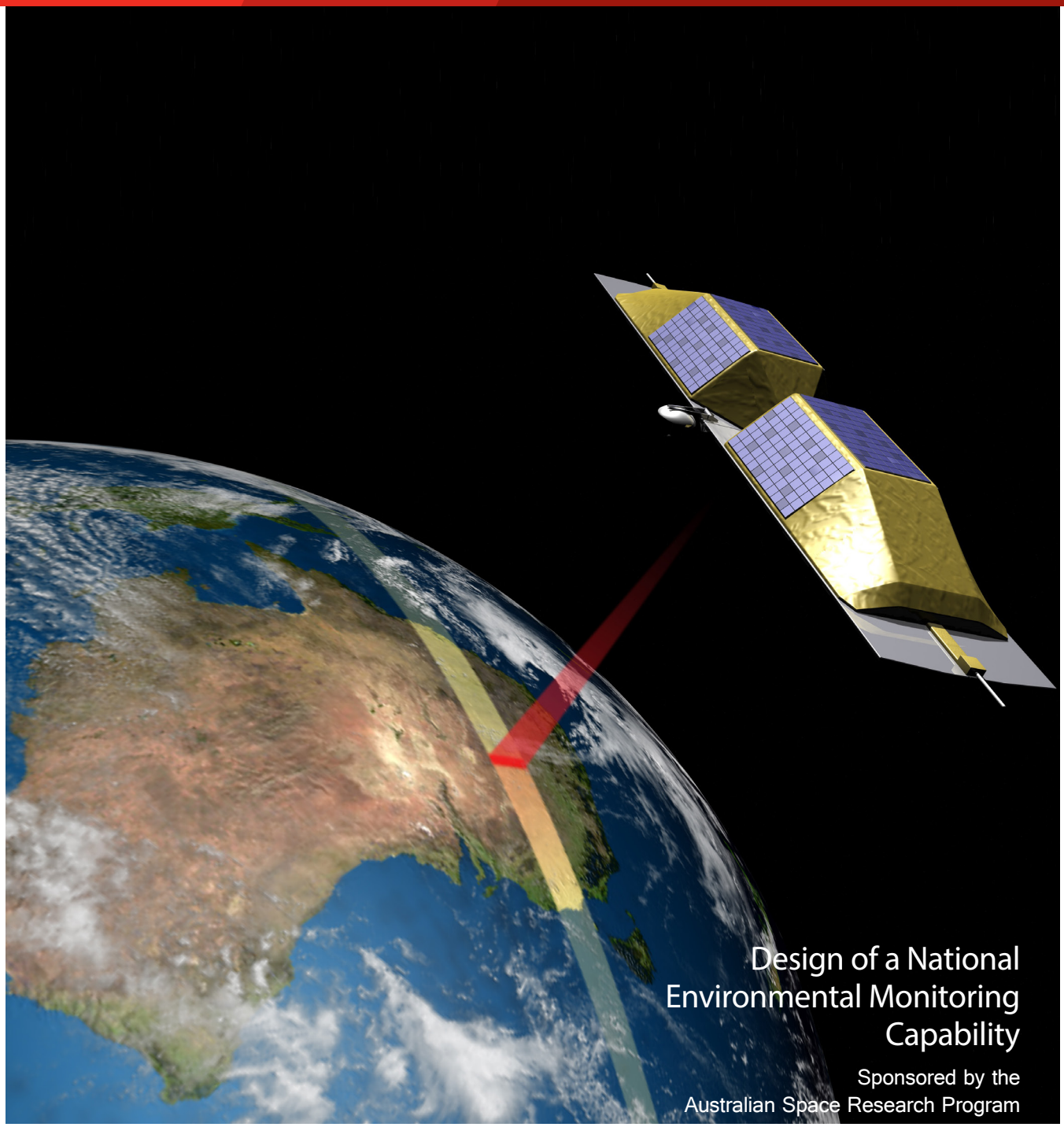
April 2013

UNSW AUSTRALIA

Finding Australia's Invisible Resource

Never Stand Still | Faculty of Engineering | Australian Centre for Space Engineering Research (ACSER)



Design of a National Environmental Monitoring Capability

Sponsored by the Australian Space Research Program

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Better Understanding our Continent

What value can be placed on information about Australia's environment? What is the value of information about climate change? About our natural resources?

