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1. Australian Space Research Project Overview
Garada Project Overview

Garada is a collaborative space engineering research project which supports the development of Australia’s capability in the rapidly expanding field of satellite earth observation (EO). Garada is investigating the design of an L-Band Formation Flying SAR satellite to support applications in flood monitoring, forest change detection and high spatial resolution soil moisture. This suite of applications is consistent with the environmental focus of the GARADA SAR Formation Flying ASRP proposal.

Industry studies have identified urgent shortfalls in Australia’s access to medium resolution optical and L-Band SAR data. There are currently no L-Band satellites and only two are planned by other countries in the years ahead.

The Garada project aims not only to help fill the gap with a design that uses high technology to achieve significant cost reduction but to build some of the essential supporting satellite navigation hardware.

In collaboration with prominent industry partners, the UNSW-led project will also identify preliminary industrialisation options, both Australian and international, for the development of the L-Band SAR.

Key Findings
4. Garada Collaborators

The Garada project comprises of 6 consortium members; 3 Universities and 3 Industry partners. The Garada project has developed strong collaborations between many of the partners which has strengthened the research activities undertaken within the project.

The University of New South Wales, is a founding member of Australia’s leading Group of Eight research-intensive universities. Within UNSW, the Faculty of Engineering has a proud history of teaching and research. It is the largest in Australia and plays an influential role in shaping the next generation of Australian engineers and scientists, with half of all engineering post-graduates, nationwide, studying or researching at UNSW. The School of Surveying and Geospatial Engineering hosts Australia’s largest group of satellite navigation researchers and is the only group investigating space based receivers. The School has a well-established international profile in research fields relevant to Space Engineering and Science and is recognised as a main area of research strength at UNSW. UNSW is the leading consortium member of the Garada project.

EADS Astrium UK is a global space industry leader, with world-class expertise and extensive prime contractorship experience across all sectors of the space business has been involved in all of the European Space Agency’s radar implementations as well as providing the central electronics for the Radar-sat-2, ERS-1 and 2, ASAR, and the current Sentinel-1 instrument. Additionally, Astrium has a 25 year history of conducting major system studies of potential new and innovative space and airborne radar systems for ESA, the European Union, and the UK government. Those studies include radars for operation in both mono and bi-static configurations, small low cost systems (AstroSAR-lite and DMC-SAR), large low frequency (P-band systems) for above-ground biomass estimation, as well as very low frequency (HF and VHF) for terrestrial and planetary sounding missions.

BAE Systems is a leading global defence, aerospace and security company. Australia is one of seven home markets where BAE Systems has a major industrial presence. The Australian organisation has key skills in engineering and systems integration and employs over 6000 people at 70 locations. BAE Systems Australia draws on the strength of the global company to deepen and broaden its capabilities to ensure customers are comprehensively supported. In electronic systems BAE Systems Australia is a leading provider of communications, electronic warfare systems, mission support systems, navigation, sensor and data fusion, spatial information systems and intelligence, surveillance and reconnaissance solutions.

Curtin University of Technology has always fostered successful partnerships with industry, business and government to enhance the quality of their scholarships, teaching and research. Curtin is recognised for the problem oriented nature of its research activities. Consistent with being a university of technology, much of its research focuses on solving real-world problems for the benefit of the community. Curtin University is involved in the formation flying algorithms developed for the Garada project. This includes investigating theory and methods to integrate the use of multiple constellations from the next generation GNSS for high-precision positioning and navigation of air-based and space-based platforms. Curtin University’s team is internationally regarded for their expertise in GNSS data processing and will closely with Delft University of Technology in the project.

Delft University of Technology collaborates with a large number of other educational and research institutes within the Netherlands and abroad and has a reputation for high-quality teaching and research. TU Delft has extensive contacts with governments, trade organisations, consultancies, the industry and small and medium-sized companies. and will closely with Curtin University of Technology in the project.

General Dynamics (NZ) has 30 years experience in electronic design, development and system integration, and the provision of leading edge hardware and software services. The Auckland-based company also manufactures and markets a range of embedded products for integration and development into systems, including the "Namuru” GPS/GNSS receiver for the UNSW Satellite Navigation and Positioning Laboratory. With years of experience in developing advanced systems, General Dynamics is uniquely capable of delivering unparalleled technology solutions. General Dynamics specialise in GPS receiver design, signal processing and RF systems design. General Dynamics was responsible for the RF and circuit board design for the space qualified GNSS receivers in the Garada project.
5. Garada Researchers

**Professor Andrew Dempster** is Director of the Australian Centre for Space Engineering Research (ACSER) at the University of New South Wales (UNSW). He is also Director of Research in the School of Surveying and Geospatial Engineering. He has a BE and MEngSc from UNSW and a PhD from University of Cambridge in efficient circuits for signal processing arithmetic.

