



ANNUAL REPORT

2017 - 2018



Australian Government
Department of Industry,
Innovation and Science

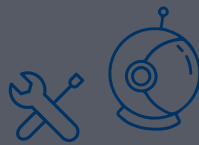
Business
Cooperative Research
Centres Program



The International Space Station

must manoeuvre away from a possible space debris collision

1 to 3 times per year
on average



What is space debris?

Any human-made object in orbit that does not serve a purpose is considered space debris. For example, components of a spacesuit, retired satellites, spent rocket bodies and fragments of satellites resulting from collisions and break up events.



Space debris moves

with high velocity in the range of
8km per second

**PRESERVING
SPACE
FOR THE
FUTURE**



170 million

pieces too small
to track are also in
orbit



30,000

softball-sized and larger
pieces are currently
orbiting Earth



500,000

marble-sized pieces
currently orbiting Earth

OUR MISSION

The Space Environment Research Centre (SERC) will develop and commercialise technologies to reduce the threat to space-based infrastructure from space debris.

SERC will consolidate currently-independent research efforts to achieve a critical mass of effort to form a platform for new investment, by providing:

- a transparent framework for international research collaboration, ensuring equity for all collaborators regardless of nationality or whether a private or public entity;
- access to state-of-the-art space research programs and infrastructure;
- new funds for consolidating research program synergies and investigating new avenues; and
- exemplary management of research, consistent focus and strategic leadership.

OUR VISION

SERC technology will play a key role in practical global efforts for space debris management, mitigation and removal.

SERC will be a collaboration vehicle of choice for compatible national, international and commercial efforts to address issues arising from space debris.



This report has been prepared in accordance with the 2017-18 Cooperative Research Centres (CRC) Programme Annual Report Guidelines and is submitted to comply with the requirements of Section 4 of the Guide.

The CRC for Space Environment Management is administered by the Space Environment Research Centre Limited (SERC).

Space Environment Research Centre
AITC2, Mount Stromlo Observatory
Weston Creek ACT 2611
PO Box 4204, Weston Creek ACT 2611

T+ 61 2 6197 0157

E info@serc.org.au

W www.serc.org.au

f www.facebook.com/serc.aus

t [@serc_aus](https://twitter.com/serc_aus)

CONTENTS

ACHIEVEMENTS

1.	Executive Summary	9
1.1.	Achievements	10
1.2.	Risks and Impediments	13
1.3.	Key Researchers	14
1.4.	Performance against activities	20
1.5.	Education and training	34
1.6.	Utilisation and Commercialisation	38
1.7.	Communications	38
1.8.	Governance – Board, committees and key staff	42
1.9.	Participants	49
1.10.	Collaboration	51
1.11.	Financial management	52

APPENDICES

2.	Glossary of Terms	55
2.1.	SERC Publications	57
2.2.	SERC Scholarship Students	62



REPORT FROM THE CEO

The need for improved space situational awareness and the establishment of an effective international space traffic management regime is growing more urgent with the emergence of plans for “mega-constellations” of satellites. As a technological society, our day-to-day lives are heavily dependent on the services and capabilities that are delivered by space-borne systems. It is imperative that these space systems can continue to operate safely within an increasingly congested space environment.

SERC was established to advance capabilities in the management and mitigation of space debris. SERC research is already providing significant improvements in space debris orbit prediction which will allow active satellites to manoeuvre to avoid collisions with space debris. Further, SERC is working to complete the systems needed to demonstrate collision avoidance interventions in space using ground-based lasers. The ability to manoeuvre debris to avoid debris-on-debris collisions will help prevent the accelerated growth of the debris population.

A new generation of entrepreneurs has made space more accessible through new technologies and enhanced launch capabilities. These entrepreneurs also have plans to launch several “mega-constellations” of communication satellites to low earth orbit. If the planned mega-constellations are all launched, the number of operational satellites will increase from the 1,800 in orbit today, to 18,000 over the next decade. Accordingly, there is urgency for industry and space agencies to establish effective global civil space traffic management capabilities.

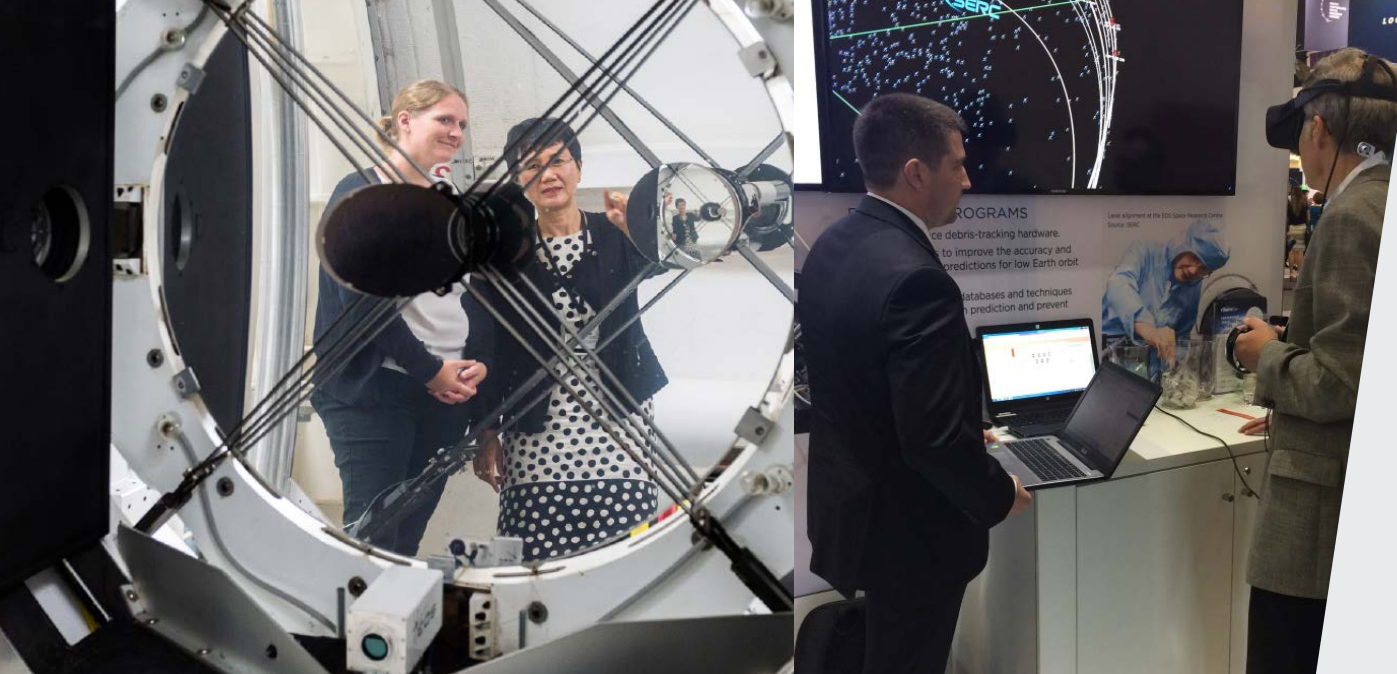
The key to effective space traffic management lies in our ability to more accurately determine and predict the orbits of space objects. Increasing the accuracy of measurements and improving the precision of orbital predictions enhances our ability to provide satellite operators with the actionable conjunction alerts necessary to avoid collisions.

The research achievements being made by SERC are valuable long-term contributions towards reducing the risk from space debris, improving space situational awareness and enhancing space traffic management capabilities.

I am pleased to report that SERC continues to make significant progress towards meeting its research objectives and is on track to conduct on-orbit experiments early in 2019.

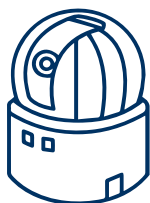
David Ball
Chief Executive Officer





Clockwise from top: 1.8m Debris tracking telescope mirror with SERC researchers, SERC stand at IAC on September 2017 in Adelaide, AITC2 clean room at Mount Stromlo and EOSSS telescope manufacturing facility, Queanbeyan, NSW.

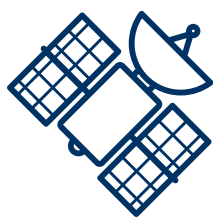
2017-2018 HIGHLIGHTS



SERC GEO TRACKER TELESCOPE

Is now integrated and provides a fully automated system to feed data into the SERC SOC

SERC PAYLOAD LAUNCHES NOVEMBER 2018



The SERC sensor and beacon payload has been manufactured and integrated on its host satellite. The launch on a SpaceX Falcon 9 launch vehicle is scheduled for November 2018 from Vandenberg Air Force Base in California.



SPACE OBJECT CATALOGUE

SERC SOC

IS COLLECTING DATA FROM OVER

1,000

SPACE OBJECT TRACKS
NIGHTLY

26



POSTGRADUATE STUDENTS

SERC is producing industry-ready students exceeding the milestones outlined in the Commonwealth Agreement.

83

SERC RESEARCH PUBLICATIONS



252

CITATIONS



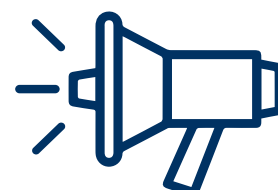
2 4 62 170

TELEVISION INTERVIEWS

RADIO INTERVIEWS

PRINT MEDIA ARTICLES

FACEBOOK STORIES



REPORT FROM THE CHAIR

As Chair of the Space Environment Research Centre Limited (SERC), I am again pleased to report that the CRC for Space Environment Management has continued to achieve our research and education objectives. Much has been accomplished over the past year on research to improve the accuracy orbital debris tracking and we are now embarking on the integration phase of SERC's activities to demonstrate the manoeuvre of orbital debris using photon pressure from high-power lasers.

SERC's members include two universities: the Australian National University and RMIT University; three industry partners: EOS Space Systems, Lockheed Martin Space Systems Company (USA) and Optus Satellite Networks; and one international public sector research agency, the Japanese National Institute of Information and Communications Technology (NICT). I thank all the members for their ongoing support and commitment to SERC and greatly appreciate their significant contributions towards SERC's goals.

I would like to extend a personal thank you to Dr Ben Greene who has successfully steered SERC as its foundation CEO. Ben has now joined the Board and is Chair of its Research Management Committee. I look forward to his wise counsel as SERC seeks to leave a strong legacy in space environment research. On behalf of my fellow directors, I am pleased to welcome David Ball to the role of CEO. David brings more than 20 years of executive management and space sector experience to the role.

I would also like to thank my fellow directors, the SERC management team, and all the researchers in the CRC for their continuing commitment to SERC.

SERC has about twelve months to run. All Participants and researchers remain fully committed to meeting our research objectives and maximising our contributions towards better tracking and management of orbital debris.

The protection of the space environment is critical in order to ensure that this valuable resource is preserved and remains available for future space endeavours.

Mary O'Kane
Chair



EOSSS Head of
Research, EOSSS
Space Research Centre,
Mount Stromlo, ACT



7 EXECUTIVE SUMMARY

The CRC for Space Environment Management is operated by the SERC. SERC is an Australian Public Company, Limited by Guarantee and is funded through the Department of Innovation Industry and Science's CRC Programme as well as through Participant contributions.

SERC has been endorsed by the Australian Tax Office (ATO) as a registered charity, effective 10 April 2014. SERC's Strategic Plan, adopted on 18 March 2015, outlines the mission, vision, core values and strategic objectives for SERC. The strategic objectives include:

- Identify and exploit synergies between the research efforts of initial participants so that the research objectives are collectively more advanced than would have been the case without SERC;
- Establish efficient, equitable and transparent processes for combining resources from a wide range of collaborating entities; and
- Develop new technologies to preserve the space environment and extend the benefits of space to future generations.

SERC's purpose is to pursue and promote world class research and education addressing the mounting risk of space collisions between satellites and debris. This risk currently threatens individual spacecraft and ultimately the viability of the entire space environment.

SERC has been established to build on Australian and international expertise in measurement, monitoring, analysis and management of space debris and to develop technologies to preserve the space environment.

SERC brings together skills and resources from leading universities, international and commercial research providers, industry and end-users to mitigate and ultimately remove the risk of space debris collisions.

SERC is consolidating independent research efforts to achieve a critical mass of effort forming a platform for new investment, by providing:

- a transparent framework for international research collaboration, ensuring equity for all collaborators regardless of nationality or whether a private or public entity;
- access to state-of-the-art space research programs and infrastructure;
- new funds for consolidating research program synergies and investigating new avenues; and
- exemplary management of research, consistent focus and strategic leadership.



1.1. ACHIEVEMENTS

There have been many highlights and achievements during the fourth year of operation including:

Chief Executive Officer

David Ball commenced as SERC CEO in December 2017. David brings many decades of space industry experience to the role.

Board Members

Prof Matthew Colless and Rod Drury completed their terms on the SERC Board in October 2017. Matthew and Rod were replaced by Professor Min Gu and Dr Ben Greene as research organisation and industry organisation directors respectively.

Research Management Committee (ResMC)

The SERC ResMC has been augmented by the addition of three new members; Matthew Bold from Lockheed Martin, Mark Skinner from Aerospace Corporation, USA and David Ball, SERC CEO. The ResMC continues to provide strong oversight and support to the research program. Committee members attended the 2018 Research Colloquium and met with researchers and students to discuss the research progress.

Research Programs (RP)

SERC Research Programs are on track to commence on-orbit photon pressure experiments in the second quarter of 2019. Research highlights and achievements are outlined in section 1.5 of this Annual Report.

Atmospheric Mass Density Model (AMD)

Significant progress has been made on the SERC AMD with the inclusion of neutral and ion density information with testing showing improvement over existing models.

High Power Laser Beam Combining

Research Program 1 (RP1) researchers have successfully demonstrated high power multi-beam combining using variable Bragg grating (VBG) techniques. This method will be employed to deliver the SERC 8 kW laser which will be used for the photon pressure experiments.

SERC Geostationary Earth Orbit (GEO) Tracker Telescope

The SERC 0.7m GEO Tracker Telescope has been integrated into the EOS Space Systems (EOSSS) sensor network. The SERC GEO Tracker Telescope now provides a fully automated tracking system to feed data (information about space objects) into the SERC Space Object Catalogue (SOC) for conjunction assessments (process of determining whether two objects are likely to collide).

Major Component Purchases

Substantial progress towards the development of the following assets has been achieved: SERC High Power Laser, Stereo Scintillation and Detection and Ranging System (SCIDAR) and the adaptive optics (AO) systems (imaging, and track and push).

SERC Payload (SPLD)

The SERC sensor and beacon payload has been manufactured and integrated on its host satellite. Environmental testing was successfully completed prior to the satellite being shipped to the United States for launch preparations. The launch on a SpaceX Falcon 9 launch vehicle is scheduled for November 2018 from Vandenberg Air Force Base in California.

SERC Space Object Catalogue (SOC)

The SERC SOC is operational and is now storing data from over a thousand space object tracks each night

Participant Collaboration

SERC Research Programs are interdependent and involve collaboration between all SERC Participants at research, education and end-user levels. Collaboration across the four Research Programs continued during the reporting period. For example:

- Research Program 3 (RP3) collaborates with RP1 and RP4 on the characterisation of space objects to identify the catalogue objects which will be suitable candidates for photon pressure experiments.
- Lumini, the SERC high-rate photometry detector, which will be used in space object characterisation for the remote manoeuvre experiment, was tested on the National Institute of Information and Communications Technology (NICT), telescope in Japan during the reporting period.
- SERC has established a number of MOUs with international optical observatories. These relationships will facilitate the establishment of a world-wide network of HRPDs in preparation of the SERC remote manoeuvre experiment.

MOU with the Polish Academy of Sciences (PAN)

SERC signed an MOU with PAN during the reporting period. The MOU establishes a framework of scientific collaboration to combine expertise, develop common specialised knowledge and increase co-operation and mutual support. Collaboration will be implemented through joint meetings, exchange of scientific personnel and joint research and development. In particular, the joint research and development may include orbital dynamics measurement, analysis and modelling of the space objects up to the geostationary altitudes, re-entry and de-orbit events analysis, conjunction analysis and common experiments.

Conference Attendance and Presentations

SERC received significant national and international exposure by supporting travel for researchers and students to participate in technical meetings and deliver technical papers at more than 52 national and international conferences and symposia. The conferences included the International Laser Ranging Workshop, (Riga, Latvia), the Advanced Maui Optical and Space Surveillance Technologies Conference, (Maui, USA), the 5th European Workshop on Space Debris Modelling and Remediation (Paris, France - invited keynote) and the 15th Annual CubeSat Developers Workshop (San Luis Obispo, USA).

International Astronautical Congress (IAC)

SERC showcased its research to an international audience at the International Astronautical Congress (IAC) which was held in Adelaide from 25 – 29 September 2017. SERC exhibited at IAC as part of the Department of Industry, Innovation and Science exhibition booth. The Congress is the world's largest interdisciplinary meeting for space professionals, researchers, corporations, space agencies, government, students and the media. IAC2017 was attended by over 4500 delegates.



EOSSS Space Research Centre. The SERC GEO Tracker Telescope is positioned in the front and centre of this image. Mount Stromlo, ACT.

Publications

During the reporting period SERC research was published more than 83 times across formal and other publication categories. Papers by two SERC students, Joe O'Leary and Alpha Bah, were published in the Royal Society and Scientific Reports (Nature) journals respectively. SERC researchers had research papers published in two Nature publications (Scientific Reports and Nature Photonics).

Citations

Citations of SERC formal publications reached 252 citations during the reporting period.

PhD Scholarships

SERC is well placed to meet or exceed its education milestones. To date, SERC has enrolled 26 postgraduate students and graduated two. By 30 June 2019, SERC expects to graduate a further 8 students; bringing anticipated totals to 26 postgraduate enrolments and 10 graduations. This would exceed the SERC education milestones outlined in the Commonwealth Agreement.

Industry Placement

Pilot Officer Harry Leonard from the Australian Defence Force Academy undertook a six week summer industry placement with SERC during January and February 2018. Harry fitted in extremely well with the SERC team and made valuable contributions towards RP3 research goals during his placement.

PhD Student Professional Development

SERC PhD and undergraduate students participated in a full-day professional development day at Mount Stromlo. Members of the ResMC and SERC Executive provided mentoring, thesis support and advice to students.

Media

SERC gained significant media attention during the reporting period including four radio interviews, two television interviews and 62 print media articles.

21st International Workshop on Laser Ranging (IWLR)

SERC will host the 21st International Workshop on Laser Ranging in November 2018. Planning for the IWLR gained momentum during the reporting period with over 200 abstracts received for the academic program. Registrations are progressing well and representatives from international space agencies, global research institutions and astronomical observatory representatives have confirmed their attendance.

IWLR Website

The IWLR website was launched and gained popularity during the reporting period, recording over 3,000 views during the five months since activation.

SERC Facebook page

170 stories were posted to the SERC Facebook page during the reporting period resulting in 693 likes.

SERC Research Colloquium

The sixth SERC Research Colloquium was held during the reporting period.

Whole of Research Program Meeting

A whole of research program meeting was held in conjunction with the 2018 SERC Research Colloquium.

Awards and Accolades

- SERC Post-Doctoral Researcher, Daniel Kucharski was shortlisted from 506 entries for the best interactive poster presentation at the International Astronautical Congress (IAC) which was held in Adelaide from 25-29 September 2017.
- SERC PhD student, Samantha Le May was awarded the silver medal in the IAC International Student Competition for her paper "Assessing the effectiveness of debris mitigation guidelines to preserve the space environment given future proposals for large satellite constellations". Samantha was invited to join the International Astronautical Association (IAA) Permanent Committee on Space Debris and to co-chair the Next Generation Plenary Session at the Adelaide IAC. As a result, Sam was invited to contribute to the International Astronautical Association (IAA) Space Debris Situation Report.
- Samantha Le May was further recognised by the International Astronautical Federation (IAF) through the award of an Emerging Space Leader Grant to enable her to participate and present at the 2018 International Astronautical Congress in Bremen, Germany and to attend the IAA Space Debris Committee meeting in Paris. The IAA Space Debris Committee is made up of leading experts in the field who are responsible for the coordination of all activities related to space debris within the International Academy of Astronautics. This is a great opportunity for Samantha to network with space industry leaders and to gain an international perspective on space debris research and priorities.
- SERC Post-Doctoral Researcher Doris Grosse was also recognised as an outstanding early career researcher at IAC. Dr Grosse was awarded an early career researcher grant to attend the event and was invited to participate as a panel member in the IAC Next Generation Plenary Session. This session was attended by 250-300 people and promoted the SERC research Doris is undertaking to an international audience of space professionals.



1.2. RISKS AND IMPEDIMENTS

During the reporting period SERC did not experience any impediments or new risks which would materially degrade its ability to meet its Commonwealth objectives.

Risk Mitigation

SERC maintains a comprehensive Risk Register which is reviewed regularly by management and the Board appointed Audit and Risk Committee (ARC). Risks with a high impact rating or above are reported to the Board. The ResMC also monitors the research risks and advises the Board accordingly.

As SERC moves from a predominately research based organisation to a demonstration phase, risks associated with this new phase are being identified and managed accordingly.

Key risks addressed during the reporting period and strategies adopted to address these risks include:

- **Loss of key personnel.** This is an ongoing business continuity risk which has been managed through regular research program meetings and annual staff performance reviews. The risk of losing key personnel increased during the reporting period as the wind-up of SERC draws closer. Interviews have been conducted with key researchers and corporate staff to ensure SERC retains sufficient resources to deliver 2019 organisational objectives and wind-up activities. One strategy has been to transition key researchers to Participant organisations on the understanding that SERC will continue to fund and direct the research activities of these positions until SERC is wound up.
- **Inadvertent disclosure of IP.** The key IP risks relate to inadequate protection or poor exploitation. SERC relies on experienced Research Program leaders to implement SERC IP processes. The inclusion of robust non-disclosure and IP protection clauses in Participant Agreements and in staff and student contracts is a key element in protecting SERC IP. To enhance awareness, IP workshops have been conducted to assist researchers and students identify and protect SERC IP. Background and foreground IP has continued to be identified and recorded on the SERC IP register during the reporting period.
- **Failure to Meet End-User/Participant Requirements.** The SERC Executive meets regularly with end-users and Participants to identify and understand industry requirements. A whole of research program meeting was held in conjunction with the SERC Research Colloquium to ensure the research is meeting SERC objectives including end-user and Participant requirements.
- **Failure to Deliver Research Outcomes.** SERC has an efficient but resilient research strategy which can accommodate multiple failures in the necessarily high-risk research effort. However there are some research outcomes which are fundamental to the success of SERC. These include the use of AO for beam propagation, the response of typical debris to laser radiation, and the achievement of unprecedented power and optical quality in laser beams. These risks have been monitored during the reporting period and contingency plans developed to mitigate risk to the SERC research program.
- **Insufficient Resources.** This risk relates to the quality and quantity of in-kind commitments from Participants. This issue was anticipated in the framing of the SERC constitution where reviews are required annually of both the quantity and quality of in-kind contributions provided to SERC by its Participants for purposes of achieving research objectives.

1.3. KEY RESEARCHERS



PROF CRAIG SMITH
RP1 PROGRAM
CO-LEADER

EOSSS

Professor Craig Smith is the CEO and technical director of EOS Space Systems (EOSSS). He leads a multi-disciplinary team of science and engineering innovators developing lasers, beam directors, precision timing systems, sensors, and control systems for the laser tracking products. Professor Smith has also held positions within EOS as CEO EOS Technologies (the US subsidiary of EOS) and Head of R&D. Prior to joining EOS Professor Smith was a Senior Research Fellow at the Australian Defence Force Academy. There he developed novel techniques for imaging-polarimetry and spectro-polarimetry at thermal Infra-red wavelengths. These remote sensing techniques are able to provide materials characteristics from the thermal signature of an object. Professor Smith has lectured in Physics and Electronics and Military Ballistics and is an Adjunct Professor at RMIT University. He obtained Bachelors and PhD degrees in Physics from the University of Melbourne.



