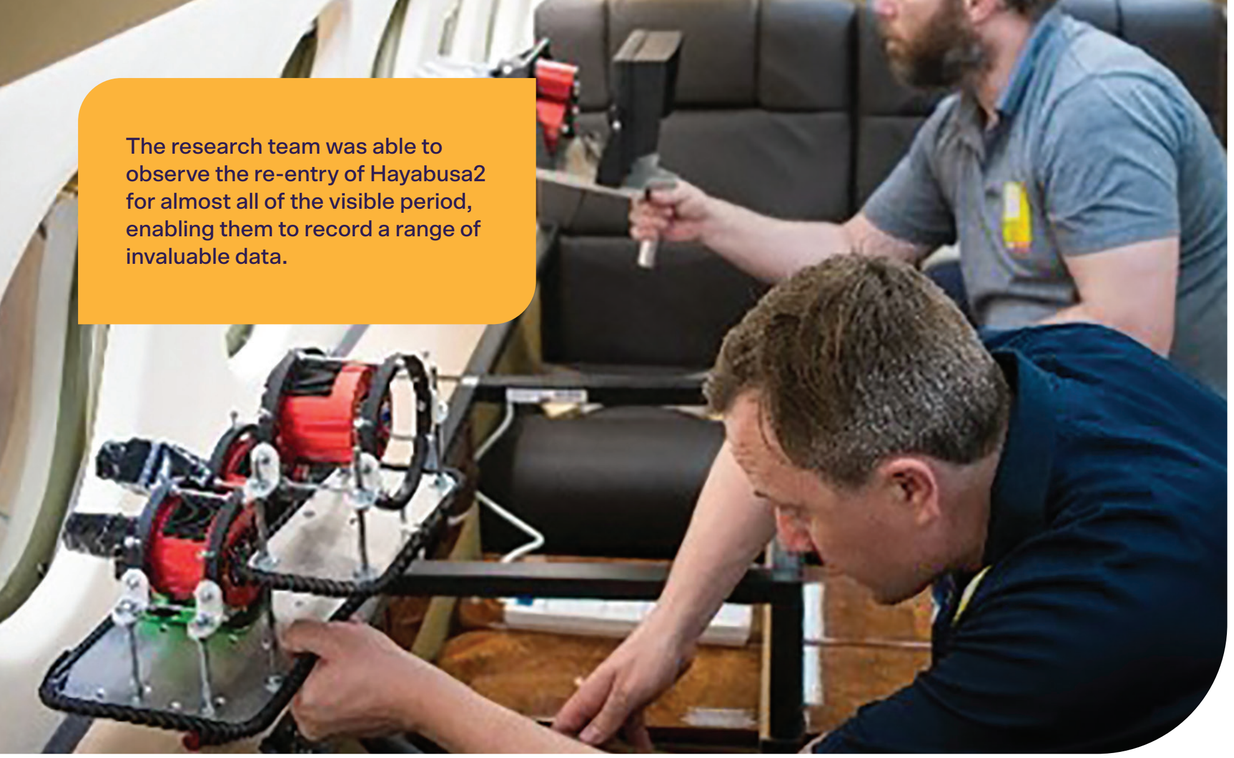
Hypersonics and Rocketry Research

The Institute for Advanced Engineering and Space Sciences' Hypersonics and Rocketry Research Program Team conducts research for the defence and aerospace industries through domestic and international collaborations in the United Kingdom, Europe, the USA and Australia.

Research Capabilities and Infrastructure

- **The longest duration hypersonic wind tunnel in Australia**, enabling hypersonic aerodynamics, free-flight, proximal body separation, heat transfer, control, and fluid-structure interaction experiments that cannot be performed elsewhere. Experimental work in this facility is supported through a wide range of state-of-the-art high speed flow visualisation techniques and instrumentation methods.
- **Solid rocket fuel laboratory** for mixing and curing of rocket propellant.
- **Engines Laboratory** to enable testing of liquid- and gas-fuelled engines. Opportunities currently exist to extend the testing capabilities to include hybrid rocket fuels, grain regression testing and optimisation.