Andrew was system engineer and project manager for the first GPS receiver developed in Australia in the late 80s and has been involved in satellite navigation ever since. He is leading the development of space engineering research at ACSER and the Garada project.

**Professor Chris Rizos** is currently Head of the School of Surveying & Geospatial Engineering at the University of New South Wales, Sydney, Australia. Chris has been researching the technology and applications of GPS since 1985, and established over a decade ago the Satellite Navigation and Positioning group at UNSW, today the largest academic GPS/GNSS and wireless location technology research laboratory in Australia.

Chris is the President of the International Association of Geodesy (IAG), and a member of the Executive and Governing Board of the International GNSS Service (IGS). Chris leads two of the work packages for Garada.

**Professor Peter Teunissen** is an internationally renowned geodesist and lauded as the inventor of a resolution method that revolutionised high-precision carrier-phase GPS positioning capabilities. His current focus is on solving critical GNSS theoretical and modelling issues in preparation for the rapid growth in global and regional navigation satellite systems. At Curtin, Peter is building a specialist research team whose focus is to improve Australia’s capability to exploit next-generation GNSS.

**Associate Professor Sandra Verhagen** obtained her PhD degree at the Delft University of Technology in 2005. Her thesis is entitled “The GNSS integer ambiguities: estimation and validation”, and gives the theory of three different classes of integer estimators and a performance analysis of different estimators within these classes. Currently, she is an assistant professor at DEOS-MGP. Sandra’s research interests are ambiguity resolution and quality control for (real-time kinematic) GNSS applications. Sandra along with Peter Teunissen from Curtin University of Technology lead work package 6 in the Garada Project.

**Kevin Parkinson** is the chief engineer and director of engineering at General Dynamics Corporation Ltd in New Zealand. He has completed many successful projects while working as an electronic design engineer over the past 25 years since completing engineering studies in Electronics and Communication engineering. He returned to UNSW in 2010 where he is currently a PhD student at the Satellite Navigation and Positioning Laboratory working on multi system GNSS receiver research. He is the designer of the UNSW Namuru GNSS receivers and is responsible for the design of new Namuru versions currently being developed for aerospace operation and for the prototype receiver that will be delivered in the project. His research interests include GNSS systems, FPGA design, embedded systems, low power RF design and signal processing.

**Ian Tuhoy**

**Andrew Larkins**

**Dr. Gordon Roesler**
Dr Steven Tsitas received his BSc(Hons) in Physics from the University of Melbourne, MS in Physics (with Distinction) from California State University Fresno and MS and PhD in Planetary Science with a Minor in Astronomy from the California Institute of Technology. His two part PhD thesis title is The effect of volcanic aerosols on ultraviolet radiation in Antarctica and A novel method for enhancing subsurface radar imaging using radar interferometry. He completed a MSc in Astronautics and Space Engineering at Cranfield University, receiving the Vega Space Systems Engineering Prize for Excellent Performance in Dynamics Related Subjects 2008/2009. Steven is a Senior Research Associate at UNSW and works on work packages 1. Steven is responsible for space systems engineering, radar applications and the business model for the Garada project.

Dr Mauro Grassi studied Computer Science and Mathematics at the University of Sydney before finding work in Buenos Aires with CONAE, the space agency of Argentina. There he worked on the SAOCOM mission. Returning to Australia, Mauro found work as part of the Garada project of UNSW. His interests are in SAR image processing and for Garada, Mauro is writing the specification of the image processor comprising WP2.

David Hall is employed by EADS Astrium where he has worked for the last 29 years. Having started in the ultra-high vacuum field working with mass spectrometers, he moved to work with thermal imaging systems and thence to Marconi, now Astrium, where his field encompasses radar, synthetic and real aperture, very low to very high frequencies as well as microwave and optical radiometers. David Hall is the head of earth observation (EO) sensors at EADS Astrium. David leads both work packages 3 and 8 of the Garada project.

Martin Cohen is a Synthetic Aperture Radar design expert who has spent over 20 years at Astrium in the UK working on the concept development, design, build and test of a range of SAR instruments. He worked on the ASAR instrument for the European Space Agencies ENVISAT spacecraft, and subsequently was involved in a range of studies looking at next generation SAR systems. Martin has run the Astrium Airborne SAR demonstrator programme since 2001. He is also the Engineering Manager and technical lead for the SAR payload on NovaSAR-S, a new low-cost SAR satellite developed in conjunction with Surrey Satellite Technology Ltd (SSTL) in the UK.