DR STEVE GOWER
RP1 PROGRAM
CO-LEADER

SERC

Dr Steve Gower is the General Manager Research for SERC and received his PhD in plasma physics and high power microwave engineering from the University of Wollongong. Prior to joining SERC Dr Gower held various senior research management roles in universities, government laboratories and the private sector. Whilst at RMIT University, as Director of Research Collaborations and Partnerships Steve was responsible for the establishment of major research partnerships with CRCs, ARC and NHMRC Centres of Excellence; bringing together industry, academia and government in collaborative research initiatives. Prior to RMIT, Dr Gower was responsible for the establishment and operation of all external facing partnerships with the Australian Synchrotron as Head of External Relations. Steve's research interests span surface analytical sciences and industrial automation.



ASSOC PROF FRANCOIS RIGAUT
ADAPTIVE OPTICS

ANU

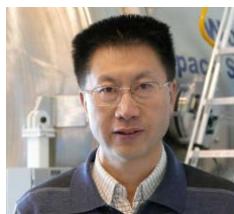
Dr François Rigaut obtained his PhD from Paris Diderot University (Paris 7) in 1992 on the first Adaptive Optics (AO) system for astronomy, COME-ON, then developed in Europe and used at the ESO La Silla observatory. Since then, Dr Rigaut has been involved in the technological and theoretical developments and promotion of Adaptive Optics at several institutes, the Canada France Hawaii Telescope, the European Southern Observatory and the Gemini Observatory; and through various instruments: PUEO, NAOS, Altair and lately the Gemini multi-conjugate AO system, the first and only Laser Guide Star Multi-Conjugate Adaptive Optics system. Dr Rigaut is the Adaptive Optics Principal Scientist at the ANU Research School of Astronomy and Astrophysics, concentrating on two main projects: the design of a Ground Layer AO system for the Subaru Japan national telescope, the Laser Tomography AO system for the Giant Magellan Telescope (GMT) and an AO prototype for conditioning of laser beams used in space debris tracking, nudging and de-orbiting.



ASSOC PROF CELINE D'ORGEVILLE
ADAPTIVE OPTICS

ANU

Céline d'Orgeville joined the ANU RSAA Adaptive Optics (AO) group in 2012 to lead Laser Guide Star (LGS) activities at the Advanced Instrumentation and Technology Centre (AITC), Mount Stromlo, Canberra. Céline was appointed AO Group Manager in July 2016 and is also the AITC Student Convenor. Prior to moving to Australia, Céline worked at the Gemini Observatory where she led the design, fabrication and commissioning of the Gemini North LFG facility in Hawaii (1999-2006), and the Gemini South LGS facility in Chile (2007-2011). The Gemini South AO system, GeMS, is the only Multi-Conjugate Adaptive Optics facility in the world. The GeMS LGS facility is also unique in creating not just one but five sodium LGS to probe the atmosphere and enable GeMS to restore the diffraction-limit of the Gemini South 8-metre telescope over a 2 arcminute field of view.



DR YANJIE WANG
SENIOR LASER
SCIENTIST

EOSSS

Dr Yanjie Wang has over 20 years research and development experience in lasers, optics and nonlinear optics. His expertise includes the design, prototyping and manufacture of high power and high energy lasers, mode-locked and Q-switched lasers, single frequency lasers, fiber lasers and nonlinear frequency conversion devices. Dr Wang holds a PhD in laser physics from the ANU.



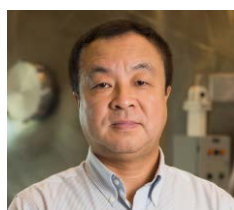
RESEARCH PROGRAM ONE



DR JAMES WEBB
GUIDE STAR
LASER SCIENCE

EOSSS

Dr James Webb is EOSSS's instrument scientist, where he applies a diverse range of skills accumulated over more than 20 years in numerous defence, academic, commercial and industrial R&D roles. After a period with the RAAF and graduation as an electronics engineer, he founded and worked in a series of start-ups developing high speed inkjet printers, smart card readers, image compression and cryptographic utilities. Following further studies in explosives, adaptive and quantum optics he spent time as a researcher with UNSW, then in Hawaii as an electronics engineer at the United Kingdom Infrared Telescope (UKIRT) and JCMT telescopes. Upon returning to Australia, James resumed consulting in the areas of medical and security product development and defence communications while employed as an R&D engineer in the field of high accuracy positioning. He is currently focussed on the creation of new telescope control systems and the EOSSS guide star laser.



PROFESSOR YUE GAO
PRINCIPAL
SCIENTIST &
HEAD OF LASER
RESEARCH &
DEVELOPMENT

EOSSS

Professor Yue Gao is the Principal Scientist and Head of Laser Research & Development Division for EOSSS. Professor Gao is responsible for the research, development, design, and project management of different type of solid state lasers and Electro-Optic devices for scientific and military applications. Prior to joining EOSSS, Professor Gao held a Postdoctoral Research position at the Australian National University in the Laser and Optical Spectroscopy Group, Research School of Chemistry where he worked on spectroscopic studies of transition metal ions in solid state inorganic compounds and other crystalline and amorphous materials. Professor Gao was appointed as an Adjunct Professor to the ANU in 2011. Professor Gao received his Bachelor of Engineering degree in laser physics, and laser technologies from Tianjin University, China and his PhD in physics from the University of Strathclyde, Glasgow, UK.



AMY CHAN
SENIOR DESIGN
ENGINEER

EOSSS

Amy Chan is the senior design engineer for EOSSS, specialising in the Opto-Mechanical area. Amy has more than 26 years' experience with EOSSS where she designed the opto-mechanical structures for the development of various products including night vision, laser ranging, solid-state laser and single-frequency seed source technologies. Amy also designed opto-mechanical structures for a variety of other laser products including - Picosecond pulse width laser oscillator, Picosecond regenerative feedback amplifier, Nanosecond high-energy laser system, including pre-amplifier, power amplifier, Continuous Wave (CW) high power (> 4000W) book piece laser and water-cooled frame (kW-class high-power continuous, pulse laser). Amy holds a bachelor of Engineering in Optical Instrument degree from Tianjin University, China and a Graduate diploma in Computing Science from the University of Canberra.



DR DORIS GROSSE
POSTDOCTORAL
RESEARCH
FELLOW

ANU

Dr Doris Grosse is an early career research scientist specialising in adaptive optics with the AITC at ANU Research School of Astronomy and Astrophysics. Dr Grosse was awarded an engineering graduate degree with the Faculty of Electrical Engineering and Information Technology of the Ruhr-University Bochum in Bochum, Germany. On completion of her engineering degree, Dr Grosse was appointed to the Photonics and Terahertz Technology research group at the Ruhr-University Bochum, where she completed a PhD in the area of three-dimensional imaging with digital and photorefractive holography. Doris joined the Adaptive Optics group at the ANU in 2016 as a postdoctoral researcher to develop an adaptive optics system as part of the SERC collision risk mitigation system.



DR FRANCIS BENNET
INSTRUMENTATION
ENGINEER
ADAPTIVE OPTICS

ANU

Dr Francis Bennet obtained a first class honours degree at the Australian National University (ANU) in Physics and was awarded a PhD from the ANU in 2011. Dr Bennet's current research interests include adaptive optics, astrophotonics, laser physics, and optical design. Dr Bennet is developing AO technologies for SERC to support the remote manoeuvre of space object(s) using ground-based lasers.

He is also undertaking research and developing AO to facilitate high performance laser communication.



DR LAUREN GLINA
SOFTWARE
ENGINEER

EOSSS

Dr Lauren Glina joined EOSSS in 2015 as a senior software engineer. Her current focus is on developing software for precision motion control of telescopes, in particular, software operating across the boundary between real-time and non real-time domains. She was responsible for developing software for, and commissioning, the SERC research telescope at Mt Stromlo. Dr Glina holds a Bachelor of Information Technology with first class honours from the University of Sydney, and a PhD in Computing from the University of Tasmania.



**DR VISA
KORKIAKOSKI**
POSTDOCTORAL
RESEARCH
FELLOW

ANU

Dr Visa Korkiakoski obtained his PhD from the Helsinki University of Technology in 2008, after an internship in the European Southern Observatory, on the topic of optimizing the control adaptive optics systems. Since then, he has continued the line of work in international research institutes such as the Institut de Planetologie et d'Astrophysique de Grenoble, Leiden Observatory, Delft University of Technology and the Netherlands Organisation for Applied Scientific Research. His work has involved the theoretical and numerical aspects of adaptive optics in various contexts, most importantly modelling the performance of the high-contrast systems intended for the next generation extremely large telescopes and conceiving novel control algorithms to deal with the challenges the future systems will confront. Since April 2016, Dr Korkiakoski has worked at the ANU Research School of Astronomy and Astrophysics as a Research Fellow concentrating on the adaptive optics for space situational awareness: improving the tracking of space debris and pushing it with high-power lasers.



**DAVID
BRODRICK**
SENIOR
SOFTWARE
ENGINEER

ANU

David Brodrick joined the ANU RSAA's Computer Section as a Senior Software Engineer in March. David's honours project was with the Cooperative Research Centre for Satellite Systems at the Queensland University of Technology, developing software for Australia's FedSat satellite. David then joined CSIRO Astronomy and Space Science where he was involved in control system development for the Australia Telescope Compact Array (ATCA), Parkes and Mopra radio observatories. David later contributed to the architecture and implementation of the control system for the Australian Square Kilometre Array Pathfinder (ASKAP) radio telescope. Most recently, David was employed by the European Spallation Source ERIC, a research consortium building the world's most brilliant neutron research facility near Lund, Sweden, where he led the work package to develop the controls for ESS's suite of fifteen neutron research instruments.



**DR MARCUS
LINGHAM**
POSTDOCTORAL
RESEARCH
FELLOW

ANU

Dr Marcus Lingham completed a Bachelor of Science (Photonics) and a Bachelor of Science (Optronics & Lasers) (Honours) at Swinburne University of Technology in Melbourne. He then completed his PhD in the field of ultracold quantum gases, also at Swinburne University. He then spent 2 years manufacturing and developing semiconductor lasers for a small company called MOGLabs based in Melbourne. He has since been working as a Postdoctoral Research Fellow for SERC and the Australian National University to assist the development of the Adaptive Optics for Tracking and Pushing Space Debris project.



**MICHAEL
COPELAND**
SERC PHD
CANDIDATE

ANU

Michael is a PhD student at the Advanced Instrumentation and Technology Centre (AITC), Australian National University (ANU). Michael is working on applying adaptive optics techniques used for astronomy for space situational awareness. He is designing and building an adaptive optics system for satellite and debris imaging for object characterisation and high precision tracking. Prior to commencing his PhD Michael worked as a systems engineer at the AITC where he worked on the GMTIFS instrument under development by the ANU for the Giant Magellan Telescope. Michael obtained a Bachelor of Engineering (Hons)/ Science from the ANU in 2015.



**ASSOC
PROF TONY
TRAVOILLON**
INSTRUMENTATION
SCIENTIST

ANU

Associate Professor Tony Travouillon joined the ANU Research School of Astronomy and Astrophysics (RSAA) AO group in 2018 to work on large telescope instrumentation and lead the Antarctic Astronomy group. Prior to joining the ANU, Tony worked for 14 years at the Thirty Meter Telescope (TMT) as a systems scientist, focusing in part on the development of high-risk components of the telescope's adaptive optics system such as its deformable mirrors and environmental sensors. He carried out the site testing for the project, measuring several atmospheric parameters key to the observatory performance and design drivers to the AO system. He obtained his PhD from UNSW in 2005 studying the Antarctic Atmosphere and its suitability for astronomical observations.



DR ROBERT NORMAN
RP2 PROGRAM
LEADER

RMIT UNIVERSITY

Dr Robert Norman is a Senior Research Fellow and member of the Satellite Positioning for Atmosphere, Climate and Environment (SPACE) Research Centre, and the Satellite Positioning and Navigation (SPAN) Laboratory at Royal Melbourne Institute of Technology (RMIT) University. Prior to joining RMIT, Dr Norman held research positions at La Trobe involving Telstra and Lockheed Martin subsidiary RLM, working on the Jindalee Over the Horizon radar project (JORN). Dr Norman's current research interests are in laser signal propagation using geometrical optics and atmospheric density modelling using Global Navigation Satellite System (GNSS) radio occultation. In addition to leading the SERC research team at RMIT, Robert is primarily responsible for the atmospheric density modelling and ray tracing research streams.



DR BRETT CARTER
ATMOSPHERIC
MASS DENSITY

RMIT UNIVERSITY

Dr Brett Carter received a BSc in Space Physics with First Class Honours from La Trobe University before completing a PhD specialising in high frequency radar backscatter from plasma irregularities in the high-latitude, auroral and sub-auroral latitudes. Dr Carter's main specialisation is in ionospheric plasma instabilities, which is important for many real-world applications.

Recently Brett has turned towards understanding the interactions between the charged particles and neutrals in the upper atmosphere due to the important role they play in understanding atmospheric drag on objects in low-Earth orbit.



DR JÉRÔME DAQUIN
POSTDOCTORAL
RESEARCH
FELLOW

RMIT UNIVERSITY

Dr Jerome Daquin received a Masters Degree in Applied Mathematics from Lille 1 University in 2011 and completed a Masters Degree in Astronomy and Astrophysics at Paris Observatory in 2012. Dr Daquin defended his PhD thesis on the long-term resonant motion of space debris, at Paris Observatory, in 2015.

His research interests are macroscopic properties of Earth satellite orbits, especially the presence of resonances and the transition order-chaos in the medium-range. Jerome also conducted research on model reductions and the establishment of effective equations in the context of highly oscillatory ordinary differential equations. These models are generally more amenable to analytical and/or numerical investigations.



DR EMMA KERR
POSTDOCTORAL
RESEARCH
FELLOW

RMIT UNIVERSITY

Dr Emma Kerr joined the RMIT Research team in February 2018. Emma has a PhD in Mechanical and Aerospace Engineering; and a Masters in Aero Mechanical Engineering both from the University of Strathclyde. Emma's research has been in orbit lifetime analysis. The aim of this research was to develop an accurate general perturbation tool for orbit lifetime analysis including an analytical time-variant and non-spherically-symmetrical atmospheric density model and an analytical solar activity model. Emma is continuing her atmospheric mass density work within RP2. Emma presented at the SERC Research Colloquium on Atmospheric Mass Density – Empirical Model.



DR YANG YANG
POSTDOCTORAL
RESEARCH
FELLOW

RMIT UNIVERSITY

Dr Yang Yang received his PhD from the School of Astronautics, Northwestern Polytechnical University, China.

Dr Yang is leading the Orbit Determination Work Package for Research Program 2 "Orbit Determination and Predicting Behaviours of Space Objects".

His current research interests include space debris tracking, orbit determination & prediction, nonlinear and non-Gaussian estimation/filtering, and GNSS-based LEO satellite orbit determination.



DR JULIE CURRIE
POSTDOCTORAL
RESEARCH
FELLOW

RMIT UNIVERSITY

Dr Julie Currie joined the RMIT SPACE Research Centre in March 2017 following the completion of her PhD at the University of Newcastle. Julie's PhD research was on the high latitude ionosphere using High Frequency radar data. Since joining RMIT her research has centred around space weather with particular focus on the properties of equatorial plasma bubbles in the ionosphere and adverse impacts on GPS applications. This research has been conducted in collaboration with the Bureau of Meteorology. Julie has since joined the RMIT SERC research team to investigate the impact of physics-based modelling of the upper atmosphere and ionosphere on atmosphere mass density modelling and satellite drag.



DR JAMES BENNETT
RP3 PROGRAM LEADER

SERC

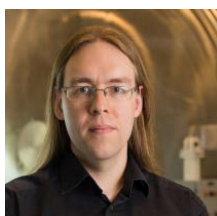
Dr James Bennett has over six experience in Astrodynamics and over 10 years' experience in industrial applied mathematics. Dr Bennett was awarded a PhD in Applied Mathematics from RMIT University in 2008. Dr Bennett is a member of the International Laser Ranging Service (ILRS) Governing Board and a member of the ILRS Western Pacific Laser Tracking Network (WPLTN). Dr Bennett is the SERC Research Program Leader for Research Program 3 and is responsible for the delivery of the SERC Space Object Catalogue and Conjunction Threat Warning Service. His research interests include orbit determination and prediction, conjunction assessments, applied mathematics, debris object characterisation, optical and laser tracking, and singular and regular perturbation methods.



DR STEVE GEHLY
RESEARCH FELLOW
ORBIT DETERMINATION

RMIT UNIVERSITY

Dr Steve Gehly grew up near Boston, Massachusetts in the USA before moving to Los Angeles to pursue his tertiary studies. Dr Gehly completed his undergraduate degree at the University of Southern California (USC), graduating with a BSc in Aerospace Engineering. Dr Gehly worked at Northrop Grumman for five years while obtaining his Master's degree at USC, and then moved to Colorado to pursue his PhD, specialising in orbit determination and space situational awareness. His dissertation research focused on multi-target estimation for space situational awareness (SSA) and other related applications such as sensor allocation and initial orbit determination. In 2015 Steve was appointed to a post-doctoral research position at RMIT to undertake research for SERC in the areas of orbit determination and sensor allocation.



DR MAREK MÖCKEL
RESEARCH FELLOW
HIGH PERFORMANCE COMPUTING

SERC

Dr Marek Möckel studied Computer Science at Braunschweig University of Technology while gaining his first hands-on experience within the Linux and open source software community. Before joining SERC, Dr Möckel worked on space debris environment models and fast orbital propagation at the Institute of Space Systems in Braunschweig. He credits his work in developing video games in the open source community to contributing to the practical skills he now applies to space research. Marek was inspired to work for SERC as it afforded him an opportunity to put his research to practical use whilst working in a field that ensures the safe use of one of the Earth's natural resources.



DR DANIEL KUCHARSKI
RESEARCH FELLOW
SATELLITE SPIN DYNAMICS

SERC

Dr Daniel Kucharski studied mechatronics at Warsaw University of Technology, with a particular focus on the use of laser technology for nano-scale measurements of surface properties. Dr Kucharski went on to study a joint PhD program with the Polish and Austrian Academies of Science, specialising in Satellite Laser Ranging (SLR) and spin determination of artificial satellites. Through his studies at the SLR stations Borowiec (Poland), The Space Research Institute in Graz (Austria), Hitotsubashi University (Japan) and the Korean Astronomy and Space Science Institute (South Korea), Daniel developed new methods for attitude and spin determination of the laser tracked objects. His work at SERC is devoted to the spin analysis and object characterisation from the light curve measurements.



DR SVEN FLEGEL
RESEARCH FELLOW
NON-LINEAR COVARIANCE PROPAGATION

SERC

Dr Sven Flegel studied Mechanical Engineering at the Technische Universität in Braunschweig, Germany, prior to aerospace where he specialised in space studies. Sven's thesis "Multi-Layer Insulation as Contribution to Orbital Debris", studied the mechanisms behind how insulating foils from spacecraft could separate to become part of the debris environment and how their orbits could evolve over time. Sven worked at the Institute of Space Systems where he upgraded a suite of space debris cataloguing software for the European Space Agency (ESA). He subsequently worked as a Research Scientist at the Fraunhofer Institute for High Frequency Physics and Radar Techniques, where he developed software for the simulation of radar measurements. Sven also performed an extensive analysis of the potential benefits of performing debris detection campaigns wherein objects with orbit inclinations below 50° could be observed. This led to the first debris detection campaign of the Tracking and Imaging Radar system in December 2015. He is currently working on the prediction of space object state uncertainties and collision risk for the SERC Conjunction and Threat Warning System.



DR MICHAEL LACHUT
RESEARCH FELLOW
ORBIT DETERMINATION & PREDICTION

SERC

Dr Michael Lachut completed his PhD in Applied Mathematics at the University of Melbourne, applying numerical and analytical methods to solve differential equations. Dr Lachut has applied his expertise to a broad range of fields, most notably in the field of micro/nano-mechanical sensing devices, and in the last two years in astrodynamics. He is currently working on improving drag and solar radiation force models in orbit determination and propagation, object characterisation and catalogue maintenance.

Michael has played an instrumental role in the development of the SERC Space Object Catalogue which will provide highly accurate ephemeris data (object position/velocity) to facilitate sensor object acquisition, conjunction analysis services to satellite operators and ground-based laser manoeuvres.



**JAMES
ALLWORTH**
GRADUATE
RESEARCH
ASSISTANT

SERC

James Allworth has recently joined EOS Space Systems after undertaking a Summer Research Internship with SERC and the ANU. James achieved first class honours in a combined Bachelor of Aeronautical Space Engineering/Bachelor of Commerce degree at Sydney University in 2016. James has been providing assistance with orbit determination and propagation research for SERC through the data analysis and the development of visualisation tools. James has an interest in machine learning and has commenced postgraduate studies in this field.



JOSEPH O'LEARY
GRADUATE
RESEARCH
ASSISTANT &
SERC PHD
CANDIDATE

SERC

Joseph O'Leary graduated from the Dublin Institute of Technology, Ireland in 2014 with a degree in mathematical sciences. Joseph received the Hamilton Award in Mathematics by Sir Roger Penrose in penultimate year of his undergraduate degree. Joseph was awarded scholarships by the University of South Australia to study relativity in space based satellite systems and a supplementary scholarship with the Space Environment Research Centre (SERC) to research orbit prediction models using the theory of relativity.



RESEARCH PROGRAM **FOUR**



**DR BENJAMIN
SHEARD**
RP4 PROGRAM
LEADER

SERC

Dr Benjamin Sheard has a Bachelor of Engineering, a Bachelor of Science and a PhD from the Australian National University. After completing his PhD he worked at the Albert-Einstein-Institute in Hanover, Germany for three years as a post-doctoral scientist working on laser interferometry for space based gravitational wave detection and for five years as a research scientist working on next generation geodesy missions, including the Gravity Recovery And Climate Experiment (GRACE) Follow-On Laser Ranging Interferometer. Before joining EOS Space Systems. Ben worked for two and half years as a systems engineer on instrument performance and analysis as well as control systems engineering for satellite optical instruments at OHB System AG near Munich, Germany. He is currently developing an instrumented satellite payload to support testing of the adaptive optics corrected laser system being developed by SERC.



**MR MATTHEW
BOLD**
PRINCIPAL
RESEARCHER

**LOCKHEED
MARTIN**

Mr Matt Bold is a Principle Researcher with the Lockheed Martin Space Systems Company Advanced Technology Center in Palo Alto, California, USA. His undergraduate studies were in physics and mathematics at the University of Dayton and graduate studies in high energy particle physics at Arizona State University. Since 1996 Matt has been studying the propagation of high energy lasers through the atmosphere with particular interest in the modelling of atmospheric optical turbulence and the performance modelling of adaptive optics systems. For the last ten years Matt has been involved in the space situational awareness research efforts at the UKIRT Telescope in Hawaii and the Lockheed Martin Space Object Tracking (SPOT) telescopes in Santa Cruz California. He is involved with the SERC Remote Manoeuvr research project assisting with system engineering and performance modelling and simulation.



**MR MIKE
PETKOVIC**
AITC TEST
FACILITIES
MANAGER

ANU

Mike Petkovic is the Test Facilities Manager at the ANU Research School of Astronomy and Astrophysics (RSAA) where he is responsible for managing astronomical hardware projects and the development of terrestrial and space instrumentation. Mike has a wealth of space hardware development experience and has held senior positions on the FedSat satellite mission and in the development of focal plane arrays and optics for the advanced along track scanning radiometer (AATSR) and along track scanning radiometer 2 (ATSR2) instrument and the Endeavour Space Telescope. He also led the mechanical assembly, integration and test (AIT) teams on the Systeme Pour l'Observation de la Terre 3 (SPOT3) and European Remote Sensing Satellite (ERS2) spacecraft, whilst on secondment in Europe, and worked on a number of defence projects whilst with Auspace and earlier with the Commonwealth Aircraft Corporation. Mike was awarded an engineering degree from Deakin University in 1982.