The story of Australia is a story of resilient people and abundant resources, including farmlands, natural wonders and iconic sites. All these resources are under complex and increasing pressures. Changing climate, increased demand, growing population, and economic competition are stressing our land, our farms, and our flora and fauna.

At the nexus of these challenges is a single fundamental resource: fresh water. It is increasingly in demand for human use and agriculture. Our wetlands have an undiminished need for water to maintain their vitality. The distribution of water in Australia is changing: rains come more in summer, less in winter. As climate changes, the amount and distribution of available water will change. No one yet knows how.

Our team at the University of New South Wales has been developing a way of measuring Australia's water. It will produce far more data, faster and more reliably, than any other method. The measurements will be made from space—providing priceless information to Australian dryland farmers, irrigators, ecologists, meteorologists, climatologists, land use planners, graziers, naturalists and policy makers. Better water-influenced decisions will be possible, and long-term trends detected earlier.

Storing carbon is one of the most effective means of responding to climate change—removing it from the atmosphere in a stable way. One of the best places to store carbon is in the root zone of forests. The system we have designed will accurately measure the growth of forests, and help monitor the effectiveness of carbon storage schemes.

Please continue reading as we discuss the water-centric climate challenges Australia faces, and how our team's research has found a new approach to understanding and reacting to these challenges.

PROFESSOR ANDREW DEMPSTER
Director, Australian Centre for Space Engineering Research

Water in Australia's soil – the invisible resource

Australia's water assets include lakes, rivers, streams, reservoirs, and the underground water table. But there is more: additional water is found in the soils, right at the surface. This is a highly significant resource – ***there is as much water in the uppermost layer of Australia's soils as in all our lakes, rivers and reservoirs***. It is also the most crucial to plant life – this is the water that plants actually consume.

In addition to the obvious importance to irrigated farming, moisture in the soil has many other far-reaching impacts.

- Soil moisture drives the **weather**. High moisture in soil heated by the sun increases the chance of cloud formation.
- It is a critical factor in determining **wind erosion**, the source of the huge dust storms that plague Australia. Advance warning of dust storm conditions will help protect people with respiratory conditions. Knowledge of soil moisture can improve the success of ground cover planting programs for dust mitigation.
- Soil moisture is critical for minimising **water erosion** of soils, by watering the plants that stabilise the soils against erosion.
- Soil moisture is a key to effective **land use planning**. Long term changes to soil moisture can force unwanted change; awareness of soil moisture trends can allow for orderly transitions and protect livelihoods. Today, most land use planning maps are static and outdated; real-time knowledge of soil moisture can make advice more responsive.
- Soil moisture is the key to the health of Australia's **unique ecologies,** including our wetlands, forests and iconic sites. The effectiveness of water diversion for ecological health and restoration is highly dependent upon the existing soil moisture levels.
- It is critical for **broad acre farming and grazing**. Soil moisture determines, for instance, how long a grazier may use a particular paddock before having to move stock.

Where is Australia's water?

All across the continent, we measure how much rain falls on Australian soils. But where does it go? How much remains in the soils? How will it affect our weather?

The importance of accounting for Australia's water is embodied in the National Water Account, being assembled by the Bureau of Meteorology. This effort grew from the National Water Initiative of 2004, which has these important stated objectives:

- Increase the productivity and efficiency of water use
- Service rural and urban communities
- Return all systems to environmentally sustainable levels of extraction
- Provide greater certainty for investment and the environment
- Underpin the capacity of Australia's water management regimes to deal with change responsively and fairly

One of the key criteria for including a water asset in the National Water Account is that "the item's volume can be quantified with representational faithfulness."

That is very difficult to do for soil moisture.

But it is an asset we must understand. In just the top 10 centimetres is as much water as in all of Australia's lakes, rivers and reservoirs. This "moisture bank" is so important that the CSIRO has initiated the Australian Water Availability Project. Its aim is "to monitor the state and trend of the terrestrial water balance of the Australian continent, using model-data fusion methods to combine both measurements and modelling."

Developing a real-time, nationwide system to measure soil moisture will improve weather forecasting, agriculture, and natural resource management.