The University's hypersonic wind tunnel enables researchers to design and test hypersonic vehicles under dynamic conditions.



The research team was able to observe the re-entry of Hayabusa2 for almost all of the visible period, enabling them to record a range of invaluable data.

Hayabusa2: Airborne Re-entry Observations

In December 2020, a team of Australian researchers, led by the University of Southern Queensland, with contributions from the University of Queensland, partnered with Rocket Technologies International to complete a privately funded Airborne Observation of the hypervelocity re-entry of the Hayabusa2 capsule. This was the first ever non-NASA airborne observation of a re-entry object and was the first step toward developing sovereign capability in Australia to gather real data of atmospheric re-entries.

Eleven visible/near-infrared spectral instruments, one video and one infrared camera were flown on the mission, which departed from the Brisbane-Wellcamp Airport near Toowoomba, Queensland, flying down to the Strezlecki desert before beginning a straight run heading N-NW (bearing 344 degrees) for the re-entry observation.

The Hayabusa2 return capsule re-entered the Earth's atmosphere at 1728UTC over the South Australian desert. The Hayabusa2 re-entry provided a new, rare opportunity to collect data on the aerothermochemistry of a high-speed capsule travelling at approximately 12km per second when entering the atmosphere.

Instruments from every observation station on the plane tracked the capsule and recorded data during the re-entry. Initial analysis of the data demonstrated acquisition of plasma emissions from the shock layer (nitrogen and oxygen lines were identified) superimposed on the black body radiation from the capsule.

Static Rocket Test Site

Access to a sandstone quarry in Helidon is allowing researchers to test rockets that are secured to the ground in a controlled environment. The facility is the only one of its kind in Australia outside of the Defence Forces and will build capacity to develop the space industry and support rocket manufacturing companies to advance technologies and sovereign capability. Testing at the site enables the delivery of both research and commercial testing services. Over 100 commercial rocket tests have been deployed on this site to date.

Comet Chasers Capture Meteor Storm

In late 2022, Earth entered a stream of cometary debris after the fragmentation event of the 73P/Schwassman-Wachman 3 comet, which occurred 27 years prior in 1995. Researchers from the University of Southern Queensland partnered with Rock Trade Industries International to lead a team of international scientists on an airborne mission to observe debris from the disintegrating comet. The team developed and applied a range of scientific systems to image the meteor shower during a three-hour flight at 40,000ft.

The airborne mission complemented ground-based observation teams, capturing images clear of atmospheric pollution. The team captured hundreds of objects piercing the atmosphere at speeds greater than 12km per second. The data collected will provide a new understanding of the composition, physical properties and flight trajectories of cometary objects.

The success of the mission demonstrated the sovereign capability of Australia to lead and deliver internationally significant research projects.

Supersonic Rocket Development

Researchers from the Hypersonics and Rocketry Group are taking supersonic propulsion in a new direction by developing new airbreathing propulsion engines which can operate at speeds much greater than the speed of sound.

An airbreathing rotating detonation engine is considered the next logical step for high-speed flight, but questions remain about how to effectively couple an airbreathing inlet to detonation combustion and achieve improved engine efficiency.

This work expands on Australia's position as a world leader in airbreathing hypersonics and complements the current expansion of the national aerospace industry. This project is funded by the Australian Research Council's Discovery Early Career Researcher Awards.

Research conducted by the University of Southern Queensland into the development and testing of rockets is essential to building Australia's sovereign space industry.

Space and Defence Research

University of Southern Queensland

Contact

Professor Allan Manalo

Executive Director

Institute for Advanced Engineering and Space Sciences

Allan.Manalo@unisq.edu.au

+61 7 4631 2547

Dr Gudrun Seynsche

Director (Research Partnerships)

Deputy Vice-Chancellor's Office (Research and Innovation)

Gudrun.Seynsche@unisq.edu.au

+61 7 3470 4419

unisq.edu.au/research

CRICOS: QLD 00244B, NSW 02225M | TEQSA: PRV12081