MR LIAM SMITH
RESEARCH
SCIENTIST

**LOCKHEED
MARTIN**

Mr Liam Smith is a Research Scientist with the Lockheed Martin Space Systems Company Advanced Technology Center (ATC) in Palo Alto, California, USA. His studies were in aerospace engineering at California Polytechnic State University San Luis Obispo where he was awarded an undergraduate and graduate degree. Since 2015 Liam has been studying the effects of high energy lasers on perturbing orbital debris in Low Earth Orbit. Liam has been involved in the space situational awareness research efforts at the UKIRT in Hawaii and the Lockheed Martin SPOT telescopes in Santa Cruz California. Liam is also involved in trajectory optimization and machine learning research at the ATC. Liam is also involved with the SERC Remote Manoeuvr research project assisting with system engineering and performance modelling and simulation.

1.4. PERFORMANCE AGAINST ACTIVITIES

SERC research is organised around four interdependent research programs, including:



RP1: TRACKING, CHARACTERISATION & IDENTIFICATION OF SPACE OBJECTS
Development of space debris-tracking hardware and adaptive optics-based solutions for reliable and accurate tracking of space objects



RP2: ORBIT DETERMINATION & PREDICTING BEHAVIOURS OF SPACE OBJECTS
Developing tools to improve the accuracy and reliability of orbit predictions for Low Earth Orbit (LEO) objects



RP3: SPACE ASSET MANAGEMENT
Creating algorithms, databases and techniques to improve conjunction prediction and prevent collisions in space



RP4: SPACE SEGMENT
Apply knowledge gained and technologies developed to manoeuvre space objects using ground-based lasers





RESEARCH PROGRAM ONE

Innovative techniques of active and passive object tracking to provide sufficient accuracy for orbit propagation and conjunction

PROJECT PARTICIPANTS

- Australian National University
- EOS Space Systems
- Lockheed Martin
- Optus Satellite Systems
- National Institute for Information and Communications Technology (Japan)

TRACKING, CHARACTERISATION AND IDENTIFICATION OF SPACE OBJECTS IN ORBIT

Program Co-Leaders: Professor Craig Smith & Dr Steve Gower

This research program is developing innovative techniques of active and passive object tracking to provide sufficient accuracy for orbit propagation and conjunction prediction.

The Active Track in Low Earth Orbit (LEO) research program is investigating and developing non-terminator acquisition and tracking of debris objects. The research is also developing new techniques to detect and provide precision orbit determination for new (currently un-catalogued) objects.



RESEARCH SNAPSHOT FOR 2018

- R1.1 Develop Passive and Active Track Sensors
- R1.2 Develop a Database for Historical Recall of Observations and Object Characterisation
- R1.3 Debris Characterisation by High Resolution Imagery
- R1.4 Development of Adaptive Optics
- R1.5 Develop Adaptive Optics Astrometry Capabilities
- R1.6 Develop High Power Lasers and Phased Laser Beam Combining

R1.1 DEVELOP PASSIVE AND ACTIVE TRACK SENSORS

Project lead: EOSSS

Participants: EOSSS, SERC

Researchers: Mark Blundell, Craig Smith, Lauren Glina, Daniel Kucharski, James Bennett

This project is designing and developing passive and active track sensors for objects at geostationary orbits. This includes technologies for telescopes, beam directors, detectors, lasers, timing systems, optical systems and command & control software.

The SERC GEO tracker telescope at Mt Stromlo has commenced routine operations. During the reporting period the telescope was commissioned to collect tracked data (information about space objects position over time) in furtherance of SERC's research goals.

During the reporting period, SERC researcher Daniel Kucharski completed the development, integration and testing of the SERC high-rate photo detector (HRPD) which will be used to measure the spin rate of satellites and generate data for more accurate characterisation of space objects. This will provide invaluable information to assist the selection of a space object target for manoeuvre as part of the RP4 experiment.

Work has commenced on automating the SERC GEO tracker routine operations, enabling data to be collected from either the telescope's charge-coupled-device (CCD) camera or the SERC HRPD.

SERC has commenced installation of HRPDs on two EOSSS telescopes in Australia. The first is located at Mount Stromlo and the second will be installed in Western Australia during the next reporting period. In addition, an international network of HRPDs is planned for implementation during the next reporting period with the installation of detectors in Japan, Austria, Poland, Korea and the USA. The integration of the data collected from this network will enable greater operational cadence and accuracy.

catalogueUI Home Satellites Observations Orbit Determinations Systems Info Health Check

OD Summary

ID	6457
Satellite ID	47
Satellite Norad ID	20026
Satellite Cospar ID	89039C
Satellite Name	COSMOS 2024 (ETALON 2)
OD Start Date	20180624000000
OD Span	3
OP Span	7
Record Status	SUCCESS
Reason	
Processing Started	20180628053809
Processing Completed	20180628055054
Scope version	3.1.1

OD Actions

- Update Status
- Check Generated CPF
- Check Residuals
- Check State
- Check Error against Obs
- Check Bias and RMS
- Check Covariance
- Check Satellite Data
- Check OD Assess
- Check Initial State
- Check Scope Output

SERC Space Object database OD user interface.
Credit: EOSSS

R1.2 DEVELOP A DATABASE FOR HISTORICAL RECALL OF OBSERVATIONS AND OBJECT CHARACTERISATION

Project lead: EOSSS

Researchers: David Kooymans, James Bennett, Alex Pollard, Michael Lachut

Participants: EOSSS, SERC

The SERC Space Object database has been created and is routinely running Two Line Elements (TLE) Orbit Determinations (OD) and using the results to characterise an initial state of regular ODs. The results are also being used as an input to the post processing of optical observations to maintain consistency with the observations. In addition, a number of time saving measures have been implemented to speed up the processing of the interface between the OD servers and the SERC Space Object database.

Work has been undertaken to provision observation ODs and TLE ODs to use a priori methods when the SERC Catalogue Orbit Prediction and Estimation Software (SCOPE) identifies that this will result in improved filtering process.

R1.3 DEBRIS CHARACTERISATION BY HIGH RESOLUTION IMAGERY

Project lead: ANU

Researchers: Francis Bennett, Michael Copeland, Visa Korkiakoski

Participants: ANU

A Scintillation and detection and ranging system (SCIDAR) has been designed and built and first light has been achieved. The generalised SCIDAR will be used to characterise the atmospheric turbulence above Mount Stromlo. This information will be used to optimise the AO system currently being developed. Work on the adaptive AO system is progressing well.

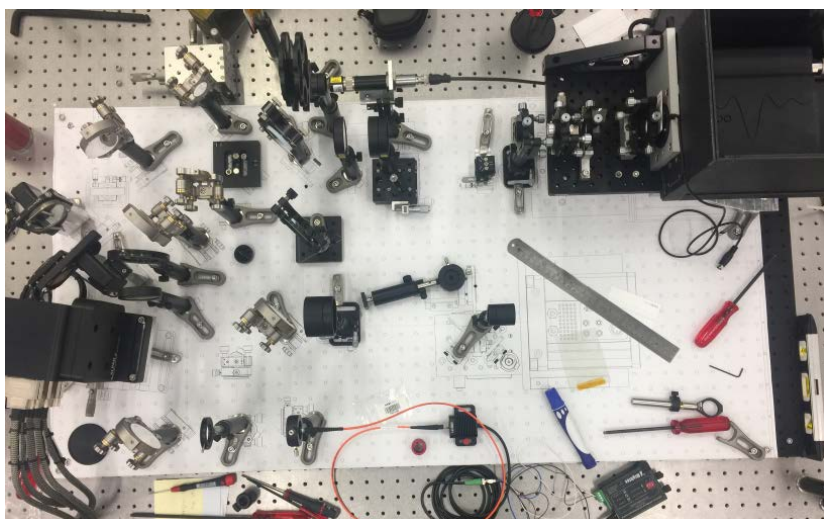
Development highlights include:

- The Stereo SCIDAR system has been designed and the requisite optics procured.
- The Adaptive Optics Imaging (AOI) system has been assembled in the AO lab and will be transported to the EOSSS Space Research Centre (SRC), Mount Stromlo in the next reporting period.
- AOI beam expander has been installed on the optical bench and integrated with the AOI/SCIDAR system.
- The AOI/SCIDAR system will be transported to the EOSSS SRC to be used to characterise space objects of interest for the remote manoeuvre experiment.

R1.4 DEVELOPMENT OF ADAPTIVE OPTICS

Project lead: EOSSS

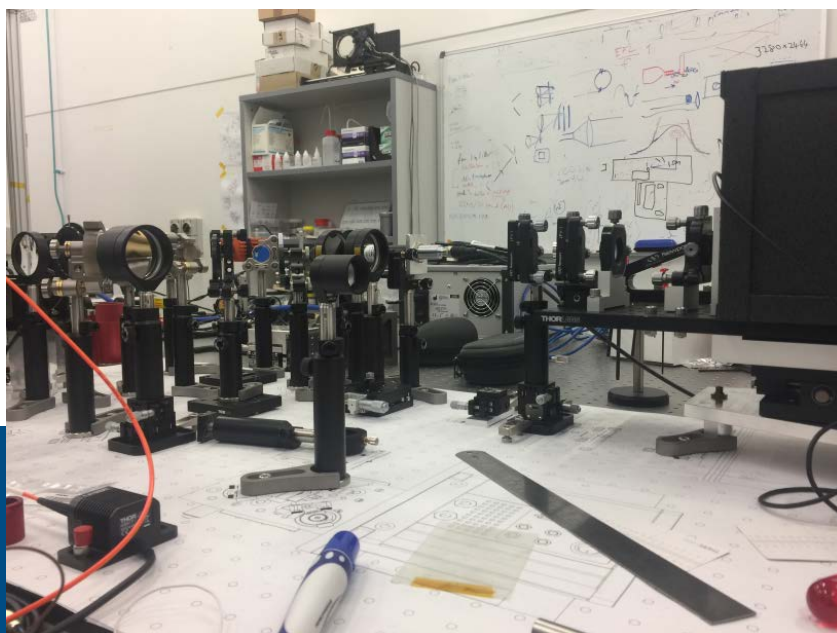
Researchers: Yue Gao, James Webb, Mark Blundell, Doris Grosse, Marcus Lingham, Celine d'Orgeville, Matthew Bold
Participants: ANU, EOSSS, Lockheed Martin



Left: AOI under development in the ANU AO Laboratory, Mount Stromlo, ACT



Above: Construction of the SERC telescope at EOSS facility in Queanbeyan, NSW



Right: Adaptive Optics system under development in the ANU Adaptive Optics Laboratory at Mount Stromlo, ACT

This research program is developing world leading AO capabilities that allow high intensity laser beams to be propagated through the atmosphere and is an enabling technology to support the remote manoeuvre experiment. The Adaptive Optics Tracking and Pushing system (AOTP) components have been designed and are under fabrication.

Further progress includes:

- Calibration instrumentation has been delivered in preparation for the lab testing of the AOTP.
- The high power deformable mirror (HPDM) has been repolished and preparations for recoating are underway.
- AOTP software development is progressing well. In particular the AO supervisory software which optimises the AO operation to enable the system to quickly acquire fast moving targets is nearing completion.

Beam Transfer Optics (BTO):

- BTO design has been completed and reviewed
- Most of the BTO components were fabricated and integration in the AO lab commenced during the reporting period.

Laser Launch Telescope (LLT):

- LLT parts have been manufactured and assembled and testing has commenced
- Testing of the LLT photodiode in high and low power modes has commenced

Guide Star Laser (GSL):

- The design of the GSL enclosure has been finalised and fabrication has commenced
- Successful operation of the GSL in the lab has been demonstrated. Effort now involves repackaging the laser and integrating it with the AOTP system.
- The GSL project benefitted from EOSSSS dedicating additional resources to this project and supporting parallel activities in the mechanical, electronic, optical and software development.
- Procurement of the fibres and equipment racks to enable the relocation of vibration sensitive GSL oscillators from the side of the telescope to the cleanroom.
- Repairs to the 1050 nm laser have been completed and operation at output power in excess of 30 watts was achieved.

GSL Mechanical:

- The GSL mounting brackets have been designed and components are being fabricated
- Support infrastructure such as chillers and equipment racks have been scoped and the necessary arrangements for their installation in the EOSSS SRC clean room have been made.

GSL Electrical:

- Duplication of the existing control hardware is underway. This will allow preliminary assessment and final control of the optical subsystems.
- Design of a cost effective and scalable solution for the GSL enclosure temperature control system has been completed.

GSL Software:

- Software activities have been concentrated on mitigating the risk of the untested laser subsystems, particularly the injection seeded amplifier within the 1342 nm subsystem.
- The amplifier appears to perform well optically, however, automatic locking of the amplifier is still in development. It is believed that this task is a deterministic engineering activity not requiring further research into possible solutions.

R1.5 DEVELOP ADAPTIVE OPTICS ASTROMETRY CAPABILITIES

Project lead: ANU

Researchers: Francois Rigaut, Celine d'Orgeville,
Michael Copeland

Participants: ANU, EOSSS

This program is developing an adaptive optics system that can reduce the point spread function of stars and targets (diffraction limit) so that higher accuracy astrometric solutions can be made to determine the absolute position on the sky of the GEO target. This will require development of high performance AO systems, sensors, calibration systems and algorithm development. R1.5 is closely linked to developments undertaken in R1.3 as they use the same AO hardware. R1.5 will utilise the Global Astronomical Interferometer (GEO GAIA) astronomical catalogue, a 3D catalogue of stars, as a natural guide star references. The method, concept, and expected performance

of the GEO GAIA method has been developed. End to end modelling and simulation of the AO system, uplink and target engagement performance has continued during the reporting period.

Lockheed Martin (LM) has provided additional data tables to other Participants. AO models have been upgraded to account for thermal blooming.

R1.6 DEVELOPMENT OF HIGH POWER LASERS AND PHASED LASER BEAM COMBINING

Project lead: EOSSS

Researchers: Yue Gao, Yanjie Wang, Amy Chan, Matthew Bold,
James Mason, Greg Madsen

Participants: EOSSS, Lockheed Martin

This research program is developing high power laser technologies and techniques to combine and phase multiple lasers for increased power, beam shaping and beam control to be used in the remote manoeuvre experiment.

High Power Lasers:

- Three YAM-2000-SM fibre 2 kW amplifier modules have been tested, with the fourth on order. This will enable high beam quality multi-kW CW laser combining using variable Bragg gratings (VBG).



ANU researcher in the ANU Adaptive Optics
Laboratory, Mount Stromlo, ACT
Credit: ANU

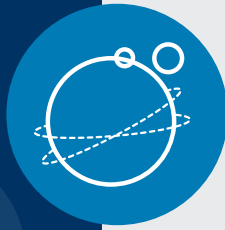


- The 10 kW laser which LM has agreed to loan to SERC has been packed for shipping from Palo Alto, USA to Canberra, Australia and will be used in the remote manoeuvre experiment.
- The bailment agreement between LMC and SERC is being drafted. In addition, the necessary maintenance plan with IPG Photonics is being arranged.
- The spectral linewidth of the LM laser will necessitate spatial combining with the SERC 8 kW laser. Work on this aspect will occur during the next reporting period.
- The above has emphasised the importance of narrowing the spectral linewidth of seed oscillators from the current 0.2 nm to 0.1 nm, and confirmed the need to actively cool the VBGs and implement motor-driven mounts for the VBGs to allow tuning of the diffraction angle accordingly.
- Different cooling schemes, including compressed air, helium gas and sandwiched structure putting VBG between high thermal conductive optical quality materials, such as sapphire and diamond as heatsink have been proposed and investigations are underway.

Laser Beam Combining:

- Various tests on the VBGs including absorption, transmission, temperature increase due to absorption and the consequent diffraction angle shift, diffraction efficiency and spectral linewidth changes have been conducted at different laser power levels.
- Beam combination of 2 wavelengths at different power levels has been achieved, however, the combination efficiency decreases with increasing power levels.





RESEARCH PROGRAM TWO

ORBIT DETERMINATION AND PREDICTING BEHAVIOURS OF SPACE OBJECTS

Program Leader: Dr Robert Norman

To predict future collisions between space objects, the orbit predictions that properly account for the variable space environment, e.g. the Earth's gravity field, atmospheric drag, solar magnetic disturbances and other perturbing forces, are required.

The primary objective of Research Program 2 is to develop advanced high precision orbit propagators.

***Orbit predictions
and atmosphere
models that
properly account
for the variable
space environment***

PROJECT PARTICIPANTS

- RMIT University
- National Institute of Information and Communications Technology (Japan)

RESEARCH SNAPSHOT FOR 2018

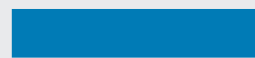
- R2.1 Develop Intelligent Systems for Real-Time Precision Orbit Determination (POD) for 'Controlled' Satellites.
- R2.2 Development of Reliable Orbit Determination (ROD) Algorithms and Software



2 PROJECTS



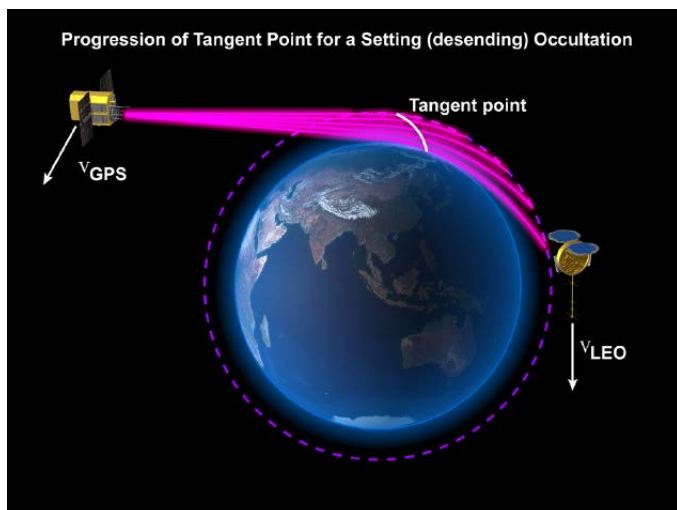
2 PARTICIPANTS



12 RESEARCHERS



7 STUDENTS



R2.1 DEVELOP INTELLIGENT SYSTEMS FOR REAL-TIME PRECISION ORBIT DETERMINATION FOR 'CONTROLLED' SATELLITES

Project lead: RMIT

Researchers: Robert Norman, Emma Kerr, Brett Carter, Julie Currie, Toshihiro Kubo-oka

Participants: RMIT, NICT

This research program is developing real-time POD software platforms that incorporate attitude modelling of 'controlled' satellites orbiting at a range of altitudes. The program will develop methods to accurately determine atmospheric mass density modelling through an improved understanding of the effects of perturbing influences, such as space weather. The POD software and report have been completed and delivered to RP3 researchers who will assess and incorporate it into the orbit determination software.

The GNSS POD software has also been completed and is undergoing on-site testing and validation at SERC. The software has the capability to process GPS two-frequency (L1/L2) pseudo-range and carrier phase measurements for precise orbit determination of low Earth orbit (LEO) satellites. This software will also provide a platform to validate the new and improved atmospheric mass density (AMD) models in terms of orbit prediction.

Testing of the new AMD software showed improvement over existing models. However, it was decided that further testing and refinement is required. The AMD software is currently undergoing testing using Planet Labs orbit ephemeris data and Stella and Starlette satellite laser ranging measurements. The AMD software developed includes models for both the neutral and ion densities in the low earth orbit atmosphere. The ion (predominately O+) density and complex dynamics have been included. The ion densities at altitudes of 1000 km can be as high as 30% of the total atmospheric density and this contributes directly to the overall atmospheric drag force.

R2.2 DEVELOPMENT OF RELIABLE ORBIT DETERMINATION (ROD) ALGORITHMS AND SOFTWARE.

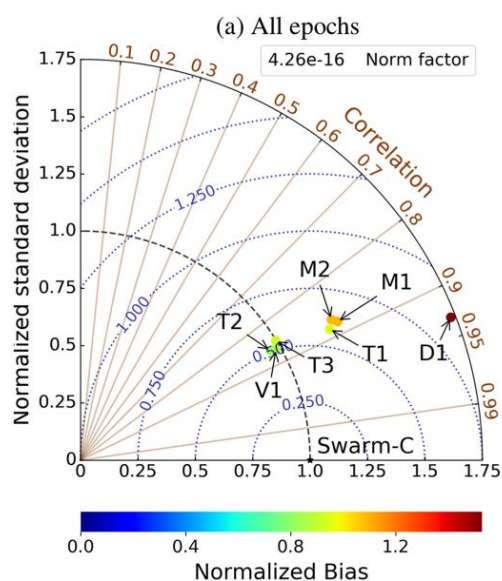
Project lead: RMIT

Researchers: Yang Yang, Jerome Daquin, Tetsuharu Fuse

Participants: RMIT, NICT

This program is developing advanced ROD platform for 'uncontrolled' space objects. The ROD software platform under development comprises versatile orbit determination algorithms that employ data from a variety of different sources; e.g. two-line elements data and satellite laser ranging (SLR). ROD Software package was delivered to SERC and RP3 on 30 June 2018.

The ROD software includes components for angular observation processing, which has been tested and validated based on Mt Stromlo datasets. More datasets (especially synchronised angles/SLR observations from the same station) are needed to test and validate the SLR processing components in the ROD software. This will be the focus of the R2.2 work over the coming 12 months.



Above: Radio Occultation Schematic
Image credit: Cosmic.ucar.edu

Top: Modified Taylor Diagrams showing Atmospheric Mass Density Model comparisons
Image credit Kodikara et al (2018)

Bottom: Soyuz MS-09 spacecraft docked at the International Space Station - Image Credit NASA



RESEARCH PROGRAM THREE

Systems that allow multi-national contributions to space object catalogues and a global distribution of asset management

SPACE ASSET MANAGEMENT

Program Leader: Dr James Bennett

This research program is developing techniques, algorithms and databases to predict and avoid potential collisions. This will provide a transparent and rational means to make decisions about asset management and how best to optimise assets and preserve the space environment.

A major focus is the development of systems that allow multi-national contributions to space object catalogues and a global distribution of asset management.

PROJECT PARTICIPANTS


- SERC
- EOS Space Systems
- Optus Satellite Systems
- RMIT University

NON-PARTICIPANT COLLABORATIONS

- University of Arizona
- University of Texas
- Graz Observatory, Austria


2 PROJECTS


4 PARTICIPANTS


14 RESEARCHERS


4 STUDENTS

RESEARCH SNAPSHOT FOR 2018

- R3.1 Develop a special Satellite Object Catalogue
- R3.2 Develop Conjunctions Analysis and Threat Warning (CATW)

R3.1 DEVELOP A SPECIAL SPACE OBJECT CATALOGUE (SOC)

Project lead: SERC

Researchers: James Bennett, Daniel Kucharski, Michael Lachut, Marek Möckel, Sven Flegel, Steve Gehly, Alex Pollard, David Kooymans, James Allworth,
Participants: SERC, Optus, EOSSS, RMIT

A core function of this research program is to develop a SOC containing space objects of interest. Several tools have been prepared to ensure quality data.