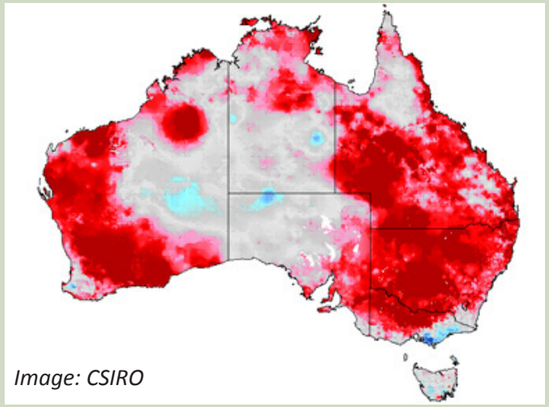
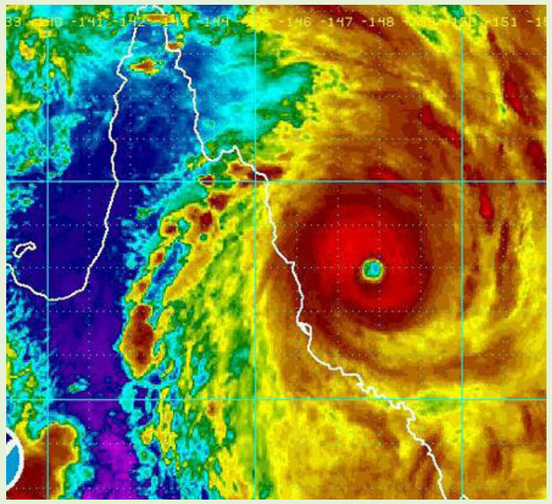


Image: CSIRO

A Weather Satellite for the Soil

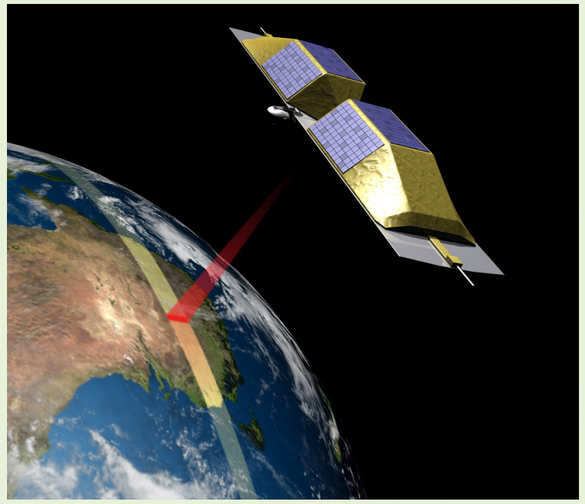


Weather pictures from space are so common today that we can all recognise them: tropical cyclones; bands of clouds sweeping across the country. Meteorologists rely on these images to make forecasts, and we see them on the TV news every night.

Weather is all about the atmosphere – winds, clouds, temperature, pressure and humidity. But the soils have a kind of "weather" too – the amount of moisture they hold.

Like the weather, soil moisture data ***must be measured from space***: Australia is so large, it would be impossible to cover even a small fraction using aircraft and sensors on the ground. Satellites circle the earth at a speed of ***seven kilometres a second***. With this capability, Australia could measure the moisture in all of our 7.6 million square kilometres every week. With two satellites, we can monitor especially sensitive areas, such as the Murray-Darling Basin, every three days.

As a project under the Australian Space Research Program, managed by the government's Space Policy Unit, our UNSW-led team has designed the same kind of always-available, easy-to-understand system for measuring water in Australia's soils as we have today for the weather. The result is the Garada satellite system.



With this satellite in operation, the people who need to understand soil moisture—natural resource managers, farmers, graziers, land use planners, dust condition monitors, ecologists, geoscientists, meteorologists—will be able to read the information just as easily as if it was a satellite picture on TV.

The satellite will sweep the soil with a radar beam, measuring fine details. This radar beam will scan a swath ***three hundred kilometres wide*** to determine: how the moisture has changed, how much of the last rainfall was absorbed, how the edges of wetlands have expanded or shrunk, how newly planted ground cover has improved moisture retention, where thunderstorms might arise, how ground water supplies are being recharged, how excavated earth piles might slide.

Interested users will be able to count on getting their moisture data **on time, as promised.** The National Broadband Network will have the capacity to provide the information to all Australian users.

This very capable satellite has a large number of other uses, such as measuring the growth of forests, monitoring damage from bushfires and floods, creating high precision elevation maps, monitoring erosion, and even detecting ships at sea. These applications are available to governments and industry internationally, and can be used as a revenue stream.