Dr. Kegen Yu completed his PhD titled “Code Acquisition and Detection for Spread-Spectrum Mobile Communications” degree at the University of Sydney in 2003. Since then, he has worked for Centre for Wireless Communications at University of Oulu in Finland, CSIRO ICT Centre, and Department of Electronic Engineering at Macquarie University where he has been an adjunct professor since March 2011. Kegen is currently with the School of Surveying and Geospatial Engineering at the University of New South Wales, working with Chris Rizos on work package 4, Bistatic Radar in the Garada project. His current research interests include GNSS Bistatic radar, ground-based and GNSS-based positioning and navigation.

Dr. Nagaraj C Shivaramaiah is a Senior Research Associate at the University of New South Wales. He obtained his Bachelor’s degree in Electronics and Communication engineering from the University of Mysore, India in 1997, Master’s degree in Electronics Design and Technology from the Indian Institute of Science, Bangalore, India in 2004 and PhD from the University of New South Wales, Sydney, Australia in 2011 for a thesis on Galileo satellite navigation receiver design. He worked at Accord Software and Systems, Bangalore, as a Senior Project Leader where he managed projects, built and nurtured successful engineering teams involved in various GNSS related activities for over eight years. Nagaraj is working on WP5, Prototype Receiver Design in the Garada project.

Dr Jinghui Wu completed her Bachelor’s degree in Electrical Engineering and Automation at the Beijing University of Aeronautics and Astronautics (BUAA) in 2004. Jinghui is currently a Research Associate with the School of Surveying and Geospatial Engineering, at the University of New South Wales. Jinghui also obtained her Master’s in Engineering in 2006 from the School of Electrical Engineering and Telecommunications, specializing in signal processing and her PhD degree in 2010 at UNSW. Her research focuses on signal processing for new GNSS and her PhD thesis title was “Binary Offset Carrier (BOC) Receiver Design”. Jinghui’s research interest includes software and hardware development for GNSS receivers. Jinghui is working on work package 5, Prototype Receiver developing the new ‘Namuru’ GNSS receiver for the Garada project.
Dr. Li Qiao is currently a Research Associate at the University of New South Wales. She obtained her Bachelor’s degree in Electrical Engineering and Automation at Nanjing University of Aeronautics and Astronautics (NUAA) in 2004. She joined UNSW as a visiting PhD student from 2009 to 2010 and obtained her PhD degree in Guidance, Navigation and Control at NUAA in 2011. Her research focuses on Satellite autonomous navigation using celestial objects and GNSS. Her research interest is satellite orbit models and determination, specializing in orbit determination, celestial navigation and GNSS algorithms. Li is working on work package 7: Orbit Models in the Garada project.

James Carrapetta graduated from the School of Electrical Engineering and Telecommunications at the University of New South Wales in 2010. James is also currently completing his Masters of Engineering Science specialising in Telecommunications at UNSW. James is the project administrator for the Garada project and oversees all of the project deliverables, collaborations, organisation and management of the project. James works on work package 11, Project Management of the Garada project and assists Prof. Andrew Dempster in the management of the entire project.
6. Project Inspired Research

Electronic Circuits for L-Band Phased Array Synthetic Aperture Radar - Thomas Cooney

Thomas Cooney is an undergraduate student from the School of Electrical Engineering and Telecommunications at UNSW. Inspired by the Garada project objective of designing an L-band synthetic aperture radar (SAR) low earth orbit (LEO) earth observation satellite, Thomas’s thesis required the design, construction, and testing of a prototype of the front end RF electronics. Known as Transmit/Receive modules, these attach directly to the antenna and amplify and phase shift signals to and from the central computer of an Active Electronically Scanned Array Radar (AESAR) for transmission of pulses and reception of pulse echoes. The Garada project calls for the ability to control the polarization of the transmitted pulses; Thomas’s research was the first implementation of this control in a single T/R module.

Thomas’s Transmit/Receive module prototype demonstrated usable amplification, phase shifting, flexible control, and a novel polarization control scheme (corrected with an additional phase shifter). Thomas’s work allows future antenna experiments to demonstrate the potential of using a phased array synthetic aperture radar for a potential Garada mission.

Synchronization of Physically Isolated Local Oscillators - Joseph Gauthier

Joseph’s research topic is the synchronization of physically isolated local oscillators (LO) in the context of a dynamic application (e.g., bistatic synthetic aperture radar (SAR) system). Although a plethora of literature is available regarding synchronization of stationary LOs, the same cannot be said for nonstationary LOs, particularly those that are physically isolated. However, in order for almost any distributed system to operate correctly, synchronization (to some degree) must be achieved.

Thus, the purpose of Joseph’s research is to pursue the development of new algorithms that may be used to achieve synchronization in the context of GPS and other available methods. Some of the errors that must be taken into account are the frequency accuracy and stability of the LOs, knowledge of their relative positions and velocities, and the scene geometry.
7. Way Forward