Observation based assessment of data quality:

- Extensive analyses have been performed on the data quality across all of the tracking systems available from EOSSS. This has allowed the data collection and ephemeris generation loop to be assessed for many different cases. The post-processor was unreliable when only using a single TLE and estimating the error state for propagation. This has been overcome by implementing a multi-TLE orbit determination process which smooths the effects of erroneous TLEs, and generates an error covariance matrix for track associations.
- The observations and ephemeris data are checked against reference objects in routine operations. These include the International Laser Ranging Service (ILRS) Geodetic objects.
- It was found that the automation of the ephemeris generation had issues for objects with highly eccentric orbits when the initial state was a TLE. An iterative solving approach is being adopted for these cases to decrease the number of orbit determination results being quarantined for manual intervention.

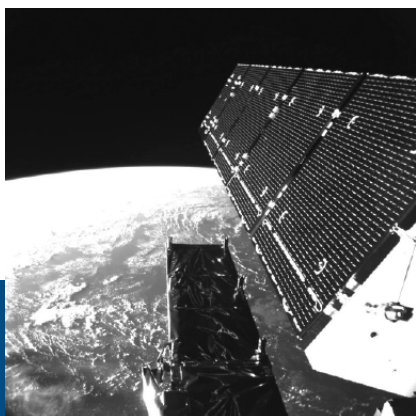
Improved SERC orbital elements and orbit propagations tested against highly accurate orbital ephemerides:

- This has been successfully integrated into regular operations and has been running as part of the ephemeris generation automation. The ILRS geodetic objects are used to validate the processes periodically. The astrometric accuracy is assessed using background star information, which directly affects the orbit quality. If the astrometric correction grows too large, a telescope mount model needs to be performed to maintain reliable star associations for observation corrections. Also, reference orbits from external organisations on non-ILRS objects have been used and external validation performed on the data accuracy.
- A high-accuracy orbital propagator has been written based on source code contributed by EOSSS. The code has been enhanced to support propagation of multiple objects and

outfitted with a modern interface and software architecture to facilitate optimisation for parallel computing. The code is currently being tested and will be used to propagate highly accurate orbital ephemerides from the object catalogue.

SOC database populated with data from SERC Participants:

- Optus ephemeris data is being stored for use in observation and ephemeris validation and for the integration into the conjunction assessment software. Recently, the orbital manoeuvre data and range observation data has been provided for testing of the manoeuvre modelling in the orbit determination code. This data will be delivered to the SERC database automatically when we are ready to use it in automated processes. Currently the orbital manoeuvre fitting is not in the production version of the automated orbit determination process. This is due to following safe coding practices.
- Lumini – a high rate photodetector for satellite light curve measurement has been developed and will contribute to the object characterisations by sampling the reflected sunlight from objects. This high rate sampling gives a very accurate knowledge of an object spin characteristics. The detector unit consists of several functional blocks and allows for satellite brightness measurements at the high sampling rates of up to 100,000 samples per second.
- Network infrastructure has been set up to collect light curve analysis data. SERC Participants can now upload their contributions to the SERC server via secure file transfer protocol (FTP).



Left: Sentinel 1 – solar wing showing impact damage from space object. Credit ESA

Above: Planewave 0.7m telescope, Credit: Planewave Instruments

R3.2 DEVELOP CONJUNCTION ANALYSIS AND THREAT WARNING (CATW) CAPABILITY

Project lead: SERC

Researchers: James Bennett, Marek Möckel, Sven Flegel,
Daniel Kucharski, Michael Lachut, Steve Gehly

Participants: SERC, Optus, EOSSS, RMIT

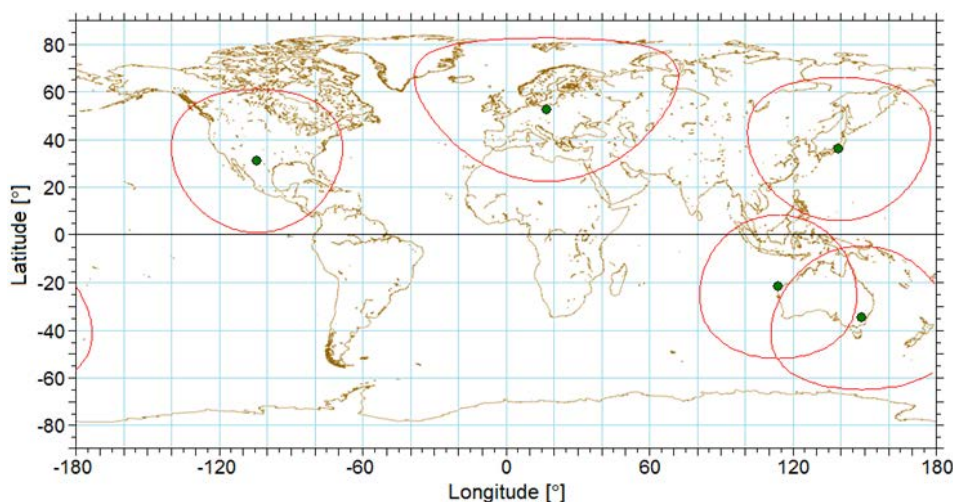
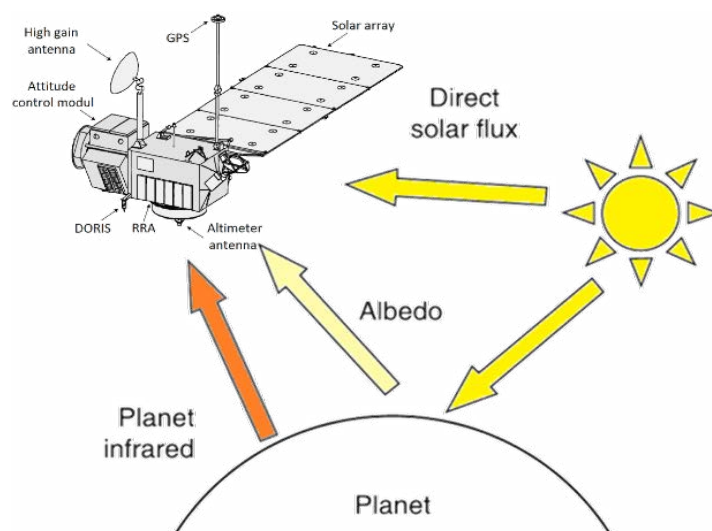
SERC is developing a conjunction analysis capability system for all objects (all-on-all conjunction analysis) in the SOC and provide alerts to subscribers. The SERC conjunction system will also distribute priority tasking to sensors in the SOC network to provide increased tracking and updating for serious potential collision prospects.

Protocols and procedures for automated distribution of conjunction warnings and sensor tasking developed and distributed to trial participants:

- The orbital propagation algorithms have been discussed with external partners. The conjunction data message structure is being developed as the conjunction assessment software reaches maturity. An early version of the conjunction data message has been developed. The automated distribution will begin when the numerical propagation is fully integrated into the conjunction assessments.
- The protocols and procedures for sensor tasking after a conjunction assessment have been automated. Trials were performed on EOSSS tracking sensors.
- A differential Entropy-based Multivariate Normality (MVN) Test has been developed. The test relies on the comparison of covariance propagated in linearised and non-linearised fashion. The linearised version employs a state transition matrix. The non-linearised version employs an unscented transform. It is much faster than the Henze-Zirkler test but requires calibration.
- A user-Interface for inspection of predicted close approaches is being developed. A Qt/OpenGL based user interface has been initiated which contains basic functionality to inspect predicted close approaches.
- The multi-sensor information gain based sensor scheduling for the network has been tested at Stromlo and interfaces have been generated by EOSSS to parse the schedule generated by the SERC scheduler.

Trial conjunction analysis and sensor tasking with lead-in customers (SERC Participants) completed:

- Network infrastructure has been set up to collect light curve analysis data. SERC Participants can now upload their contributions to the SERC server via secure FTP
- Preparations are underway to provide secure and authenticated access to the conjunction threat warning system for SERC Participants. This system can later be used in a commercial context. The conjunction assessments are running nightly on Optus objects. There have been follow up tracking from conjunction assessments completed in discrete campaigns and now the work is being put to automating the closed-loop service. The probability of conjunction is being integrated into the conjunction assessment capability and the method to estimate the expected breakdown in Gaussianity is being tested for integration into the catalogue. This is an important component for actionable conjunction knowledge.



Above: Possible high rate photodetector sensor locations and FOV @ 1000 km

Left: Solar photon pressure force and torque on TOPEX.



RESEARCH PROGRAM *FOUR*

Preservation of the Space Environment

SPACE SEGMENT

Program Leader: Dr Benjamin Sheard


Apply knowledge gained and technologies developed in research programs 1-3 to manoeuvre space objects using ground-based lasers.



5 PROJECTS



3 PARTICIPANTS



14 RESEARCHERS



4 STUDENTS

PROJECT PARTICIPANTS

- ANU
- EOS Space Systems
- Lockheed Martin

NON-PARTICIPANT COLLABORATIONS:

- UNSW Canberra

RESEARCH SNAPSHOT FOR 2018:

- R4.1 System Engineering
- R4.2 Payload Development
- R4.3 Demonstration of Remote Manoeuvre of Space Debris and Photon Pressure
- R4.4 Bus and Payload Integration
- R4.5 Launch and Operations

R4.1 SYSTEM ENGINEERING

Project lead: SERC

Researchers: Benjamin Sheard, Liam Smith, Mike Petkovic, Francis Bennet

Participants: SERC, ANU, Lockheed Martin

Non Participants: UNSW

RP4 has been focusing on an opportunity to include a secondary payload on an Australian cubesat scheduled for launch in November 2018. A hosted payload is a cost-effective risk mitigation strategy which will negate the necessity for SERC to launch a dedicated satellite to measure laser irradiance on-orbit.

The system engineering for this payload has been completed. The payload will consist of a pair beacon assemblies to enable tracking and assessment of the adaptive optics system; and a pair of photodiodes to measure laser irradiance on-orbit.

R4.2 PAYLOAD DEVELOPMENT

Project lead: SERC

Researchers: Benjamin Sheard, Mike Petkovic, Andrew Bish, Gaston Gausachs, Francis Bennet

Participants: SERC, ANU

The system engineering work resulted in the development of a prototype of the sensor and beacon assembly which successfully passed vibration testing. Improvements to the design were identified and implemented and the project moved towards the manufacture, assembly, integration and test phase for the flight payload.

The main PC-104 card with the analogue to digital converter (ADCs) and Inertial Measurement Unit (IMU) was also put through vibration testing as a risk mitigation as the earlier vibration test used the original design without the SERC payload components. No critical issues were identified and the flight as well as flight spare PC-104 boards were manufactured by UNSW for integration in the flight spacecraft. The components for the flight sensor and beacon assembly were procured and partly

assembled. Additional photodiodes were procured to increase the number available for spares. Modifications to a calibration system were identified as necessary after performing an end-to-end test with the engineering model.

Although the software for the flight payload computer has been finalized, the flight software on the on-board computer (OBC) for the SERC payload is still being developed. Spare detector assemblies have been sent to the National Measurement Institute in Sydney for spectral calibration in preparation for data analysis of the planned RAAF Mission 1 (M1) solar calibration experiments. These tests will also inform the specification of an optical bandpass filter for a future payload.

R4.3 DEMONSTRATION OF REMOTE MANOEUVRE OF SPACE DEBRIS AND PHOTON PRESSURE

Project lead: SERC

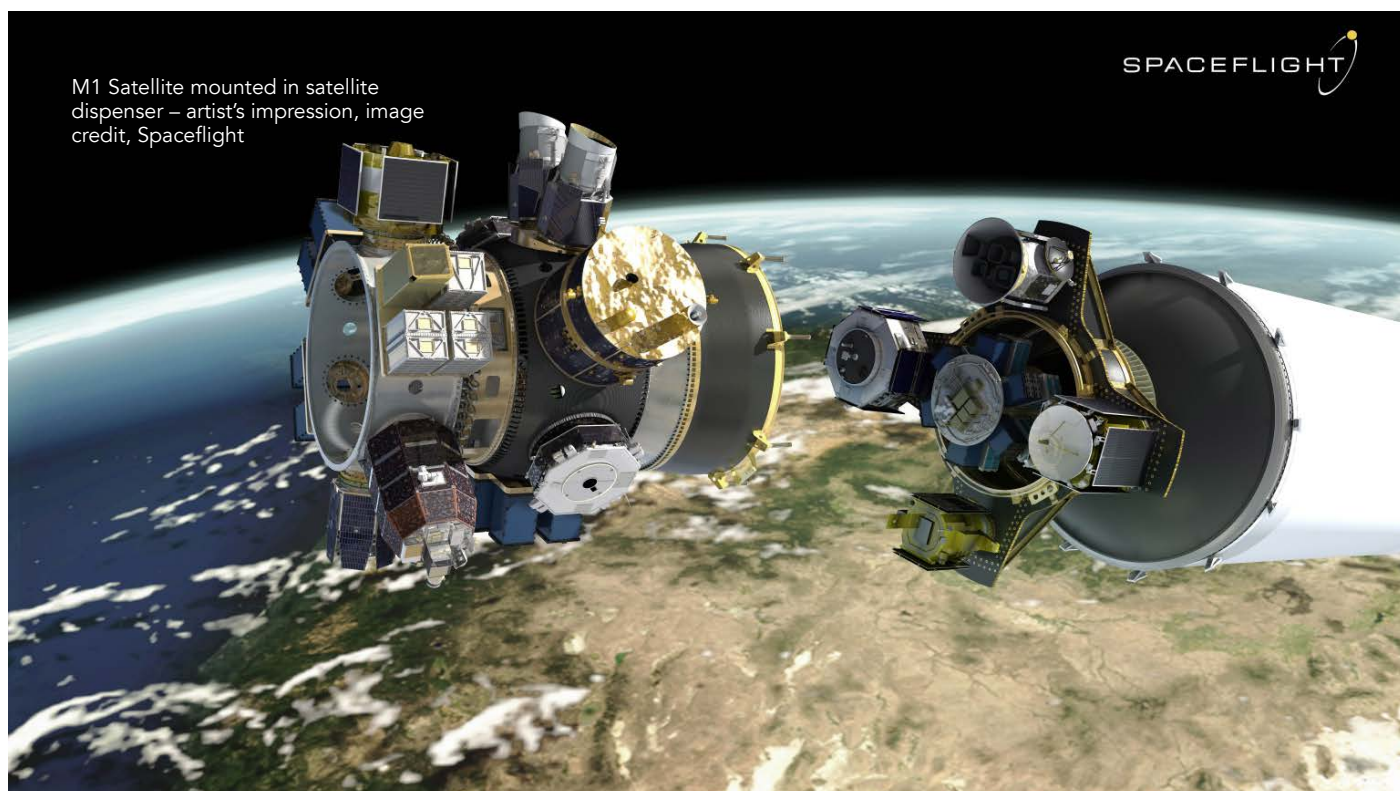
Researchers: Benjamin Sheard, Matthew Bold, Ben Greene, Craig Smith, Yue Gao

Participants: EOSSS, ANU, Lockheed Martin

This program combines the outputs of active tracking, orbit computation and beam propagation through the atmosphere to make small but measurable changes to the orbit of a space object. The aim of the project is the demonstration of a practical active collision avoidance system using photon pressure.

SERC has developed a high-rate photomultiplier-based detector for characterisation of debris objects to facilitate manoeuvre detection. A further five detector systems are under construction and will be located across a network extending from Europe, Asia, North America to Australia. Once deployed, SERC will begin a characterisation campaign to identify debris objects suitable for a remote manoeuvre demonstration.

The M1 Cubesat with the SERC payload is scheduled for launch in late 2018. SERC is pursuing the option of early experiments (e.g. tracking the LEDs beacons as soon as possible, illuminating the spacecraft with the output of a single 2 kW fibre amplifier) as the southern-hemisphere summer solstice is likely to have



M1 Satellite mounted in satellite dispenser – artist's impression, image credit, Spaceflight

SPACEFLIGHT

some advantages in terms of operation and it is expected that the space environment will degrade critical components of the satellite such as the LEDs and photodiodes over time. Operations, especially early operations involving illumination with a laser, will require agreement third parties such as UNSW.

R4.4 BUS AND PAYLOAD INTEGRATION

Project lead: SERC
Researchers: Benjamin Sheard, Mike Petkovic
Participants: SERC, ANU
Non Participants: UNSW

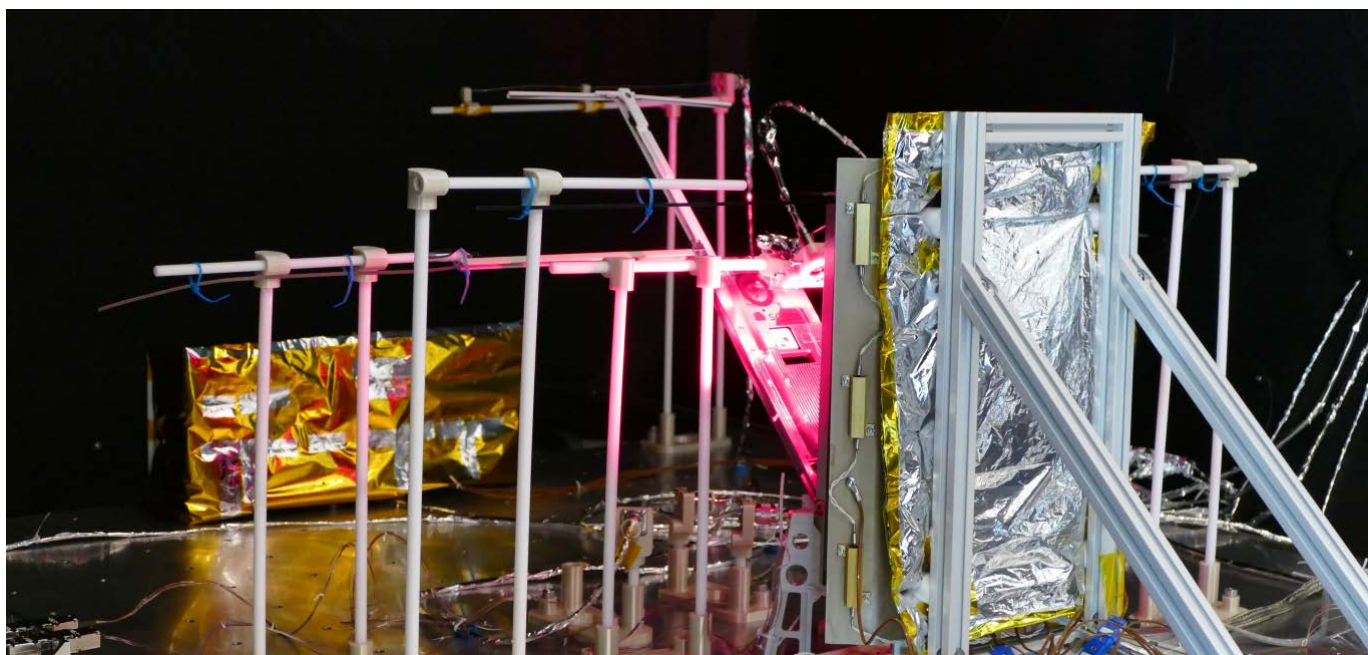
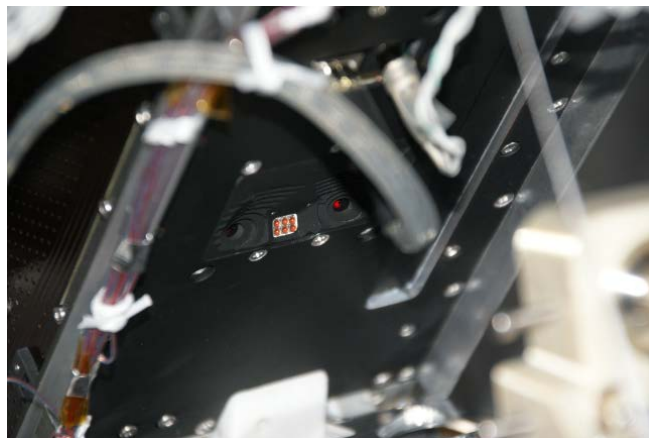
The focus of for the first half of 2018 has been the integration of the SERC payload into the M1 CubeSat. The assembly of the flight model components of the payload were completed and the payload was successfully integrated into the flight model satellite after performing initial checkout at the payload level.

After integration with the spacecraft the payload was tested for its spatial response and successfully passed a thermal vacuum (TVAC) test campaign. The spacecraft with the SERC payload underwent a successful acceptance vibration test and operation of the photodetectors and LEDs were confirmed.

R4.5 LAUNCH AND OPERATIONS

Project lead: SERC
Researchers: Benjamin Sheard, Mike Petkovic
Participants: SERC, ANU
Non Participants: UNSW

Launch of the hosted payload is scheduled for late 2018. The M1 Cubesat has been packed and transported to Spaceflight's facility in Seattle for integration prior to shipping to the launch site.



SSO-A:
Smallsat Express

Single largest dedicated rideshare mission on a US launch vehicle.

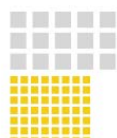
Launch Vehicle: SpaceX Falcon 9
Launch Site: Vandenberg Air Force Base
Destination: Sun Synchronous Lower Earth Orbit



70+
spacecraft

35+
customers

Microsats: 15



Cubesats: 56

Countries
represented: 18



Top: SERC payload mounted in the RAAF Mission 1 (M1) spacecraft undergoing testing

Middle: TVAC testing of M1 Satellite with SERC payload

Left: Small Sat Express infographic (includes M1 Payload)

1.5. EDUCATION AND TRAINING

SERC has undertaken to enrol 24 postgraduate students and graduate 10 over the five-year Commonwealth funding period.

During the fourth year of operation, SERC exceeded student enrolment commitments by awarding the 26th SERC PhD scholarship to an outstanding candidate. A further highlight during the period was the graduation of the second SERC PhD candidate, Dr Samuel Francis.

SERC is on track to meet or exceed its commitment of 10 or more students submitting their PhD thesis by the end of the five-year funding period.

STUDENT INVOLVEMENT IN SERC ACTIVITIES

SERC's education priorities include building capability in the space industry sector, providing professional development and industry placement opportunities for SERC PhD candidates and creating opportunities for knowledge transfer and research collaboration. Throughout the reporting period, SERC continued to provide education and training opportunities for SERC scholarship recipients including involvement in the following activities:

PhD Candidate Professional Development Day

SERC PhD candidates took part in a professional development day at Mount Stromlo in March 2018. Students presented a 20 minute overview of their research project to members of the international Research Management Committee, SERC Executive and Research Program Leaders. Students were then given the opportunity to discuss any challenges they were experiencing and receive feedback and guidance from international subject matter experts.



Dr Samuel Francis

Dr Samuel Francis graduated with a PhD from the Australian National University in December 2017.

Dr Francis' research focused on the simplification of the optical design of inter-satellite laser links. Samuel designed an optical fibre interferometer to move the optical design complexity into digital signal processing.

This achievement has contributed to SERC RP1 research in the area of optical phased array and continuous wave laser ranging projects.

Sam has relocated to the USA and is currently working at NASA's Jet Propulsion Laboratory.



SERC PhD Candidate Professional Development Day, Mount Stromlo March 2018



PhD Candidate Stromlo Residential

Two University of South Australia PhD candidates spent an extended period at Mount Stromlo with their RP3 supervisors to develop a strong foundation in astrodynamics to support their research. This intensive training was designed to meet the individual student's needs and research requirements. The students' areas of research involve the modelling of collision probability of short-term encounters in LEO and relaxing the spherical cannonball assumption in orbit predictions.

SERC Research Colloquium

SERC PhD candidates participated in a three day Research Colloquium at Mount Stromlo Observatory during the reporting period. The Colloquium was attended by all SERC Participants and end-users and afforded students the opportunity to network and collaborate with senior SERC researchers and potential collaborators and employers. Students attended presentations covering all SERC research programs and gained a greater understanding of SERC activities and their role in the SERC research program.