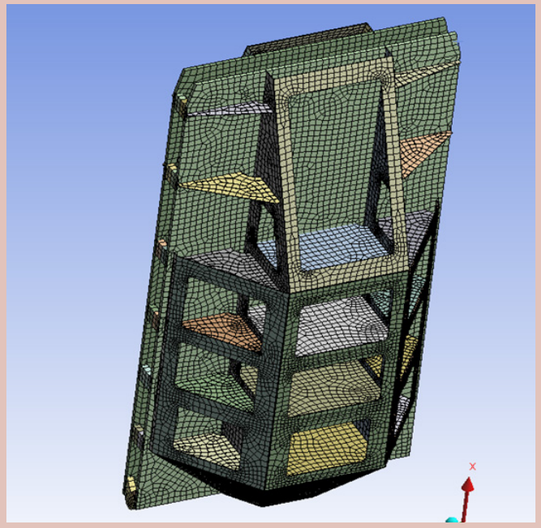
Our Technical Team

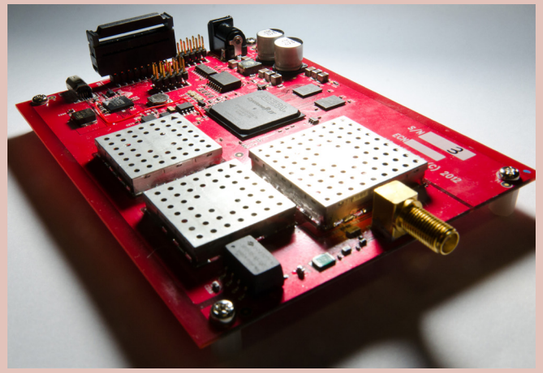
This soil moisture monitoring project, officially titled the Garada Synthetic Aperture Radar (SAR) Formation Flying Spacecraft project, is funded in part by the Australian Space Research Program (ASRP). It is a collaborative project led by the **University of New South Wales** with five other partners, all of whom are world-class in their particular fields, and each providing funding that matches the government funding.

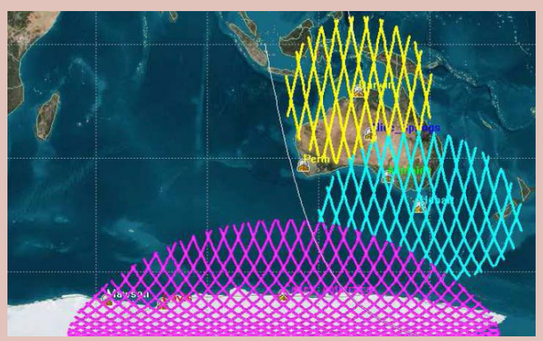
UNSW has Australia's largest engineering faculty which leads three ASRP projects and is a partner in two others. UNSW hosts Australia's largest group of satellite navigation researchers and is developing a strong team in satellite systems and remote sensing. **EADS Astrium** provide specialist satellite systems engineering expertise to the consortium, exploiting their heritage and experience in SAR spacecraft. **BAE Systems Australia** provides a detailed ground segment study and Australian industry capability report.

Curtin University and **Delft University of Technology** bring some of the world's best expertise in high-precision positioning for satellites applied to formation flying algorithms. **General Dynamics (NZ)** has designed a world first FPGA-based multi-Global Navigation Satellite System receiver.

The project consortium links Australia's leading satellite navigation researchers with key local and international industry partners to build new national capabilities in state-of-the-art earth observation from space. These capabilities will have regional and global applications measuring the moisture in Australia's soils.







Space Attracts our Best and Brightest

Thomas Cooney's final year research project was to design a signal processing board for the satellite's radar antenna. He worked with the radar designers at Astrium in the UK to identify all requirements, then designed the board. When built, the board was successful on the first try. Thomas has finished his degree and is working for an Australian biotechnology company.

What were some of the activities you were involved in within the project?

"My job was to design and test an innovative circuit board that processes radar signals going in either direction (transmitting and receiving) from the spacecraft. This new circuit board will ultimately allow the radar to produce more images. I had to determine the exact requirements for the circuit board and which components were already available without export control issues. I then created the circuit schematic and produced a printed circuit board design which was manufactured, tested and worked."