Presentations at International Industry Conferences

SERC students receive, as part of their scholarship award, a discretionary fund of \$3,000 to attend and present at international conferences and industry symposia. This affords students the opportunity to network with international space industry professionals and gain experience presenting to international audiences.

During the 2017-18 reporting period, SERC students presented more than 14 papers at nine international

conferences including the Advanced Maui Optical Society (AMOS) conference in Hawaii, the International Astronautical Conference in Adelaide and the Australian and New Zealand Control Conference on the Gold Coast.

Student Publications

SERC students were listed as authors on 16 publications during the reporting period. A full list of SERC publications is provided at Appendix 1.

Research Exchanges

During the 2017 Research Colloquium, SERC researcher Dr Daniel Kucharski relocated to the University of Texas in Austin as a visiting researcher to continue his SERC spin characterisation work under the supervision of Associate Professor Moriba Jah.

STEM AND COMMUNITY OUTREACH

STEM X Academy - SERC supported the Australian Science Teachers Association (ASTA) STEM X Academy for the third consecutive year. STEM X is a five-day residential professional learning program for primary and secondary teachers of science, technology, engineering and mathematics. This innovative professional development program delivers access to resources, networks and methods and empowers teachers to structure their classrooms as laboratories for STEM-authentic problem solving to develop and inspire the next generation of space scientists.

SME ENGAGEMENT

Small to medium enterprise (SME) representation in the Australian space sector is largely comprised of technology companies and service providers who support international space missions and provide solutions to owners of space based infrastructure.

A further market segment comprises companies who provide goods or services which rely on satellite technology. This industry sector has much greater SME representation.

SERC supports SME engagement across the space industry sector through the following activities:

SME Participants

EOSSS is an SME Participant and represents the interests of SMEs within SERC. Professor Craig Smith, CEO and Technical Director, EOSSS is a co-leader of RP1. Through leading the RP1 research team, Professor Smith ensures that SME interests are considered through the delivery of SERC research outcomes.

Board Representation

Independent Board Member, Mr Brett Biddington, AM, is an SME business owner and ensures that SME interests and perspectives are considered at a Board level. Further, EOS took up a Board position in December 2017 thereby increasing SME board representation.

Research Management Committee Representation

SME interests are represented at the Research Management Committee (ResMC) level through participation by the EOS Group Chief Executive Officer and the EOSSS CEO.

Conferences and Industry Events

SME engagement and consultation on a national and international level is achieved through participation at space industry conferences, workshops and symposia. During the reporting period SERC representatives attended over 20 space industry events and held meetings with a broad range of SME space industry professionals.

International Aeronautical Congress September 2017

SERC exhibited at the International Astronautical Congress (IAC) as part of the Department of Industry, Innovation and Science "Big Country, Big Sky, Big Ideas" exhibition stand in Adelaide. IAC is the world's largest space conference and was attended by 4500 space industry delegates. SERC representatives engaged with international space industry SMEs during the congress and identified opportunities for further international SME engagement for further hosted payloads. Extensive industry engagement was achieved through participation at IAC.

SERC management met with national and international space sector operators including Airbus Defence and Space, Boeing, Fleet Space Technologies, Inovor Technologies, Lockheed Martin, Planet Labs, SpaceX and SSL to brief them on SERC activities.

The meetings discussed the need for the establishment of an international space traffic management capability and to explore potential additional hosted payload opportunities. Discussions were held with several entities which will likely result in SERC adding additional satellite fleets into the RP3 conjunction assessment research.

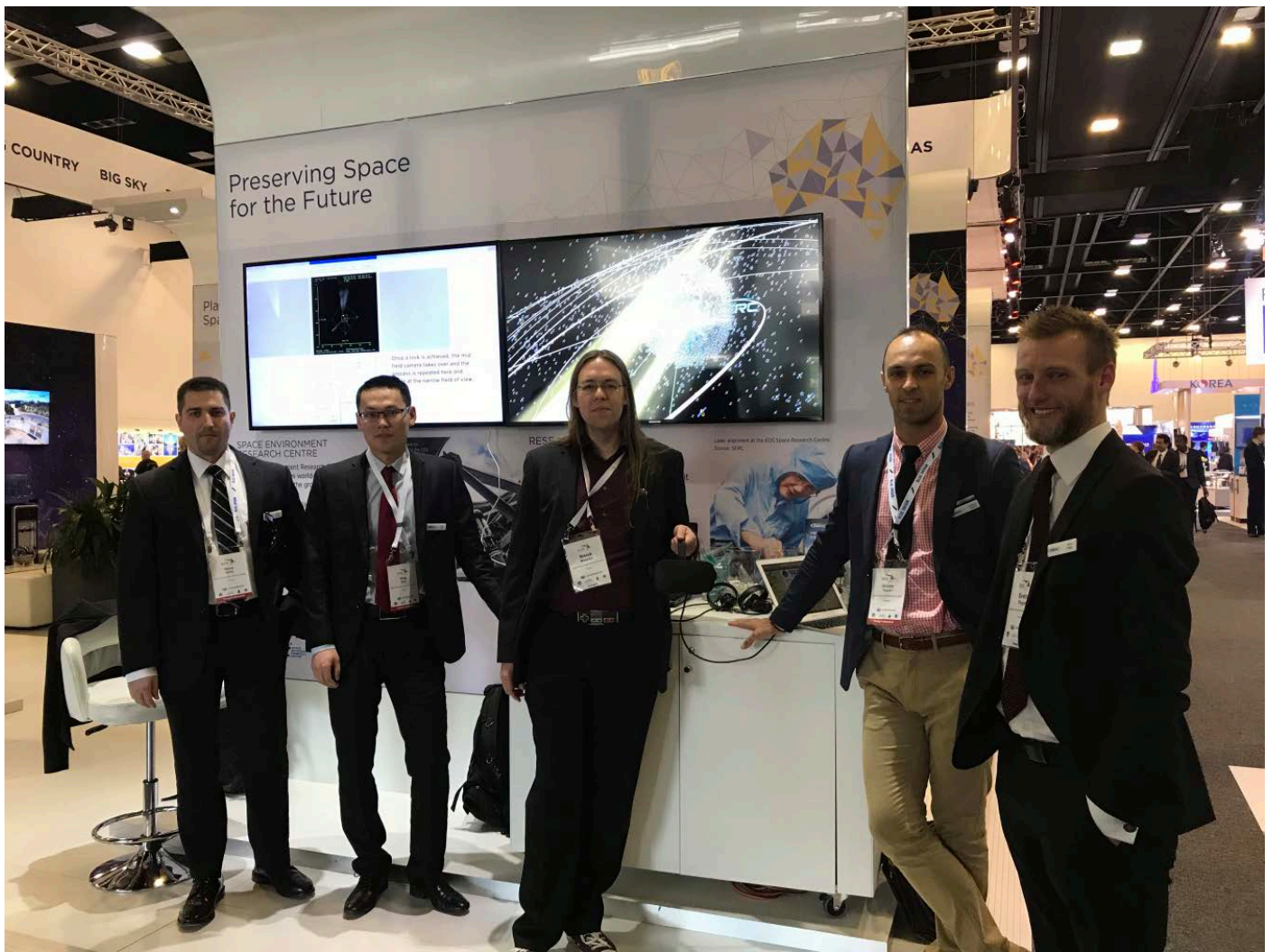
Space Working Group

SERC is a member of the ACT Government Space Working Group (SWG). The SWG has a number of SME space industry representative members and has recently signed an MOU with the South Australian and Northern Territory Governments to expand collaborations.

Top: SERC exhibition booth at IAC 2017 in Adelaide. SERC Researchers (L to R) Steve Gehly, Yang Yang, Marek Moeckel, Jerome Daquin and Sven Flegel

Bottom right: The SERC Space Object Catalogue virtual reality experience was demonstrated at IAC 2017

Bottom left: Department of Industry, Innovation and Science "Big Country, Big Sky, Big Ideas" exhibition booth at the International Aeronautical Congress (IAC) 2017



1.6. COMMERCIALISATION

During the reporting period, SERC contributed just over half a full time equivalent (FTE) to utilisation activities. These activities comprised integration of the RP1 GeoTracker telescope into the EOSSS sensor network; and RP3 research outputs into the EOSSS sensor scheduling and object propagation software.

These integration activities will enable SERC to undertake on orbit photon pressure experiments. It is expected that EOSSS will benefit as an SME from integration of these research outputs through increased commercial opportunities

in future years. SERC is not expected to undertake any commercialisation activities during the funding period. The opportunity to commercialise SERC IP will be available to SERC Participants in accordance with the Commonwealth Agreement.

1.7. INTELLECTUAL PROPERTY

SERC is employing industry best practice in the management of Intellectual Property (IP) as detailed in the National Principles of Intellectual Property Management for Publicly Funded Research.

In support of IP management, SERC:

- Adheres to the *Australian Code for the Responsible Conduct of Research*
- Has clear policies and procedures in relation to the ownership and associated rights for all IP generated through Centre activities (Centre IP).
- Has clear policies relating to the exploitation of IP generated through Centre activities.
- Makes all Centre IP openly accessible through licencing arrangements which provide exclusive opportunities to undertake commercial exploitation.
- Provides support to researchers in identifying, developing and protecting Centre IP whilst upholding the academic requirement to publish.
- Provides guidance in relation to potential conflicts concerning IP management, ownership, promotion, dissemination, exploitation and, where appropriate, protection of IP.
- Provides guidance on the licensing of copyright, in particular, the criteria for publishing under the terms of open access licences.

The *SERC Intellectual Property Confidentiality and Disclosure Policy* was reviewed by the SERC Governing Board during the reporting period. This Policy makes clear to all staff their responsibilities in relation to IP management including, where appropriate, the maintenance of research records (including lab books where possible, and field notebooks) and the handling of research results prior to promoting and disseminating the IP or obtaining IP protection.

IP Awareness and Training

To build awareness of the importance of IP amongst researchers, SERC has implemented a number of initiatives:

1. Numbered lab notebooks have been issued to all SERC researchers and students.
2. Prior to publication approval being given, all publications and presentations are vetted by SERC for unintentional disclosure of Centre IP.
3. Participant Quarterly Reports have a section relating to IP. Information disclosed in these reports is used to populate a comprehensive register of both Participant background IP and Centre IP developed during the quarter.

No registered IP was sold, transferred or licensed for commercialisation during the reporting period.

1.8. COMMUNICATIONS

SERC communication activities during the 2017-18 reporting period focused on:

- Strengthening internal communication and collaboration amongst Participants; and
- Strengthening brand recognition and awareness of SERC activities within the national and international space sector.

In addition, the SERC Communications Strategy was reviewed and updated in line with Commonwealth annual reporting requirements.

INTERNAL COMMUNICATION

SERC Newsletter

The SERC newsletter, *SERCular*, is published quarterly and distributed to Participants, students and stakeholders to strengthen internal communication and collaboration. The newsletter features articles about research progress, publications, awards and accolades, researcher profiles, upcoming events and informs participants about SERC activities.



Left: SERC Colloquium, SERC CEO David Ball and RP2 Leader, Robert Norman, RMIT

Below: SERC PhD Candidate, Hansani Perera, presenting her PhD outline at the SERC PhD candidate development day



Meetings with Participants

SERC management meet regularly with Participants to foster communication and ensure all aspects of the CRC are running as efficiently as possible. This is especially important with Participants who are not located in the same physical location.

SERC CEOs, Dr Ben Greene (to December 2017) and David Ball (from December 2017), met with senior representatives from each end-user Participant organisation to ensure that SERC research is addressing their needs and requirements. In addition, SERC General Manager - Research, Dr Steve Gower, attended weekly, fortnightly and monthly research and technical meetings to ensure that the research is tracking well against research and utilisation and milestones. Dr Gower updates the Research Master Schedule following these meetings and prepares a monthly research progress overview for the Board.

In addition, extensive liaison and strategy meetings have been held with Participant organisations and key researchers to discuss appetite for and resource requirements to extended the wind-up period of SERC to facilitate an additional six months on-sky for the SERC remote manoeuvre experiment. The extended wind up of SERC is further discussed in Section 3 (Additional Requirements) of this Annual Report.

Colloquium

The SERC Research Colloquium is held annually to foster communication and collaboration at a whole of Program level. The Colloquium is an opportunity to brief all researchers, students, and Research Management Committee members on research progress and success, monitor the research schedule at a whole of Program level and identify areas where potential slippage could occur and identify opportunities for further research and collaboration.

LinkedIn

SERC established a LinkedIn profile during the last reporting period to track SERC alumni. This initiative enables SERC to keep in touch and track the careers of SERC Scholarship students and post-doctoral researchers.

Quarterly Reports

Participants compile reports on their progress against milestones on a quarterly basis. Individual reports are compiled into a whole of organisation progress report which is circulated to Participants twice annually.

SERC Research Colloquium

The 2018 SERC Research Colloquium was held over three days from 20 -23 March at Mount Stromlo Observatory, Canberra and was attended by SERC researchers, students and Participant organisations. The format of the Colloquium changed from previous years with 26 presentations including progress reports from each of the SERC research programs and sub-programs split across instrumentation, data collection and analysis, and targets sessions. Chair of the Research Management Committee, Dr Ben Greene, presented a whole of organisation overview outlining the path forward and timelines for the remote manoeuvre experiment. Through these presentations, all members of the organisation gained a deeper understanding of program, end-user requirements and commercialisation pathways.

SERC's latest appointment to the Research Management Committee, Mark Skinner, gave a presentation titled Conceptual Development of a Civil Space Traffic Management (CSTM) Capability. This provided researchers with a greater understanding of the requirements necessary for a global CSTM system.

Program Review Meetings

Program test plan review meetings were conducted for all research programs in accordance with the Commonwealth Agreement utilisation milestones. In addition, a whole of organisation review meeting followed the 2018 SERC colloquium. This enabled an inter-research program and cross-organisation (Participant) review and has informed the development of a master schedule which tracks the progress and delivery of research, and delivery of milestones including utilisation milestones.

EXTERNAL COMMUNICATION

Establishment of the Australian Space Agency

SERC has been successful in raising awareness of space debris and space situational awareness (SSA) across the space industry sector. The Australian Space Agency refers to both debris and SSA in its communications and has SSA listed as one of the Agency's priority areas.

Website

The SERC website informs Participants, students, space industry stakeholders and the public about SERC objectives and research activities. Content was further developed during the reporting period and traffic to the site has grown significantly with 17,000 views being recorded during the reporting period and 50,000 since establishment.

Facebook

SERC Facebook page continued to attract support during the reporting period. Posts have highlighted SERC events and activities as well as space debris stories of interest. SERC maintained an average of three posts or reposts per week which has resulted in 693 likes from 170 posts to the SERC Facebook page.

Press and Radio Coverage

SERC issued a number of press releases throughout the year which resulted in significant media coverage including:

- two television interviews including ABC National News;
- one international BBC interview and subsequent podcast;
- four radio interviews; and
- 62 web stories about SERC activities.

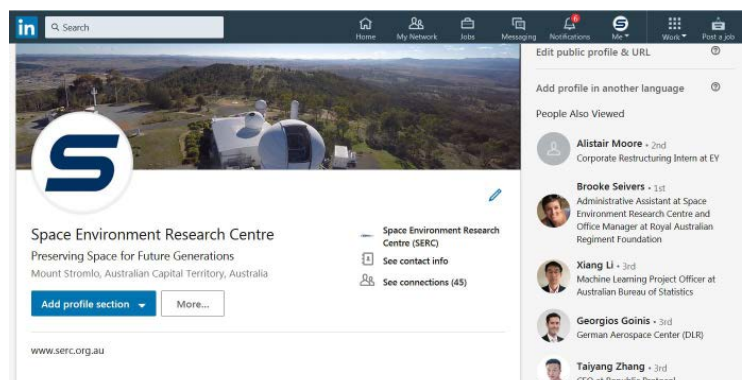
Industry Liaison and Conference Attendance

SERC continued to build brand awareness and further clarify non-Participant end-user requirements through signing of Memoranda of Understanding and non-disclosure agreements (NDA) with 3rd party end-user organisations, and participation at national and international events and conferences. During the reporting period:

- SERC supported 96 researchers and students to participate in technical meetings, and deliver technical papers at more than 52 national and international conferences and symposia including the International Astronautical Conference (Adelaide), International Laser Ranging

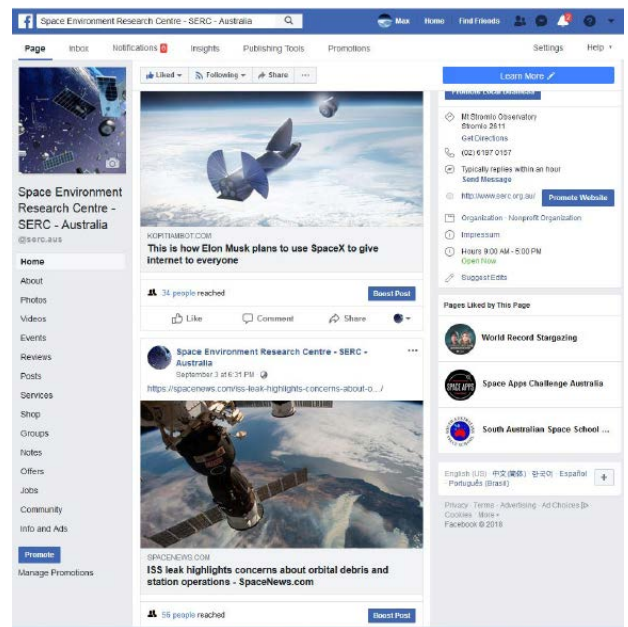
Workshop, (Riga, Latvia), AMOS, (Maui, USA) and the European Conference on Space Debris, (Darmstadt, Germany). Conference attendance enables SERC researchers and students to network with space industry professionals and communicate SERC research objectives and success to a national and global audience.

- The SERC CEO participated in an Aerospace Sector Workshop which was facilitated by KPMG on behalf of the NSW Government. The NSW Government is currently reviewing their industry development plans for the aviation and space sectors.
- The SERC CEO was also invited to join the Steering Committee of the bid-team for the CRC for Space Systems and Advanced Communications (SmartSat CRC). This CRC could potentially further develop some of the research started by SERC. The bid has been submitted to the 20th CRC selection round.
- The CEO also continued in his role as Board Member and Treasurer of the Space Industry Association of Australia (SIAA) and participated in a strategic planning session to determine the development goals for the SIAA following the successful outcome achieved in hosting IAC2017.
- The CEO participated in a panel on International Space Traffic Management at the Satellite 2018 conference (Washington DC, USA) and also moderated a panel on "Collisions in Space – Virtual and Physical" at the Satellite Industry Forum (Singapore).
- Dr Jerome Daquin gave an Invited presentation, "Resonances, chaos and transport in terrestrial orbits" at the Department of Aerospace and Mechanical Engineering, University of Arizona, Tucson
- Dr Daquin was also awarded a travel grant to present two papers at Dynamics Days 2018, Jan 4-6, Denver, Colorado.
- The article by J. Daquin, A.J Rosengren, E.M Alessi et al, "The dynamical structure of the MEO region: long-term stability, chaos, and transport", CMDA (2016) awarded during the CELMEC VII conference (3-9 September 2017 in Italy) for the best original research paper on Celestial Mechanics and Astrodynamics.
- Professor Craig Smith was invited to present a keynote address at the 5th European Workshop on Space Debris Remediation in Paris in June 2018.
- Signed an MOU with The Polish Academy of Sciences (Polish: Polska Akademia Nauk, PAN) to facilitate scientific exchange and collaborative research.
- Signed an NDA with a European company to enable



Left: SERC Researchers at International Society for Optics and Photonics (SPIE), Austin, Texas

Above: SERC is building a presence on LinkedIn



Above: SERC Facebook page is gaining popularity
Top left: The SERC Newsletter, SERCular is distributed quarterly to Participants
Bottom left: Television interview with CNBC Asia
Below: IWLR2018 website and prospectus

information exchange and facilitate discussions re hosting payloads on future satellite missions.

- Signed an NDA with a low-earth orbit satellite operator to exchange satellite fleet ephemeris data and discuss SERC atmospheric density modelling.
- Signed an NDA with a service provider for collaboration on RP3 research.
- Commenced negotiations to establish an NDA with a geostationary satellite operator to cover exchange of satellite ephemeris data for RP3 conjunction analysis.

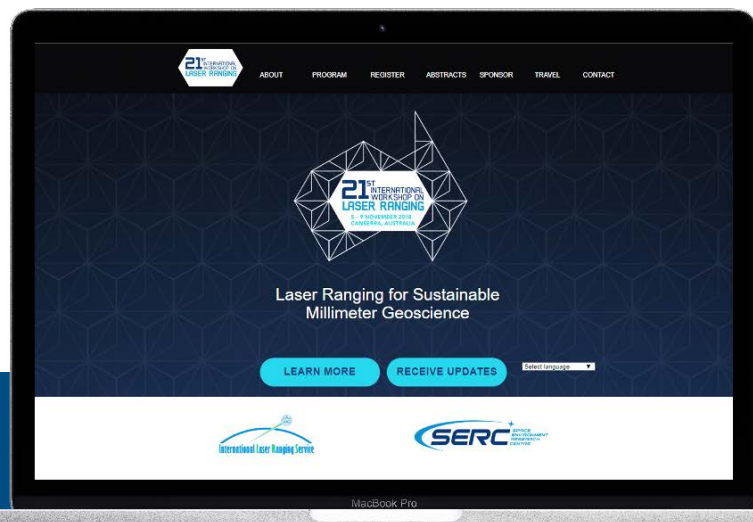
Publications and Citations

During the reporting period SERC research was presented more than 83 times across formal and other publication categories and the total number of SERC citations reached 252 citations. Through publications and citations, SERC is building brand awareness, developing a reputation for delivering world class research and education, and gaining acknowledgement for making a significant contribution towards global space debris management efforts.

International Workshop on Laser Ranging (IWLR)

SERC utilisation milestones include delivering an international workshop to communicate SERC research outcomes to an international audience. SERC was successful during the last reporting period in winning a bid to host IWLR 2018. This event will be held in Canberra from 5-9 November 2018 and is regarded as the world's leading workshop in this field. Planning and organisation of this event is well advanced with sponsorship and registration targets tracking to schedule. Current registrations include delegates from international space agencies, space research centres and universities including (but not limited to):

- NASA
- Smithsonian Astrophysical Observatory
- German Research Centre for Geosciences
- European Space Agency (ESA)
- International Laser Ranging Network Stations from around the world including observatories from Europe, USA, China, Korea and Australia.



1.9. GOVERNANCE – BOARD, COMMITTEES AND KEY STAFF

SERC is an Australian Public Company, Limited by Guarantee. SERC was endorsed by the ATO as a registered charity on 10 April 2014 and is exempt from income tax under Subdivision 50-A of the Income Tax Assessment Act 1997.

The SERC Board of Directors was established, on 10 April 2014, with three Independent Directors. An Industry Participant Director and a Research Participant Director were elected to the Board on 18 November 2014.

The term for the Industry and Research Director appointments expired during the 2017 financial year. The Nominations and Remuneration Committee sought nominations of potential Directors from the Membership.

Professor Min Gu (RMIT) was nominated for the Research Director position (effective from 26 October 2017) and Dr Ben Greene (Electro Optic Systems) was nominated for the Industry Director position (effective from 11 December 2017). The nominations were approved by the SERC Board and SERC Members confirmed the appointments at the 2017 Annual General Meeting on 26 October 2017.

The Board governs SERC in accordance with the SERC Constitution which was adopted by Members at the 22 May 2015 General Meeting. Amendments to the Constitution were adopted by Members at the 22 October 2015 Annual General Meeting. The SERC Board has adopted, and operates within, the Cooperative Research Centre's Programme Principles for CRC Governance.

The Board delegates to Board Committees and management in accordance with the SERC Delegations of Authority Policy, which was adopted in March 2015 and reviewed annually or as required. The Delegations of Authority Policy was last updated and approved on 18 May 2018.

SERC BOARD OF DIRECTORS



**PROFESSOR
MARY O'KANE
AC
INDEPENDENT
DIRECTOR,
CHAIR**

Professor Mary O'Kane is Principal of O'Kane Associates, a Sydney-based company specialising in major government and research reviews. She is Chair of the New South Wales Independent Planning Commission and a company director, being Chair of the Cooperative Research Centre for Digital Health, the Institute of Marine and Antarctic Studies Board at the University of Tasmania, and FrontierSI, and a Director of the Capital Markets CRC and the Innovative Manufacturing CRC. She was New South Wales Chief Scientist & Engineer from 2008-18 and Vice-Chancellor of the University of Adelaide from 1996 to 2001. She was formerly Chair of the Australian Centre for Renewable Energy and is a former member of the Australian Research Council, the CRC Committee, the Tax Concession Committee, the board of the CSIRO and the board of F.H. Faulding & Co Ltd. She is a Fellow of the Academy of Technology and Engineering and an Honorary Fellow of Engineers Australia.



**MR BRETT
BIDDINGTON
AM
INDEPENDENT
DIRECTOR**

Mr Brett Biddington is the founder of a Canberra-based consulting firm that focuses on space and cyber-space policy, security and industry development matters. He led the team that delivered the International Astronautical Congress in Adelaide in 2017. He is a director of the Institute for Regional Security, a Canberra-based 'think-tank' and is Chair of the Advisory Committee of the Victorian Space Science Education Centre (VSSEC) in Melbourne. Between 2002 and 2009 Mr Biddington was a member of the Global Space Team of Cisco Systems. This followed a 23 year career in the Royal Australian Air Force where he specialised in intelligence, security and capability development. Mr Biddington sponsored a wide range of command and control, intelligence, surveillance and reconnaissance projects, including the Jindalee Over the Horizon Radar Project (JORN) and classified space projects. In 2012 he was admitted as a Member of the Order of Australia for services to the space sector.





**MS ELIZABETH
WHITELAW**
**INDEPENDENT
DIRECTOR**

Ms Elizabeth Whitelaw is a former senior partner of law firm Minter Ellison. She is an experienced board member, having performed both Chair and non-executive Director roles for government-owned corporations, partnership boards, advisory bodies and not-for-profit organisations. Ms Whitelaw was a member Minter Ellison's National Partnership Board, Canberra, Chair of Partners, a National Government Industry group leader and leader of the Canberra Infrastructure and Finance team. Ms Whitelaw was also Minter Ellison's board representative on the National Risk Assessment and Management Committee.



MR ROD DRURY
CSC
**INDUSTRY
PARTICIPANT
DIRECTOR**
(FROM JULY 2014 -
11 DEC 2017)

Mr Rod Drury is the Managing Director, Australia and New Zealand for Lockheed Martin Space. In this role he is responsible for the execution and growth of LM Space's portfolio of products and services across Australia and New Zealand. Mr Drury has significant experience in the global aerospace sector, where he has held various levels of responsibility including strategy, governance, business development, government relations, program management and research and development activities. Mr Drury is a member of the Board of the Space Industry Association of Australia and a member of the South Australian Space Council.



**PROFESSOR
MATTHEW
COLLESS**
**RESEARCH
PARTICIPANT
DIRECTOR**
(FROM DEC 2015 –
26 OCT 2017)

Professor Matthew Colless is Director of the Research School of Astronomy and Astrophysics at the Australian National University (ANU). He was previously, for nine years, the Director of the Australian Astronomical Observatory (AAO). He obtained his BSc at Sydney, his PhD at Cambridge, and has held positions at Durham, Kitt Peak and Cambridge as well as AAO and ANU. Professor Colless is a Fellow of the Australian Academy of Science, an Honorary Fellow of the Royal Astronomical Society, an ISI Citation Laureate and a former Vice-President of the International Astronomical Union. He is a member of the ANU Council, the ANU's Founder representative for the Giant Magellan Telescope (GMT) project, and the Australian astronomer on the European Southern Observatory Council.



**PROFESSOR MIN
GU (FAA, FTSE)**
**RESEARCH
PARTICIPANT
DIRECTOR**
(APPOINTMENT
FROM 26 OCT
2017)

Professor Min Gu is Distinguished Professor and Associate Deputy Vice-Chancellor at RMIT University and was a Laureate Fellow of the Australian Research Council. He is an author of four standard reference books and has over 450 publications in nano/biophotonics. He is an elected Fellow of the Australian Academy of Science as well as the Australian Academy of Technological Sciences and Engineering. He is also an elected Fellow of the Australian Institute of Physics, the Optical Society of America, the International Society for Optical Engineering, the Institute of Physics (UK), and the International Institute of Electric and Electronic Engineers. He was Present of the International Society of Optics within Life Sciences and Vice-President of the Bureau of the International Commission of Optics (ICO) (Chair of the ICO Prize Committee, Galileo Galilei Award Committee) and a Director of the Board of the Optical Society of America. He was awarded the Einstein Professorship of the Chinese Academy of Science (2010), Laureate Fellowship of the Australian Research Council (2010), the W. H. (Beattie) Steel Medal of the Australian Optical Society (2011), the Ian Wark Medal and Lecture of the Australian Academy of Science (2014), and the Boas Medal of the Australian Institute of Physics (2015), and the Victoria Prize for Science and Innovation (2016). Professor Gu was elected as a Foreign Fellow of the Chinese Academy of Engineering in 2017.



DR BEN GREENE
**INDUSTRY
PARTICIPANT
DIRECTOR**
(APPOINTMENT
FROM 11 DEC 2017)

Dr Ben Greene is the Group Chief Executive Officer of Electro Optic Systems (EOS). Dr Greene is internationally recognised for his expertise in space research and the development and commercialisation of innovative solutions in the tracking, monitoring and management of space debris. He is also the author of numerous patents and the architect of a number of international space tracking systems.

DIRECTOR	BOARD MEETINGS	
	Number Eligible to Attend	Number Attended
Professor Mary O'Kane	6	6
Mr Brett Biddington	6	6
Ms Elizabeth Whitelaw	6	5
Professor Matthew Colless	3	3
Mr Rod Drury	3	3
Dr Ben Greene	3	3
Professor Min Gu	3	3

MEETINGS OF DIRECTORS

The number of Directors' meetings and number of meetings attended by each of the Directors of the Company during the reporting period are listed on the table to the left.

Table 1: Meetings of Directors 2017-2018
Financial Year

SERC COMMITTEES

The SERC Board is advised by the following Board Committees; Audit and Risk Committee, Contracts and Licences Committee, Nominations and Remuneration Committee and Research Management Committee.

Audit and Risk Committee

The Audit and Risk Committee is a Committee of the Board and assists on matters pertaining to financial reporting, audit and risk management including:

Financial Reporting – Review accounting policies, statutory financial statements, structure and format of management financial reports and monitor any developments likely to affect financial reporting.

Audit – Review audit plans, results and reports of the external audit and satisfy itself that management's response to audit recommendations is adequate. Evaluate the independence and effectiveness of the external auditors and recommend to the Board any changes that may be required. To be responsible for ensuring that internal control policies and procedures are in place in relation to safeguarding assets and the maintenance of reliable and detailed financial records.

Risk – Review the SERC Risk Management Policy and framework and recommend it to the Board. Monitor risks by making inquiries of management and the auditors about risks or exposures and assess the steps taken by management to minimise risk. Maintain the Risk Register and ensure it is provided regularly to the Board, highlighting areas where the residual risk is considered high. Review the schedule of insurances annually and maintain the Risk Register.

Synergy was retained as the SERC independent auditor during the reporting period.

Contracts and Licences Committee

The Contracts and Licences Committee (CLC) is a Committee of the Board and assists with the identification, disclosure and management of actual, apparent or perceived conflicts of interest.

SERC Directors and the SERC CEO complete and update conflict of interest forms annually (and as required) and the information is maintained as a register of declared personal interests. Where there is no actual, perceived or apparent conflict of interest, and the SERC CEO is not aware of circumstances suggesting the contrary, the CEO may approve contracts in accordance with the Delegations of Authority Policy without referral to the CLC.

Where an actual, apparent or perceived conflict of interest exists, the CLC shall review a referral providing details of the contractual arrangement or licence proposed and consider any actual, apparent or perceived conflict of interest and the application of the Corporations Act, SERC Constitution, and Conflict of Interest Policy to the arrangement. SERC management refers any contractual arrangement or licence falling within the Committee's Terms of Reference of the Committee for consideration. During the reporting period seven referrals were considered by the Committee.

A monthly report outlining any contract or expenditure cumulatively over \$10,000 (with any supplier, over a rolling 12-month period) is compiled by management, checked against the conflicts of interest register and made available to the Committee for review on request.

COMMITTEE MEMBER	Audit and Risk		Contracts and Licences		Nominations and Remuneration		Research Management	
	A	B	A	B	A	B	A	B
Professor Mary O'Kane			1*	1*	0**	0**		
Mr Brett Biddington	2	2	1*	1*	0**	0**		
Ms Elizabeth Whitelaw	2	2	1*	1*	0**	0**		
Mr Rod Drury	1	1						
Ms Jane Tisdall	2	2						
Dr Ben Greene							2	1
Associate Professor Moriba Jah							2	1
Dr Fumihiko Tomita							2	2
Professor Craig Smith							2	2
Mr Andrew Edwards							2	2
Ms Elaine Sadler							2	1
Dr Mark Skinner							2	2
Mr Matthew Bold							2	2
Mr David Ball							1	1

Table 2: SERC Committee meetings
A=Number of meetings held during the time the Committee Member held office
B=Number of meetings attended

* In addition to formal meetings, the CLC considered seven referrals during the reporting period

** While the NRC did not formally meet as a committee during the Financial Year, the Constitutional requirement for the Board to approve Director nominations was met during the non-executive sessions at the Board meeting prior to the SERC AGM

Nominations and Remuneration Committee

The Nominations and Remuneration Committee (NRC) is a Board Committee with the principal function of ensuring that appropriate controls and processes are in place to identify all risks relating to nominations and remuneration and that these risks are being effectively monitored and managed. The NRC considers the appointment/reappointment of Board and Committee members and makes recommendations to the Board accordingly. The Committee also considers the appointment and remuneration of the SERC CEO.

Research Management Committee

The Research Management Committee (ResMC) is a Board committee which advised the Board on decisions relating to the SERC Research Program, including setting research priorities, identifying education and student development opportunities and providing recommendations to the Board on utilisation, intellectual property and commercialisation issues.

The Committee provides expert advice to the Board on the scope and effectiveness of research activities; whether the

program is on target to meet research objectives; and assists in identifying worldwide developments in relation to space technologies and space debris mitigation.

The principal function of the ResMC is to:

1. evaluate the merits of proposed research activities;
2. advise the Board on the conduct and nature of research undertaken by SERC;
3. ensure the research undertaken is scientific in nature and is, or may prove to be, of value to Australia; and
4. administer the SERC Research Fund to determine how philanthropic funds are applied to research purposes.

The Committee has representation from international research Participants, end-user Participants, SME Participants and independent subject matter experts. During this reporting period, ResMC members attended the SERC 2018 Research Colloquium and whole of Research Program meeting to review progress against the SERC Master Schedule, identify impediments to achieving research outcomes and make recommendations to update the Research Master Schedule to include integration interdependencies.

NAMES AND SPECIAL RESPONSIBILITIES

EXPERIENCE AND KEY SKILLS



MS JANE TISDALL

Audit and Risk Committee

Financial Controller, DMTC Ltd

Ms Jane Tisdall was appointed as an independent member of the Audit and Risk Committee in September 2015. Ms Tisdall is the founder of a virtual CFO services firm providing on-demand accounting services to SMEs and not for profit organisations. Prior to commencing her own consulting business, Ms Tisdall worked in the corporate and not for profit sector for almost 20 years. She spent 12 years working in public practice providing accounting, taxation and business services to a diverse range of clients ranging from servicing client public unlisted companies, not for profit entities, small to medium sized private entities, self-managed superannuation funds and individual taxpayers. Ms Tisdall was Financial Controller of DMTC Ltd from September 2011 – March 2018 and held the position of Company Secretary for 5 years. Ms Tisdall holds a Bachelor of Business/Arts (Japanese) from Swinburne University, is a CPA, Chartered Accountant, registered tax agent and an Associate Member of the Governance Institute of Australia.



DR BEN GREENE

Chair of the Research Management Committee

Dr Ben Greene is the Group Chief Executive Officer of Electro Optic Systems Pty Limited (EOS). Dr Greene is internationally recognised for his expertise in space research and the development and commercialisation of innovative solutions in the tracking, monitoring and management of space debris. He is also the author of numerous patents and the architect of a number of international space tracking systems.



PROFESSOR MORIBA JAH

Independent member of Research Management Committee

Associate Professor Aerospace Engineering and Engineering Mechanics

The University of Texas at Austin

Dr. Moriba Jah received his BSc in Aerospace Engineering from Embry-Riddle Aeronautical University, Prescott, Arizona, and his MSc and PhD in Aerospace Engineering Sciences from the University of Colorado specializing in astrodynamics and statistical orbit determination. While working at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, CA, he was a spacecraft navigator on several Mars missions. Dr. Jah worked next at the U.S. Air Force Research Laboratory where he was the Technical Advisor for Satellite guidance, Navigation, and Control, and also the Mission Lead for Space Situational Awareness. Dr. Jah is an elected Fellow of the Air Force Research Laboratory, the American Astronautical Society, the International Association for the Advancement of Space Safety, and the Royal Astronomical Society. He is also an elected member of the International Academy of Astronautics and an Associate Editor of the Elsevier Advances in Space Research, official journal of the Committee on Space Research (COSPAR).



MR ANDREW EDWARDS

Member of Research Management Committee

Manager Satellite Support Optus Satellite Systems

Mr Andrew Edwards has over 30 years' experience in Satellite Operations and Orbit Dynamics. He is currently manager of the team which is responsible for the spacecraft engineering, orbit dynamics and computer equipment for current and future Optus operated spacecraft. Andrew has supported mission analysis, station keeping, propulsion subsystem and fuel life estimation for all five generations of Optus's spacecraft.


**PROFESSOR
ELAINE SADLER**

Independent member of Research Management Committee

Director, Centre of Excellence for All Sky Astrophysics (CAASTRO)

Elaine Sadler is Professor of Astrophysics in the School of Physics at The University of Sydney, and Director of the Australian Research Council Centre of Excellence for All-sky Astrophysics (CAASTRO). Professor Sadler was elected as a Fellow of the Australian Academy of Science in 2010, and is currently a member of the Council of the Academy. She has served as President of Division VIII (Galaxies and the Universe) of the International Astronomical Union (2009-2012) and Chair of the National Committee for Astronomy (2010-2012), and currently chairs the CSIRO ATNF Steering Committee. As CAASTRO Director, Professor Sadler oversees a 180-strong team of scientists and research students across seven Australian university nodes and 11 partner institutions around the world.


**DR FUMIHIKO
TOMITA**

Member of Research Management Committee

Vice President, Member of the Board National Institute of Information and Communications Technology (NICT) Japan

Dr Fumihiko "Tom" Tomita is responsible for research strategy at the National Institute of Information and Communications Technology (NICT) Japan. Dr Fumihiko is also a member of the Telecommunication Technology Committee responsible for future ICT innovation projects. He was awarded a BS degree in physics and MS and PhD in geophysics by the Tohoku University of Japan. After an appointment as Assistant Professor of Tohoku University, he joined the Radio Research Laboratory (RRL) which later became NICT. He has been supervising various research strategies and programs in NICT including the Space Weather Forecast Program and is currently the Chief Research and Strategy Officer, Vice President, and Member of the Board of NICT.


**PROFESSOR
CRAIG SMITH**

Member of Research Management Committee

CEO and Technical Director, EOSSS

Professor Craig Smith is the CEO and technical director for EOS Space Systems. He leads a multi-disciplinary team of science and engineering innovators developing lasers, beam directors, precision timing systems, sensors, and control systems for the laser tracking products. Professor Smith has also held positions within Electro Optic Systems (EOS) as CEO EOS Technologies (the US subsidiary of EOS) and Head of Research and Development. Prior to joining EOS Professor Smith was a Senior Research Fellow at the Australian Defence Force Academy where he developed novel techniques for imaging-polarimetry and spectro-polarimetry at thermal IR wavelengths. Professor Smith obtained Bachelors and PhD degrees in Physics from the University of Melbourne.


**MR MATTHEW
BOLD**
(from 30/10/2017)

Member of Research Management Committee

Principle Researcher Lockheed Martin

Mr Matt Bold is a Principle Researcher with the Lockheed Martin Space Systems Company Advanced Technology Center in Palo Alto, California, USA. His undergraduate studies were in physics and mathematics at the University of Dayton and graduate studies in high energy particle physics at Arizona State University. Since 1996 Matt has been studying the propagation of high energy lasers through the atmosphere with particular interest in the modelling of atmospheric optical turbulence and the performance modelling of adaptive optics systems. For the last ten years Matt has been involved in the space situational awareness research efforts at the UKIRT Telescope in Hawaii and the Lockheed Martin Space Object Tracking (SPOT) telescopes in Santa Cruz California. He is involved with the SERC Remote Manoeuvre research project assisting with system engineering and performance modelling and simulation


**DR MARK
SKINNER**
(from 30/10/2017)

Member of Research Management Committee

Senior Project Leader for Space Traffic Management The Aerospace Corporation

Dr Mark Skinner is internationally recognised as a researcher in space object characterisation and commercial space situational awareness. He is currently leading The Aerospace Corporation's effort to support the transition of space traffic management (STM) from the Defence realm to the Civil. For almost two decades he supported research efforts at the AMOS facility on Maui, Hawaii, and now supports STM in Washington, DC. For the last six years, he has served on the US delegation to UN Committee on the Peaceful Uses of Outer Space (COPUOS), as an expert on space debris and Space Situational Awareness.


MR DAVID BALL
(from 27/11/17)

Member of Research Management Committee

CEO, SERC

Mr David Ball is the Chief Executive Officer of the Space Environment Research Centre (SERC). David has 25 years' experience in the Defence, space and telecommunications sectors with a significant portion of his career spent specialising in satellite communications. David has held senior positions with several satellite operators, including Intelsat and PanAmSat, with roles encompassing sales management, business development, systems engineering and space systems development. David also led communications projects for the Australian Department of Defence (through Envista Pty Ltd) during 2016 and 2017. Earlier in his career, David was a commissioned officer in the Royal Australian Air Force and was responsible for the engineering management of Defence communications systems with his final posting focused on military satellite communications systems. David holds a Bachelor of Engineering in Communications Engineering and a Graduate Diploma in Business Management. David is a Board member of the Space Industry Association of Australia and also acts as Treasurer for the Association.

STRATEGIC PLAN

The SERC Strategic Plan, adopted by the Board on 18 March 2015, outlines the mission, vision, core values and strategic objectives for the organisation. SERC's strategic objectives include:

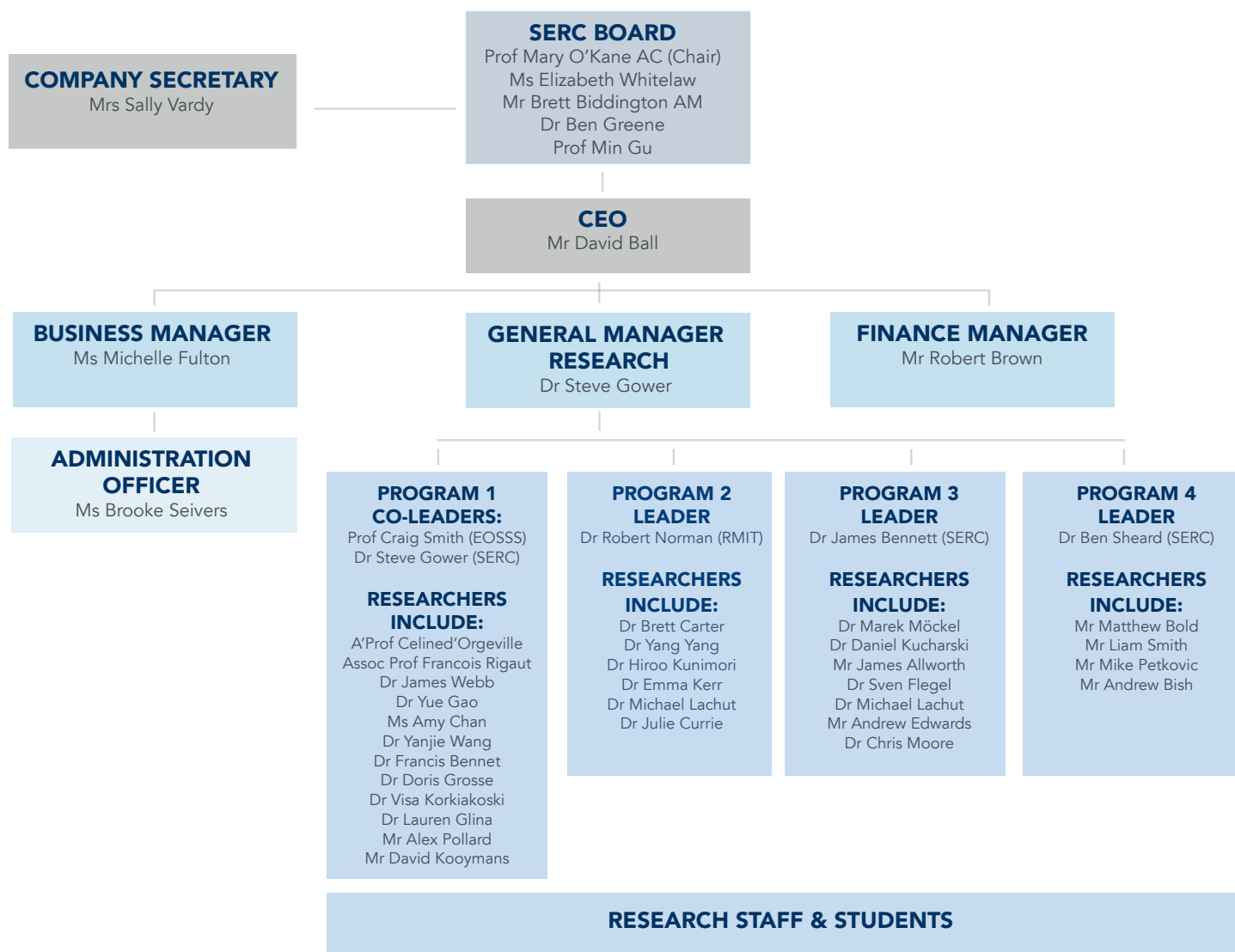
- Identify and exploit synergies between the research efforts of initial participants so that the research objectives are collectively more advanced than would have been the case without SERC;
- Establish efficient, equitable and transparent processes for combining resources from a wide range of collaborating entities; and
- Develop new technologies to preserve the space environment and extend the benefits of space to future generations.

KEY STAFF

The SERC team is led by Chief Executive Officer, Mr David Ball. Dr Steve Gower performs the role of General Manager of Research as well as research program co-leader for RP1.