Would you want to do more work on a space program some day?

"My interest has always been in electronics, and certainly there's a lot of electronics in space engineering. I've received a great electrical engineering education from UNSW, which can be applied to many fields. If in the future there ever is a space program in Australia, I would be very interested."

For this work, Thomas Cooney was awarded the 2012 VSSEC-NASA Australian Space Prize and will be attending the NASA Academy at Ames in 2013.

George Constantinos performed the structural analysis for the spacecraft. It had to be strong and stiff enough to survive the shaking and vibration of the rocket launch. George used the training he had received to perform a complete structural study. George is now in an internship with a European satellite manufacturer.

What were some of the activities you were involved in within the project?

"When you launch a satellite, it's so violent that damage could occur to your spacecraft. My job was to ensure that whatever we sent up would meet the launch requirements—that the satellite would survive the launch. I used a technique called finite element analysis. It is a method of simulating the vibrations and shaking of the launch. You assign material properties to the three-dimensional model in a computer. Then you simulate the launch conditions—you vibrate it, you shake it, and apply forces."

What is the dream career accomplishment for you?

"I'd like to see moving around in space done with ease, interplanetary or even interstellar. I'd like to help make access to space more routine. It's so easy to do intercontinental travel today—space travel should be like that. There are so many resources and opportunities we could utilize out there."

The Innovation Connection

Australia is a world leader in the operation and control of satellites, and communication with them, in their orbits. Australia is also a world leader in processing massive amounts of data from space—particularly scientific imagery of Earth. This is exactly the kind of data the new Garada system will generate.

Many other capabilities are present in Australia in small companies. They would receive a boost through participation in the spacecraft development. So in creating the system, we build **on** Australian capabilities, and we build **up** Australian capabilities.

Clearly, the information product will be critical for our sensitive environment and our farms—some of Australia's most important resources. We believe that embarking on this project will develop yet another Australian resource: our high-tech workforce. As many other nations have done, we can use this project to inspire young people to pursue careers in engineering and science. At the same time, we will be creating new companies and organizations, or helping them grow, with new, exciting job opportunities in Australia.

Other economic sectors will also benefit, when these trained, motivated and experienced Australians spread their expertise throughout the economy. This will fuel the climate of innovation so important to a bright Australian future.

Our Australian Industry Capabilities Survey identified, by name and product line, each Australian manufacturer or firm with engineering capability that could add value to projects such as this one. If Australia were to commit to enhancing this industrial base, in a short time the economy would gain a space engineering sector. This would have a strong market worldwide, and attract our brightest engineering graduates.

The important environmental data we will produce will be needed by other nations, not just Australia. This will deepen our bonds with our Asian neighbours. As water is a critical resource for Australia, so it certainly is for China and India. In an international partnership, our neighbours' resources will be protected and enhanced. It also represents an opportunity for technology cross-fertilisation and exchange. This will strengthen Australia during the Asian Century, and further opportunities to use the growing Australian expertise will emerge.

A Path To the Future

Within a generation or two, the global economy will expand into the solar system. Nations that develop expertise in space systems will benefit most from this new interplanetary activity. Also, if the right approaches are taken, using resources in space can protect Earth's environment as well.

Building a large, capable satellite is an expensive undertaking. A significant commitment from the national government would be required over several years. Building this new monitoring system for Australia's resources will also be technically challenging. Some of the technologies we will require are beyond anything that can be found in Australia today. Our Australian Industry Capabilities Survey identified the Australian industries that can be called upon to contribute their expertise.

But the importance of finding moisture in Australia is critical to our sustainability, to the protection of unique habitats, and to maintaining our agricultural productivity. To address the technical challenges, some near-term investments can improve the maturity of the technologies, as well as providing competence and experience to Australian high-tech businesses.

We are producing a "risk reduction plan" for the Government. This will assist in evaluating the commitment required in order to provide Australia with these important new capabilities.

Image: esa

Where Can I Learn More?

The point of contact for developing and implementing this capability is Professor Andrew Dempster, Director of the Australian Centre for Space Engineering Research. His email address is **a.dempster@unsw.edu.au**

For technical information on the Garada satellite design, visit the website at **www.garada.unsw.edu.au**

"Intuition can only take us so far. To make truly great decisions about our essential water resources, farmers and ecologists, climatologists and policy makers need to know where the water is and how its distribution is changing. The only conceivable way to monitor this is from space."