NAMES AND SPECIAL RESPONSIBILITIES	EXPERIENCE AND KEY SKILLS
 <p>MR DAVID BALL Chief Executive Officer</p>	<p>Mr David Ball is the Chief Executive Officer of the Space Environment Research Centre (SERC). David has 25 years' experience in the Defence, space and telecommunications sectors with a significant portion of his career spent specialising in satellite communications. David has held senior positions with several satellite operators, including Intelsat and PanAmSat, with roles encompassing sales management, business development, systems engineering and space systems development. David also led communications projects for the Australian Department of Defence (through Envista Pty Ltd) during 2016 and 2017. Earlier in his career, David was a commissioned officer in the Royal Australian Air Force and was responsible for the engineering management of Defence communications systems with his final posting focused on military satellite communications systems. David holds a Bachelor of Engineering in Communications Engineering and a Graduate Diploma in Business Management. David is a Board member of the Space Industry Association of Australia and also acts as Treasurer for the Association.</p>
 <p>DR STEVE GOWER General Manager Research Co-Leader Research Program 1</p>	<p>Dr Steve Gower is the General Manager Research for SERC and received his PhD in plasma physics and high power microwave engineering from the University of Wollongong. Prior to joining SERC Dr Gower held various senior research management roles in universities, government laboratories and the private sector. Whilst at RMIT University, as Director of Research Collaborations and Partnerships Steve was responsible for the establishment of major research partnerships with CRCs, ARC and NHMRC Centres of Excellence; bringing together industry, academia and government in collaborative research initiatives. Prior to RMIT, Dr Gower was responsible for the establishment and operation of all external facing partnerships with the Australian Synchrotron as Head of External Relations. Steve's research interests span surface analytical sciences and industrial automation.</p>
 <p>MS MICHELLE FULTON Business Manager</p>	<p>Ms Michelle Fulton is the Business Manager for SERC. Michelle has 25 years' experience in business and industry development, stakeholder engagement, project initiation and management, corporate governance and compliance. Prior to joining SERC, Michelle held various public and private sector appointments in the information technology, space, communication and tourism sectors. Michelle holds a Bachelor of Arts (Management) from the University of Canberra.</p>
 <p>MR ROBERT BROWN CPA AGIA ACIS Finance Manager</p>	<p>Mr Robert Brown is SERC's Finance Manager and has a Bachelor of Business (Accounting/Business Management) from Charles Sturt University and is a member of CPA Australia and Associate Member of Governance Institute of Australia. Robert brings 23 years' experience in both finance and governance working for NSW Local Government, Not for Profit and for profit Agricultural business and Non-Government Organisations (NGO). Robert has worked as a Company Secretary for 4 years, Acting Director of Governance and held the positions of Finance Manager for a number of NSW Local Councils and NGOs. During this time Robert has been a member of management and focus committees and worked for both large and small organisations performing and overseeing all aspect of finance supervising up the twenty staff. Robert has practiced continuous improvement by implementing new core operating systems and restructured general ledger to improve financial service delivery in those organisations.</p>

SERC ORGANISATIONAL STRUCTURE AS AT 30 JUNE 2018



NAME	ORGANISATION	CRC POSITION/ROLE	TIME COMMITMENT
Mr David Ball	SERC	Chief Executive Officer	100%
Dr Steve Gower	SERC	General Manager Research and Research Program 1 Co-Leader	100%
Ms Michelle Fulton	SERC	Business Manager	100%
Mr Robert Brown	SERC	Finance Manager	100%
Dr Craig Smith	EOSSS	Research Program 1 Co-Leader	51%
Dr Robert Norman	RMIT	Research Program 2 Leader	100%
Dr James Bennett	SERC	Research Program 3 Leader	100%
Dr Benjamin Sheard	SERC	Research Program 4 Leader	100%

Table 3: SERC Key Staff and Time Commitments

1.10. PARTICIPANTS

SERC has partnered with world leading organisations and research institutions with strong track records in scientific discovery and space technology development.

In light of the limited, five year, funding term, SERC has not recruited additional Participants due to insufficient timeframes to integrate them into SERC research programs. International collaboration has, however, been achieved through the execution of MOUs with the University of Arizona (USA), the Space Research Institute in Gratz (Austria), the Polish Academy

of Sciences (Poland), the Korean Astronomy and Space Science Institute (Korea) and the University of Texas at Austin (USA).

There were no changes to Essential or Other Participants during the reporting period. The Participants listed in the Commonwealth Agreement were the SERC Participants during the 2017-18 reporting period, including:



EOS SPACE SYSTEMS

ABN 11 008 587 451

- Essential Participant
- Publically listed company
- SME
- End-User Participant

EOS Space Systems specialises in the design, development and production of satellite and space tracking technologies and the provision of space-based services. EOS Space Systems technologies are applied to a variety of space surveillance applications in the aerospace and defence industries globally and have generated of \$400m in exports for Australia. EOS Space Systems has extensive optical tracking infrastructure and highly regarded expertise in locating and tracking space debris.



Australian
National
University

AUSTRALIAN NATIONAL UNIVERSITY

ABN 52 234 063 906

- Essential Participant
- University Participant

The ANU Research School of Astronomy and Astrophysics (RSAA) is internationally recognised in the research and development of astronomical instrumentation and construction of precision instruments for astronomy. In particular, RSAA has considerable expertise in the field of adaptive optics, a technique that corrects the effects of turbulence in the atmosphere to un-blur telescopic images.



RMIT UNIVERSITY

ABN 49 781 030 03

- Essential Participant
- University participant

The RMIT SPACE Research Centre is internationally recognised in the areas of astrodynamics, GPS tracking, atmospheric density modelling, space weather and ionospheric research. RMIT SPACE has considerable expertise in developing models for reliably propagating orbits in the variable space environment. In a successful Australian Space Research Program collaboration, RMIT SPACE was instrumental in developing improved orbit determination algorithms, providing a platform for continued SERC research.



LOCKHEED MARTIN

- Other Participant (International)
- Industry and End-User Participant

Lockheed Martin is one of the world's largest aerospace organisations. It is both a potential end-user for SERC technologies and service provider. Lockheed space business exceeds US\$8 billion annually. Lockheed brings a wealth of technology and space research expertise and international networks to SERC.



OPTUS SATELLITE SYSTEMS

ABN 15 091 789 945

- Other Participant
- Industry and End-User Participant

Optus Satellite Systems has been providing satellite services for more than 30 years and is the only network provider in Australia to own and operate a fleet of satellites. Since 1985, Optus has successfully launched ten satellites and operated thirteen spacecraft. The Optus Satellite fleet currently consists of five geostationary satellites providing services across Australia and New Zealand, and to McMurdo Sound in the Antarctic.



NATIONAL INSTITUTE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY (NICT)

- Other Participant (International)
- Research and End-User Participant

NICT is charged with promoting the Japanese ICT sector as well as research and development in ICT, to drive economic growth and create an affluent, safe and secure society. NICT has a strong space mandate because ICT is heavily dependent on space assets. In collaboration with Australia, NICT has deployed multiple optical laser tracking facilities throughout Japan and is considered a global leader in optical space tracking and orbital science relating to high precision orbits.

MEMORANDA OF UNDERSTANDING

SERC enhances its international collaboration and global reach through execution of Memoranda of Understanding (MOUs) with strategic research partners.



THE UNIVERSITY OF ARIZONA

SERC further strengthened its international collaboration efforts after signing an MOU with the University of Arizona (UA), USA. UA's Space Object Behavioural Sciences (SOBS) mission is to assemble and lead the world's top multi-disciplinary science and technology research and development talent and focus it to solve problems requiring rigorous and comprehensive capabilities in assessing, quantifying, and predicting the behaviour of objects in space, both man-made and natural.

UA SOBS also aims to imagine, identify, develop and deliver new space object behaviour capabilities; make expertise on space object behaviour available to a variety of stakeholders including all branches of government, private industry, academia, and international entities; and help guarantee the University of Arizona's leadership in the area through education, excellence, innovation and practicality in space object behavioural sciences and related fields.

The MOU establishes a framework for scientific collaboration between the two organisations that will result in the combining of the organisations' research expertise to achieve scientific goals whilst developing common specialised knowledge and effective use of facilities. The MOU also opens the door to the exchange of scientific personnel including students in addition to opportunities for joint research and development.



THE SPACE RESEARCH INSTITUTE IN GRAZ

SERC signed a Memorandum of Understanding (MOU) with the SLR Observatory of the Space Research Institute, Graz, Austria. The MOU signals a marked increase in collaboration efforts between our two organisations.

The Space Research Institute in Graz is one of the largest Institutes of the Austrian Academy of Sciences. The institute focuses on physics and exploration of the solar system, covering the whole chain of research needed in its fields: from developing and building instruments such as the SLR, to analysing and interpreting the data returned by these instruments, with support from theoretical studies. SERC is excited to be engaging in closer collaboration with the Space

Research Institute in Graz, Austria, combining northern and southern hemisphere data on laser and optical observations of space debris including high-area-to-mass ratio objects and defunct satellites, spin dynamics analysis of observed targets, and determination of space debris optical properties for characterisation purposes.



THE UNIVERSITY OF TEXAS

SERC signed an MOU with Aerospace Engineering and Engineering Mechanics, Cockrell School of Engineering, The University of Texas at Austin on 14 August 2017. The school is currently ranked world number eight for graduates and undergraduates in aerospace engineering and the fourth most influential scientific research institution in aerospace from 2004-14. The school has a research budget of US\$15.2 million and is interested in research and STEM collaboration with SERC.



POLISH ACADEMY OF SCIENCES

The Polish Academy of Sciences (Polish: Polska Akademia Nauk, PAN) is a Polish state-sponsored institution of higher learning. Headquartered in Warsaw, it is responsible for spearheading the development of science across the country by a society of distinguished scholars and a network of research institutes. SERC signed an MOU with the Academy's Space Research Centre to facilitate scientific exchange and collaborative research.



KOREA ASTRONOMY AND SPACE SCIENCE INSTITUTE

The Korea Astronomy and Space Science Institute (KASI) is the national research institute in astronomy and space science of South Korea and is funded by the South Korean Government. KASI's areas of research include optical astronomy, radio astronomy, space science, and theoretical astronomy. KASI is collaborating with SERC in the area of space debris laser ranging and object characterisation.

1.11. COLLABORATION

SERC's Vision Statement positions SERC as a collaboration vehicle of choice for global efforts to address issues arising from space debris and for SERC's technology to play a key role in the management, mitigation and removal of space debris. This vision, shared by Participants and emphasised in the SERC Strategic Plan, places collaboration at the core of SERC's activities.

SERC research programs are interdependent and foster collaboration between Participants and industry. Research results, including collaborations, are discussed in section 1.5: Performance against Activities. A cross section of SERC collaboration activities during the reporting period are provided below:

PROJECT: RP3.1: DEVELOP A SPECIAL SATELLITE OBJECT CATALOGUE

Collaborators: EOSSS, RMIT, NICT

External Collaborators: Space Laser Ranging Observatory (Graz, Austria), Borowiec Space Research Centre (Poland), Korea Astronomy and Space Science Institute (Korea) and the Cockrell School of Engineering at the University of Texas at Austin.

Results: SERC expanded the already extensive collaboration with Participants and external organisations to further the development of a global network of spin characterisation sensors to support the Space Object Catalogue. These collaborations have afforded access to space object data from a global network of Satellite Laser Ranging stations. The collaborations have also furthered SERC's goal to establish industry credibility and promote SERC technology and research capabilities to an international audience. International collaborations are supported through the signing of Memorandum of Understanding to facilitate the sharing of confidential data and information.

Collaborator: NICT

Date: July-Sept 2016

Collaboration: Installation and testing of the SERC Lumini on the 1.5m Satellite Laser Ranging telescope in Konagei, Japan. The detector has been developed by SERC to collect space object light curve data (sunlight reflected from the space object) that will support the space debris object characterisation and the SERC remote manoeuvre experiment.

External Collaborator: Cockrell School of Engineering, University of Texas at Austin

Date: June 2018

Collaboration: A SERC researcher has relocated to the US as a Visiting Fellow to continue the development of the spin characterisation network.

PROJECT: RP3.2: DEVELOP CONJUNCTION ANALYSIS AND THREAT WARNING (CATW)

Collaborator: EOSSS

External Collaborators: University of Braunschweig Germany, European Space Agency

Date: Ongoing

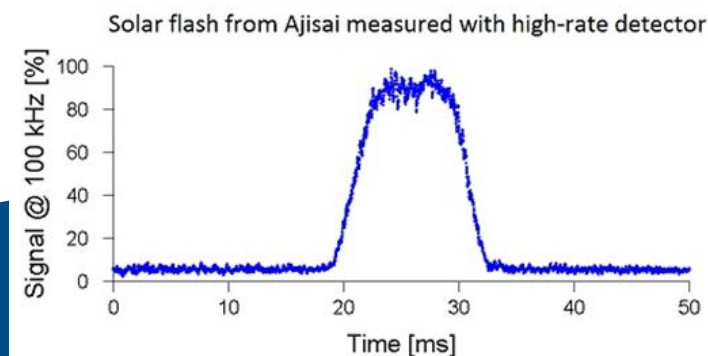
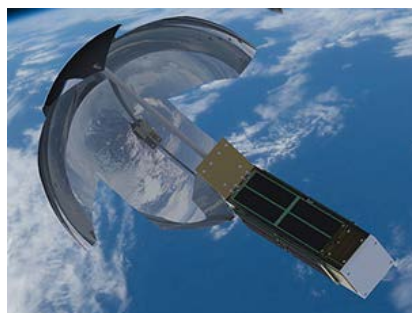
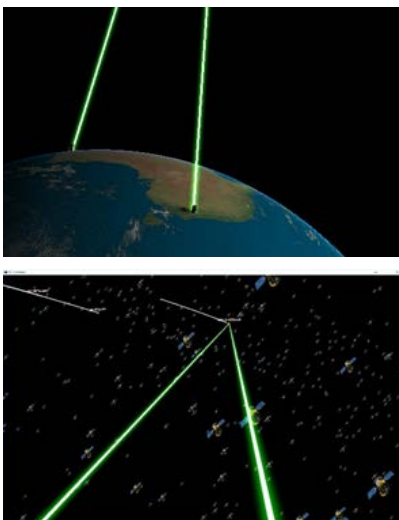
Collaboration: Exchange of visualisation software code and coordination of propagator interfaces. This collaboration will ensure interoperability of SERC conjunction analysis software and will help position SERC software as the defacto industry standard.

PROJECT: RP4.2 – PAYLOAD DEVELOPMENT

Collaborators: EOSSS, Lockheed Martin

External Collaborators: NASA Ames, UNSW Canberra

Results: SERC collaboration with both NASA Ames and University of New South Wales – Canberra (UNSW) is centred on the development, integration and launch of the SERC hosted payload. NASA has replicated the SERC payload however it does not include the photodetector. This payload will be included on a future TechEdSat satellite and will provide an on-orbit light source to allow testing of the SERC AO system.



Top: Laser engagement of space objects visualisation

Middle: The fifth satellite in the TechEdSat series (TechEdSat -5) launched from the International Space Station in 2016. Credit NASA

Bottom: Solar flash from Ajisai measured with spin characterisation detector

1.12. FINANCIAL MANAGEMENT

SERC continued to implement stringent financial management practices in an aggressive attempt to allow 70% of all cash funds to flow to the SERC research and education programs.

Although administrative costs were slightly higher this financial year, SERC's managed to contain administrative costs to 29% of cash expenditure.

SERC has continued to improve its financial processes throughout the reporting period, with a number of key achievements:

- Improved functionality and management of accounting and payroll processes
- Enhanced budgeting and forecasting process implemented
- Better financial reporting to the Board, Committees and research programs
- Adherence to stringent budgeting guidelines ensured SERC tracked well against budgets and maintained a strong cash-flow position

There were no significant issues with respect to financial management during the 2017-18 reporting period.

FUNDS CARRIED FORWARD

SERC carried \$6,192,020 forward at 30 June 2018. These funds are (largely) committed to supplier and employee expenses to enable the completion of the Research Programs.

ADMINISTRATIVE COSTS

SERC is now operating with a full complement of administrative resources to support the research programs and continued to focus reducing administrative costs over the reporting period.

KEY CHANGES FROM 2017

SERC has continued to track well against its aggressively lean cash flow projections. The key changes in 2018 relate directly to developments in research. SERC was able to secure a hosted payload launch for the in-orbit sensor which removed the need to launch a dedicated satellite mission.

The other key change related to research infrastructure. SERC has been designing and building experimental apparatus to enable on-orbit manoeuvre demonstrations.

The SERC Board chose to discontinue one of these developments during the reporting period and instead elected to lease a capability as a service during the on-sky experiment phase of SERC.

PARTICIPANT CASH CONTRIBUTIONS

During the reporting period, SERC received 100% of pledged cash contributions from Participants. Cash contributions were \$380,000 (in line with Participant Agreements).

PARTICIPANT IN-KIND CONTRIBUTIONS

SERC is required, under its constitution, to audit all Participant contributions claimed for both quantity (magnitude) and quality.

Aggregate in-kind contributions received from Participants were in excess of 107% of the pledged amounts during the 2017/18 reporting period.

SERC Participants contributed a total of 15.32 FTE which was 120% of the pledged 12.80 FTE.

Non-staff in-kind contributions received from Participants totalled \$3.772 million which was in excess of the \$3.217 million pledged.

SERC expects that Participant contributions will continue to meet or exceed pledged In-kind contributions through to the completion of the program.

FINANCIAL STATEMENTS

The Annual Financial Statements have been prepared as general purpose accounts in accordance with the Commonwealth Government reporting requirements for Cooperative Research Centres; and in-line with Australian Accounting Standards.

Profit & Loss

Space Environment Research Centre Limited for the period 12 months ended 30 June 2018

	2018	2017
	\$	\$
<u>Income</u>		
Government funding	\$5,090,383	\$3,065,032
Interest Income	\$32,723	\$39,938
Member contributions	\$8,134,924	\$7,390,512
Total Income	\$13,258,030	\$10,495,482
<u>Less operating expenses</u>		
Employee costs	\$928,877	\$656,534
Directors fees & expenses	\$103,737	\$108,570
Operating expenses	\$256,783	\$493,415
Depreciation	\$286,631	\$200,254
Asset Impairment	\$459,672	-
Event hosting	\$38,644	\$48,506
Insurance	\$8,864	\$9,673
Legal expenses	\$8,003	-
Research Program - RP1	\$6,575,977	\$5,384,477
Research Program - RP2	\$2,163,089	\$1,963,824
Research Program - RP3	\$1,173,289	\$971,964
Research Program - RP4	\$920,103	\$403,820
Scholarships	\$334,361	\$254,445
Total operating expenses	\$13,258,030	\$10,495,482
Net profit	-	-

Balance Sheet

Space Environment Research Centre Limited as at 30 June 2018

<u>Assets</u>	2018	2017
	\$	\$
<u>Current assets</u>		
Cash and cash equivalents	\$6,192,020	\$6,686,532
Receivables	-	\$25
Other assets	\$62,427	\$41,801
Total current assets	\$6,254,447	\$6,728,358
<u>Non-current assets</u>		
Other assets	-	-
Plant and equipment	\$196,895	\$799,432
Total non-current assets	\$196,895	\$799,432
Total assets	\$6,451,342	\$7,527,790
<u>Liabilities</u>	2018	2017
	\$	\$
<u>Current liabilities</u>		
Payables	\$592,356	\$860,406
Provisions	\$79,433	\$61,422
Deferred revenue	\$5,744,188	\$6,578,571
Total current liabilities	\$6,415,977	\$7,500,399
<u>Non-current liabilities</u>		
Provisions	\$35,365	\$27,391
Total non-current liabilities	\$35,365	\$27,391
Total liabilities	\$6,451,342	\$7,527,790
Net assets	-	-



GLOSSARY OF TERMS

TERM	DEFINITION	TERM	DEFINITION
AAO	Australian Astronomical Observatory	COTS	Commercial Off The Shelf
AATSR	Advanced Along Track Scanning Radiometer	COPOUS	Committee on the Peaceful Uses of Outer Space
ACNC	Australian Charities and Not-for-profits Commission	CRC	Cooperative Research Centre
ADC	Analogue to Digital Converter	CSTM	Civil Space Traffic Management
AIT	Assembly, Integration and Test	CW	Continuous Wave laser refers to a laser that produces a continuous output beam.
AITC	The ANU's Advanced Instrumentation and Technology Centre located at Mount Stromlo Observatory in Canberra, Australia.	DM	Deformable Mirror
AMD	Atmospheric Mass Density	DMTC	Defence Materials Technology Centre
AMOS	The Advanced Maui Optical and Space Surveillance Technologies Conference. The premier technical conference devoted to space surveillance.	EIPT	Economic Impact Performance Tool (round 11 onwards)
ANU	The Australian National University	Emphemeris	Tables of values which provide the positions of objects (natural and man-made) in space at a given time(s).
AO	Adaptive Optics is a technology used to improve the performance of optical systems by reducing the effect of wavefront distortions: it aims at correcting the deformations of an incoming wavefront by deforming a mirror in order to compensate for the distortion.	EOS	Electo Optic Systems Proprietary Limited
AOI	Adaptive Optics Imager	EOSSS	EOS Space Systems Pty Limited
AOTP	Adaptive Optics Tracking and Pushing	ERS2	European Remote Sensing Satellite 2
ARC	Audit and Risk Committee	ESA	European Space Agency
ASIC	Australian Securities and Investment Commission	FTP	File Transfer Protocol
ASTA	The Australian Science Teachers Association	GAIA	Global Astrometric Interferometer for Astrophysics
ATC	Lockheed Martin Space Systems Company Advanced Technology Center	Gaussian	Being or having the shape of a normal curve or a normal distribution
ATO	Australian Taxation Office	GEO	Geostationary Earth Orbit
ATSR2	Along Track Scanning Radiometer 2	Geodesy	Also known as geodetics, is the earth science of accurately measuring and understanding the Earth's geometric shape, orientation in space and gravitational field.
BTO	Beam Transfer Optics	GMT	Giant Magellan Telescope
CAASTRO	Council Centre of Excellence for All-sky Astrophysics	GNSS	Global Navigation Satellite System, a constellation of satellites providing signals from space transmitting positioning and timing data.
Centre IP	Refers to IP held by SERC	GPS	Global Positioning System
CCD	Charge-coupled device	GRACE	Refers to the Gravity Recovery and Climate Experiment (GRACE) twin satellites which measure the movement of mass, and hence gravity, around earth every 30 days.
Colloquium	An academic conference or seminar	Graz SLR	The Space Research Institute in Graz, Austria
COSPAR	Committee on Space Research	GSL	Guide Star Laser

GLOSSARY OF TERMS

TERM	DEFINITION	TERM	DEFINITION
IB	International Baccalaureate	PYP	Primary Years Programme
HA	High Area to Mass Ratio	R&D	Research and development
HDR	Higher Degree by Research	RAAF M1	RAAF Mission 1
Lumini	SERC high-rate photo detector	ResMC	Research Management Committee
IAC	International Aeronautical Congress	RMIT	Royal Melbourne Institute of Technology University
IAF	International Astronautical Federation	ROD	Reliable orbit determination
ILRS	International Laser Ranging Service	RP	Research Program
IMU	Inertial Measurement Unit	RSAA	The Australian National University's Research School of Astronomy and Astrophysics.
IP	Intellectual Property	SBM	Satellite Body Model
IWLR	International Workshop on Laser Ranging	SCOPE	SERC Catalogue Orbit Prediction and Estimation Software
JAXA	Japan Aerospace Exploration Agency	SCIDAR	Scintillation and Detection and Ranging System
JORN	Jindalee over the horizon radar project	SERC	Space Environment Research Centre
JSON	JavaScript Object Notation	SLR	Space Laser Ranging
JPL	NASA's Jet Propulsion Laboratory	SME	Small to Medium Enterprise
KASI	Korea Astronomy and Space Science Institute	SOC	Space Object Catalogue
LED	Light Emitting Diode	SPACE	RMIT's Satellite Positioning for Atmosphere, Climate and Environment Research Centre
LEO	Lower Earth Orbit	SPAN	RMIT's Satellite Positioning and Navigation Laboratory
LGS	Laser Guide Star	SPIE	Society of Photographic Instrumentation Engineers
LIDAR	Light Detection and Ranging	SPOT	Space Object Tracking
LLT	Laser Launch Telescope	SPOT3	Système Pour L'Observation de la Terre 3
LM	Lockheed Martin	SRC	Space Research Centre
M1	RAAF Mission 1 (UNSW contract to develop, launch and operate the first of three spacecraft for the Royal Australian Air Force)	SSA	Space Situational Awareness is the ability to accurately characterise the space environment and activities in space.
MOU	Memorandum of Understanding	SLR	Satellite Laser Ranging
MVN	Multi Variant Normality	STM	Space Traffic Management
NICT	The National Institute of Information and Communications Technology (Japan)	STEM	Science, Technology, Engineering and Mathematics
nm	Nanometer	STEM X	The Australian Science Teachers Association's Science, Technology, Engineering and Mathematics teacher development program.
OBC	On Board Computer	SWG	ACT Government Space Working Group
OD	Orbit Determination	TLE	Two-line element data, a format for distributing orbital elements data.
Photodiode	Semiconductor device that converts light into an electrical current.	TVAC	Thermal Vacuum
OPTUS	OPTUS Satellite Systems	UKIRT	The United Kingdom Infrared Telescope. Located in Hawaii
Qt/OpenGL	Graphics programming language	VBG	Variable Bragg gratings
PAN	Polish Academy of Sciences	WPLTN	Western Pacific Laser Tracking Network (WPLTN)
POD	Precision Orbit Determination		

2.1. SERC PUBLICATIONS

The following tables provides a list of SERC publications (as defined in the MDQ).

FORMAL PUBLICATIONS

DATE	PUBLISHED IN / PRESENTED AT	TITLE	AUTHORS	PUBLICATION TYPE
Jul-17	Proceedings of 31st International Symposium on Shock Waves	Optimising the X3R Reflected Shock Tunnel Free-Piston iver for Long Duration Test Times	Stennett, S. J., Gildfind, D. E. & Jacobs, P. A.	Proceedings
Aug-17	Nature Photonics, Volume 11, pages 502–508 (2017)	Satellite-to-ground quantum-limited communication using a 50-kg-class microsatellite	Hideki Takenaka, M Toyoshima	Journal Paper
Sep-17	7th International Meeting on Celestial Mechanics (CelMec VII), 3-9 September, Viterbo, Italy	The abstract Simulation issues in chaotic medium Earth orbits	Murawiecka, Daquin, Lemaitre	Proceedings
Oct-17	Acta Astronautica, Volume 139, October 2017, Pages 367-376	An adaptive optics aided differential optical positioning for passive orbit determination of the space debris at the geostationary orbit	P Piatrou, F Rigaut	Journal Paper
Oct-17	Acta Astronautica, 2017 – Elsevier, PP1-9,2017	LEO-to-ground optical communications using SOTA (Small Optical TrAnsponder)–Payload verification results and experiments on space quantum communications	A Carrasco-Casado, H Kunimori, T Fuse, M Toyoshima, et al.	Journal Paper
Oct-17	Superconductor Science and Technology, Volume 30, Number 12	Timing discriminator based on single-flux-quantum circuit toward high time-resolved photon detection	S Miki et al.	Journal Paper
Oct-17	Earth and Space Science, Volume 4, Issue 10, 1 October 2017, Pages 661-668	Photon Pressure Force on Space Debris TOPEX/Poseidon Measured by Satellite Laser Ranging	D Kucharski et al	Journal Paper
Dec-17	2017 Australian and New Zealand Control Conference, ANZCC 2017, Volume 2018-January, 20 February 2018, Pages 17-22	Modelling and identification of adaptive optics systems to satisfy distributed Kalman filter model structural constraints	J Cranney, J De Dona, P Piatrou, F Rigaut, V Korkiakoski	Conference Paper
Feb-18	Optics Express Vol. 26, Issue 4, pp. 4942-4953 (2018)	Transmission analysis for OFDM signals over hybrid RF-optical high-throughput satellite	D R Kolev and M Toyoshima	Journal Paper
Feb-18	Science China: Physics, Mechanics & Astronomy, February 2018 Vol. 61 No. 2: 020331	Quest towards ultimate performance in superconducting nanowire single photon detectors	S Miki	Journal Paper
Feb-18	IEEE Transactions on Geoscience and Remote Sensing	Improvement of Reflection Detection Success Rate of GNSS RO Measurements Using Artificial Neural Network	Hu, A., Wu, S., Wang, X., Wang, Y., Norman, R., He, C., Zhang, K.	Journal Paper
Mar-18	IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control	Advanced Satellite-based Frequency Transfer at the 10-16 Level	M Fujieda, T Gotoh, et.al	Journal Paper
Mar-18	Scientific Reports (Nature)	Realization of ultra-thin metasurface to facilitate wind bandwidth, wide angle beam scanning	A Bah, P Qin, R W Ziolkowski, Q Cheng, Y J Guo	Journal Paper
Apr-18	Royal Society Open Science, Open Access, Volume 5, Issue 4, 11 April 2018, Article number 171109	Generalized transformations and coordinates for static spherically symmetric general relativity	Hill, J.M., O'Leary, J.	Journal Paper
Jun-18	Applied Physics Letters, Vol. 112, Page 262601_1-5	Superconducting coincidence photon detector with short timing jitter	S Miki, et.al.	Journal Paper

OTHER PUBLICATIONS

DATE	PUBLISHED IN / PRESENTED AT	TITLE	AUTHORS	PUBLICATION TYPE
Jul-17	Proceedings of 31st International Symposium on Shock Wave, Nagoya, Japan, July 2017	Optimisation and design of a fully instrumented Mach 12 nozzle for the X3 expansion tube	P Toniato, Gildfind, D Jacobs, P Morgan, G Richard	Conference
Jul-17	CELMEC VII conference (3-9 September 2017 in Italy)	Simulation issues in chaotic medium earth Orbits	J Daquin	Poster Presentation
Jul-17	Cryogenic Engineering Conference and International Cryogenic Materials Conference (CEC/ICMC 2017)	Multi-pixel superconducting nanowire single-photon detectors with cryogenic signal processors using single-flux-quantum circuits	H Terai, S Miki	Presentation & Manuscript
Jul-17	Seminar in Space Communication Laboratory	Key Elements Experiment for Deep Space Optical Communication and Ranging Using Geosynchronous Satellite	H Kunimori, et al.	Presentation
Jul-17	2017 European Frequency and Time Forum & International Frequency Control Symposium	One-on-multi RF transfer system using optical fibers	M Fujieda, T Gotoh, et al.	Proceedings
Jul-17	ANU RSAA Winter School	Adaptive Optics Research @ ANU	D Grosse	Presentation
Jul-17	Das Zentrum - Australian German Institute	Space Debris: How it is affecting us and what is done about it in Australia and Europe	D Grosse	Presentation
Aug-17	RMIT Space Research Centre Seminar Series	Space Debris Models and Collision Risk Assessment	S Flegel	Presentation
Aug-17	URSI 2017 GASS	Hybrid High-throughput Satellite Communications System Using Radio and Optical Frequencies	M Toyoshima	Proceedings
Aug-17	ANU Physics Market	Adaptive Optics Research @ ANU	F Bennet, M Copeland, D Grosse, V Korkiakoski, F Rigaut, E Thorn, C d'Orgeville	Poster Presentation
Aug-17	Goethe Institute Science Workshop	Space Debris	D Grosse	Presentation
Sep-17	Proceedings of the 2017 International Astronautical Congress, Adelaide 2017	Evaluation of atmospheric mass density models and their impact on the orbit propagation of low Earth orbit satellites	C He, Y Yang, B Carter, S Wu, K Zhang	Presentation & Manuscript
Sep-17	Proceedings of the 2017 International Astronautical Congress, Adelaide 2017	Improved Tracklet Correlation for Initial Orbit Determination	H Cai	Presentation & Manuscript
Sep-17	Proceedings of the 2017 International Astronautical Congress, Adelaide 2017	Assessing the effectiveness of debris mitigation guidelines to preserve the space environment given future proposals for large satellite constellations	S Le May, S Gehly, B Carter	Presentation & Manuscript
Sep-17	Proceedings of the 2017 International Astronautical Congress, Adelaide 2017	Heterogeneous multiscale methods for orbital	J Daquin	Presentation & Manuscript
Sep-17	Proceedings of the 2017 International Astronautical Congress, Adelaide 2017	Distributed Fusion Sensor Networks for Space Situational Awareness	S Gehly, J Bennett	Presentation & Manuscript
Sep-17	Proceedings of the 2017 International Astronautical Congress, Adelaide 2017	Analysis of Adaptive Gaussian Mixture Unscented Kalman Filter Using Sparse Optical Observations for Orbit Determination	Y Yang, H Cai	Presentation & Manuscript
Sep-17	Proceedings of the 2017 International Astronautical Congress, Adelaide 2017	Towards State Uncertainty Accuracy Requirements for Actionable GEO Collision Risk Assessments	S Flegel	Presentation & Manuscript

OTHER PUBLICATIONS

DATE	PUBLISHED IN / PRESENTED AT	TITLE	AUTHORS	PUBLICATION TYPE
Sep-17	Proceedings of the 2017 International Astronautical Congress, Adelaide 2017	Next Generation Plenary Panel	D Grosse	Panel Discussion
Sep-17	Proceedings of the 2017 International Astronautical Congress, Adelaide 2017	Presentation & Paper: Space Debris Manoeuvre with Adaptive Optics Using a Ground-based Telescope	D Grosse et al.	Presentation & Manuscript
Sep-17	68th International Astronautical Congress	Attitude dependent perturbations of space debris orbital dynamics during solar activity extremes	D Kucharski, G Kirchner, J C. Bennett, F Koidl	Poster Presentation
Sep-17	ILRS Technical Workshop 2017	An analysis of the close approach between Jason 2 and Topex/Poseidon	J Bennett	Presentation
Sep-17	AMOS Conference	Prediction accuracy analysis from orbital elements generated for a new space object catalogue	J Bennett, M Lachut, B Greene, S Gehly, D Kooymans, J Allworth, A Pollard, C Smith	Presentation & Manuscript
Sep-17	AMOS Conference	Poster & Paper: Satellite and debris characterisation in LEO and GEO using adaptive optics	M Copeland, F Bennet, F Rigaut, V Korkiakoski, C d'Orgeville and C Smith	Presentation & Manuscript
Sep-17	AMOS Conference	High-Altitude Airborne Platform Characterisation of Adaptive Optic Corrected Ground Based Laser	F Bennet et al.	Presentation & Manuscript
Sep-17	AMOS Conference	Presentation & Paper: Stereo-SCIDAR System for Improvement of Adaptive Optics Space Debris-tracking Activities	E Thorn, V Korkiakoski, D Grosse, F Bennet, F Rigaut, C d'Orgeville, J Munro	Presentation & Manuscript
Sep-17	7th International Conference on Quantum Cryptography	Performance improvement of NbTiN superconducting nanowire single photon detectors by avalanche switching architecture	S Miki and et al.	Oral Program Book TH455
Sep-17	ABC News TV	Presentation: Satellite and Debris Characterisation using Adaptive Optics	C d'Orgeville & D Grosse	ABC News TV and web
Sep-17	AO4EL5 Conference	Paper: Site characterization at Mount Stromlo Observatory: the first results	V Korkiakoski, D Grosse, E Thorn, M Copeland, F Bennett, J Osborn, J Munroe, P Piatrou, F Rigaut, C d'Orgeville	Proceedings
Oct-17	JSASS-2017-4535, pp1-5.,2017	Key Elements Experiment for Deep Space Optical Communication and Ranging Using Geosynchronous Satellite(in Japanese)	H Kunitori, et.al	Proceedings
Oct-17	UNSW Adaptive Optics Workshop	Satellite and Debris Characterisation using Adaptive Optics	M Copeland	Presentation
Oct-17	UNSW Adaptive Optics Workshop	From Dye Laser Factory to Portable Semiconductor Laser: 4 Generations of Sodium Guide Star Lasers for Adaptive Optics in Astronomy and Space Situational Awareness	C d'Orgeville	Presentation
Oct-17	UNSW Adaptive Optics Workshop	Site monitoring at Mount Stromlo using SCIDAR	V Korkiakoski	Presentation
Oct-17	Institute of Electronics, information and Communication Engineers-Superconductive Electronics Conference	Fabrication and evaluation of 1 k-pixel SSPD imaging array	M Yabuno, S Miki, et al	Proceedings

OTHER PUBLICATIONS

DATE	PUBLISHED IN / PRESENTED AT	TITLE	AUTHORS	PUBLICATION TYPE
Oct-17	NICT News OCT. 2017 No.466	Optical Satellite Communication toward the Future of Ultra high-Speed Wireless Communications A Deep-space Optical Communication and Ranging Application	H Kunimori	Organization News
Nov-17	IEEE International Conference on Space Optical Systems and Applications (ICSOS) 2017	Research and Development on a Hybrid High Throughput Satellite with an Optical Feeder Link —Study of a Link budget analysis—	M Toyoshima ,H Kunimori, T Fuse, T Kubooka, et al.	Proceedings
Dec-17	CREST the Second Symposium	Development of photon detection technologies by using superconducting electronics	S Miki	Proceedings
Jan-18	Journal of the NICT Vol.64 No.1	Channel Estimation Experiment for Physical Layer Cryptography in Free-space Optical Communication	Hi Endo, M Toyoshima, et al.	Journal Paper
Jan-18	Free-Space Laser Communication and Atmospheric Propagation, SPIE Photonics West 2018	Design status of the development for a GEO-to-ground optical feeder link, HICALI	Y Munemasa, T Fuse, H Kunimori, T Kubooka, M Toyoshima, et al.	Proceedings
Mar-18	The Optical Networking and Communication Conference & Exhibition (OFC2018)	Superconducting Nanowire Single-Photon Detectors for Future Optical Communications	H Terai, S Miki, et al.	Proceedings
Mar-18	SERC Research Colloquium 2018, Canberra	Progress Against the Master Schedule – A Snapshot as at 31 Dec 2017	S Gower	Presentation
Mar-18	SERC Research Colloquium 2018, Canberra	AO Program Overview and Laser Guide Star Facility Update	C D'Orgeville	Presentation
Mar-18	SERC Research Colloquium 2018, Canberra	Atmospheric Turbulence Monitoring with SCIDAR	V Korkiakoski	Presentation
Mar-18	SERC Research Colloquium 2018, Canberra	Adaptive Optics Imager	M Copeland	Presentation
Mar-18	SERC Research Colloquium 2018, Canberra	Adaptive Optics for Tracking and Pushing Space Debris	D Grosse	Presentation
Mar-18	SERC Research Colloquium 2018, Canberra	AO Supervisory Software	V Korkiakoski	Presentation
Mar-18	SERC Research Colloquium 2018, Canberra	Development and Project Status of the Sodium Guidestar Laser	J Webb	Presentation
Mar-18	SERC Research Colloquium 2018, Canberra	Multi-Beam Combination for High Beam Quality Multi-kW CW Laser - Progress Made	Yue Gao	Presentation
Mar-18	SERC Research Colloquium 2018, Canberra	Lockheed Laser Integration	L Smith	Presentation
Mar-18	SERC Research Colloquium 2018, Canberra	Integration of the AO System and Lasers on the EOS 1.8 m Telescope	C Smith	Presentation
Mar-18	SERC Research Colloquium 2018, Canberra	The SERC Telescope - More than just a Geotracker	L Glina	Presentation
Mar-18	SERC Research Colloquium 2018, Canberra	Automated Multi-Sensor Scheduling	J Allworth	Presentation
Mar-18	SERC Research Colloquium 2018, Canberra	Catalogue Maintenance	D Kooymans	Presentation
Mar-18	SERC Research Colloquium 2018, Canberra	Automating the assessment of orbit predictions and estimations for maintaining the SERC catalogue	M Lachut	Presentation
Mar-18	SERC Research Colloquium 2018, Canberra	RP2 Updates and Atmospheric Mass Density Modelling	B Carter	Presentation

OTHER PUBLICATIONS

DATE	PUBLISHED IN / PRESENTED AT	TITLE	AUTHORS	PUBLICATION TYPE
Mar-18	SERC Research Colloquium 2018, Canberra	Atmospheric Mass Density – Empirical Models	E Kerr	Presentation
Mar-18	SERC Research Colloquium 2018, Canberra	Sequential Orbit Determination for Space Objects with Ground-based Observations	Y Yang	Presentation
Mar-18	SERC Research Colloquium 2018, Canberra	Updates on Macroscopic Orbital Propagations	J Daquin	Presentation
Mar-18	SERC Research Colloquium 2018, Canberra	Actionable Collision Risk Warnings	S Flegel	Presentation
Mar-18	SERC Research Colloquium 2018, Canberra	Building a Commercial Conjunction Assessment Service	M Möckel	Presentation
Mar-18	SERC Research Colloquium 2018, Canberra	Conjunction and Threat Warning System Overview and Progress	J Bennett	Presentation
Mar-18	SERC Research Colloquium 2018, Canberra	Conceptual Development of a Civil Space Traffic Management (CSTM) Capability	M Skinner	Presentation
Mar-18	SERC Research Colloquium 2018, Canberra	HA Object Identification for Photon Pushing	L Smith	Presentation
Mar-18	SERC Research Colloquium 2018, Canberra	HA Object Characterisation by High Sample Rate Spin Analysis	D Kucharski	Presentation
Mar-18	SERC Research Colloquium 2018, Canberra	SERC Payload for RAAF-M1	B Sheard	Presentation
Mar-18	SERC Research Colloquium 2018, Canberra	The Path Forward	B Greene	Presentation
Apr-18	European Conference on Antennas and Propagation (EuCAP 2018), London, April 2018	Design and analysis of a wide angle impedance matching metasurface for wideband antenna arrays.	A Bah et al	Proceedings
May-18	Space Communications Laboratory Seminar	Status of HICALI project experiment plan	HTakenaka, H Kunimori, T Kubooka, et.al	Presentation

2.2. SERC SCHOLARSHIP STUDENTS

The following table provides a list of all SERC scholarship students.

NAME OF STUDENT	RP	START DATE	EXPECTED COMPLETION DATE	HOST RESEARCH INSTITUTION	TYPE	COUNTRY OF ORIGIN	PROJECT TITLE
Shasidran Raj	RP1	05/01/2016	10/10/2018	ANU	HDR	Malaysia	Space Debris Tracking using Continuous Wave Laser
Michael Copeland	RP1	14/04/2016	14/10/2019	ANU	HDR	Australia	Advanced Imaging and Wavefront Sensing for Satellite Laser Ranging and Tracking
Paul Sibley	RP1	22/06/2016	22/06/2019	ANU	HDR	Australia	Laser Written Waveguides for an Optical Phased Array Head
Richard Samuel	RP3	1/10/2017	30/09/2020	ANU	HDR	Australia	A method for determining near-earth object characteristics and behaviour using iterative orbital refinement and convergence
Jesse Cranney	RP1	02/05/2016	7/07/2019	Newcastle	HDR	Australia	Predictive Control of Adaptive Optics Systems for Observations and Tracking of Space Objects and Debris
Adam Harris	RP2	28/06/2016	12/09/2020	RMIT	HDR	USA	Precise Orbit Determination and Advanced Astrodynamics Research for Application in Satellite Positioning and Tracking.
Changyong He	RP2	01/01/2016	1/01/2019	RMIT	HDR	China	Precise Thermospheric Density Correction for Robust Orbit Determination and Prediction of Low-Earth-Orbit Objects
Han Cai	RP2	12/09/2016	30/06/2019	RMIT	HDR	China	Tracklet Correlation and Multi-target Tracking Of Space Debris Initial Orbit Determination for Enhanced Catalogue Maintenance and Conjunction Analysis
Samantha Le May	RP2	12/07/2017	12/07/2020	RMIT	HDR	Australia	NLP as a Sensor of Soft (human based) Inputs to Support SSA and Space Traffic Management Activities
Michael Afful	RP2	01/01/2016	1/01/2019	RMIT	HDR	Ghana	Space Debris Characterisation for Reliable Orbit Determination and Prediction
Timothy Kodikara	RP2	01/01/2016	30/06/2019	RMIT	HDR	Sri Lanka	Enhancing Atmospheric Mass Density Modelling for Space Situational Awareness
Joseph O'Leary	RP3	07/09/2016	7/06/2019	UniSA	HDR	Ireland	GPS Application of General Relativity
Pierpaolo Toniato	RP4	01/01/2016	1/11/2018	UQ	HDR	Italy	Mach 12 Scramjet Testing in X3 Expansion Tube
Samuel Stennett	RP4	01/01/2016	23/04/2019	UQ	HDR	Australia	Flow Condition Optimisation and Characterisation for a New Large Scale Reflected Shock Tunnel
Timothy Cullen	RP3	08/01/2016	8/04/2019	UQ	HDR	Australia	Re-entry Shock Layer Thermography
Kyle Damm	RP4	01/01/2016	30/12/2018	UQ	HDR	Australia	Multipoint, Multi-objective Geometric Optimisation of a Hypersonic Launch Vehicle
Alpha Bah	RP1	01/02/2016	2/03/2019	UTS	HDR	Sierra Leone	Reconfigurable Ultra-wideband Tightly Coupled Arrays.
Hansani Perera	RP3	23/01/2018	22/01/2021	UniSA	HDR	Sri Lanka	Collision Probability Modelling For Short-Term Encounters In Low Earth Orbit Space Satellites
Chandana Samarasingh	RP3	9/01/2018	8/01/2021	UniSA	HDR	Sri Lanka	Relaxing the Spherical Cannonball assumption in orbit predictions

NAME OF STUDENT	RP	START DATE	EXPECTED COMPLETION DATE	HOST RESEARCH INSTITUTION	TYPE	COUNTRY OF ORIGIN	PROJECT TITLE
GRADUATED STUDENTS							
Lyle Roberts	RP2	05/01/2015	5/06/2016	ANU	HDR	Australia	Development of a High-power Optical Phased Array for Space Debris Tracking and Manoeuvring
Samuel Francis	RP4	08/01/2015	31/12/2017	ANU	HDR	Australia	A Robust Laser Interferometer for Multiplexed Measurements of Optical Path Lengths
Anna Zovaro	RP1	01/01/2016	31/12/2016	ANU	U/grad	Australia	Simpler Adaptive Optics using a Single Device for Processing and Control
Samantha Le May	RP4	01/01/2016	31/12/2016	RMIT	U/grad	Australia	Modelling the Future Evolution of the Orbital Debris Population
Alexander Stuchbery	RP1	14/04/2016	31/12/2016	ANU	U/grad	Australia	Design, Construction & Testing of a Camera Latency Measurement Device
FORMER STUDENTS							
Anna Zovaro	RP1	14/04/2016	28/02/2016	ANU	HDR	Australia	Adaptive Optics for Space Debris Manoeuvring and Astronomy
Yang Zhao	RP1	20/01/2015	19/01/2018	RMIT	HDR	China	Two-line Element Data Quality Control and its Application in Space Situational Awareness
Elliott Thorn	RP1	14/04/2016	14/04/2019	ANU	HDR	Australia	Design of SERC Adaptive Optics Laser Guide Star Facility
Alea Yeasmin	RP2	12/09/2016	12/09/2019	RMIT	HDR	Bangladesh	Monitoring, Mapping and Modelling Atmospheric Density Using the Swarm Mission



Australian Government
Department of Industry,
Innovation and Science

Business
Cooperative Research
Centres Program