Alan Finkel, AM, FTSE
Chancellor, Monash University
Founder, Cosmos and G: The Green Lifestyle Magazines

"Australia's critical dependence on a meagre supply of water is evident to all. Measurement of water from space is a bold and appropriate step for continued economic vitality and environmental stability. Furthermore, investment in space systems will establish a high productivity industry for future economic growth, one which attracts the brightest and most innovative of our graduates."

Fred Hilmer, AO
Vice Chancellor, University of New South Wales
Former Chair, National Competition Policy Review Committee

"One of greatest challenges for managing rivers and wetlands is understanding the patterns of flow and moisture and how they change with natural and human impacts. This satellite platform can potentially make a big difference, given we have to work at such large landscape scales."

Richard Kingsford, PhD
Professor of Environmental Science, UNSW
Director, Australian Wetlands & Rivers Centre

A Project of the Australian Space Research Program
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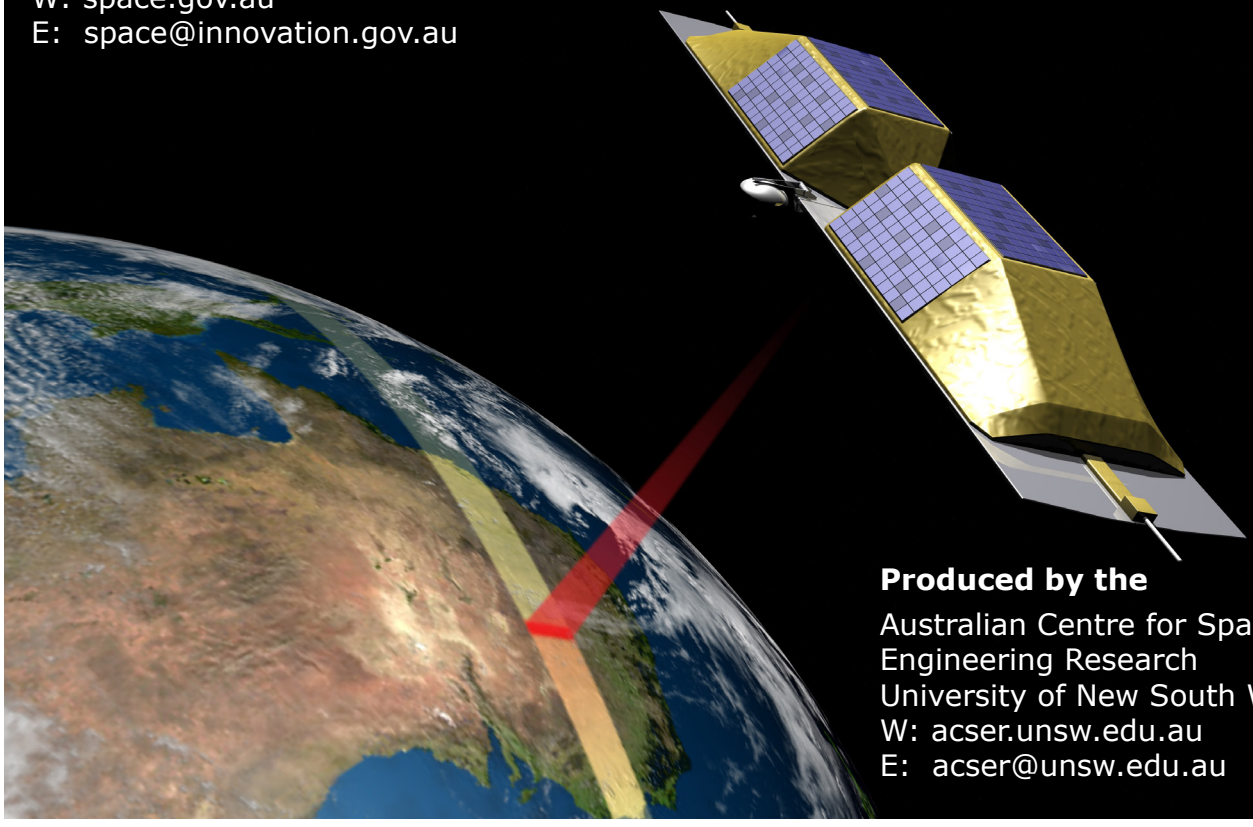

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