ICRAR

International Centre for Radio Astronomy Research

ICRAR Annual Report 2014-2015

ICRAR Annual Report
Cover Images

1 The core region of SKA-low antennas that will be placed across the Murchison Radio-Astronomy Observatory as part of SKA Phase 1 (computer rendered representation).
Credit: Swinburne Astronomy Productions, ICRAR, U. Cambridge and ASTRON.

2 ICRAR staff and students at our first (and now annual) ICRAR-Con retreat on Rottnest Island.
Credit: ICRAR.

3 Supernova 1987A continues to reveal its secrets to ICRAR researchers. In this image we see an outline of the equatorial ring and inner debris in the supernova remnant, as seen with the Hubble Space Telescope (green/blue contours), on top of ALMA observations of the remnant (red/orange, with rendering).
Credit: G. Zanardo, ICRAR.

4 Multiwavelength image of galaxies NGC 1512 and NGC 1510 combining optical and near-infrared data (light blue, yellow, orange), ultraviolet data (dark blue), mid-infrared data (red), and radio data (green).
Credit: Á. R. López-Sánchez, T. Westmeier, C. Esteban, and B. S. Koribalski.

5 Electrical engineering and computing student, Shane Overington, working in the ICRAR electronics laboratory to diagnose and repair a faulty MWA data transmission printed circuit board.
Credit: ICRAR.

6 The 'spinal cord' of a supercomputer at the Pawsey Centre.
Credit: ICRAR.

7 The Murchison Widefield Array telescope from the air.
Credit: Curtin University.

8 A captivated audience watches on as Professor Chris Power, Dr Rick Newton and Dr Paul Scott-Taylor present their custom planetarium show 'Spinning the Cosmic Web in a Supercomputer' at the Scitech Planetarium.
Credit: ICRAR.

9 Work experience student Cole Bannister and Summer Studentship (now Masters) student Kirsty Butler, measuring the temperature of the Sun using a radio telescope during the annual Electrical Engineering Summer School.
Credit: ICRAR.

10 Two simulated galaxies during their intricate dance through space as they interact and later combine.
Credit: Chris Power and the ICRAR Simulations Team.

11 Dr Randall Wayth working on an antenna designed to detect the elusive 'Epoch of Reionisation' signal from the early Universe.
Credit: BIGHORNS team.

INTERNATIONAL CENTRE FOR RADIO ASTRONOMY RESEARCH (ICRAR)

Annual Report 2014-15

For the Western Australian Office of Science

To comply with the 2014-19 Financial Assistance Agreement (FAA) Clause 13.2 and Schedule Item 3.2

SECTION A: HIGHLIGHTS

A.1 HIGHLIGHTS OF 2014-15

Please provide the highlights as bullet points of two to five sentences each, suitable for release into the public domain and written for a lay readership. Each must include the significance of the highlight, such as the potential/achieved benefits for Western Australia (WA), including benefits for industry and other end-users (quotes from end-users can be included).

At least five science/engineering/data-related highlights are required (include in these the significance and also an explanation of i) the relevant advance/output and ii) the link between the advance/output and the implications). Other examples of highlights include financial, industry engagement or educational highlights.

ICRAR ORGANISATION

ICRAR Plan

The Premier and Science Minister, Colin Barnett MLA approved the ICRAR Plan V3.0 on 26 March 2015. This Plan covers the period 2014 – 2019 and outlines a comprehensive set of programs and projects amounting to a $52M cash investment by the State Government and the Joint Venture partners.

Independent Review of ICRAR

A review was successfully completed by Deloitte Access Economics (DAE) during the reporting period and the report was submitted to OoS. **The key points were:**

- The estimated value added to the State investment in ICRAR for 2013-14 alone was $17.5 million. This represents more than a 4:1 return on investment. This suggests that the State Government has recouped its initial investment purely through the economic value generated by the ongoing operations of the Centre and the visitors it has attracted to WA.

- The modelling undertaken for the study confirms that WA's Gross State Product is estimated to increase by a little over $110 million (in net present value terms) over the period to 2033 due to the investment related to the construction and operation of the Square Kilometre Array (SKA) project. In addition, the project is also expected to generate an average of 127 full time equivalent jobs each year between 2018 to 2033.

- ICRAR was assessed to be among the top 5 university based radio astronomy organisations globally by DAE in their report submitted in August 2014 (DAE Report attached at Appendix D).

ICRAR Visiting Committee Report

ICRAR's success in the science and technology academic areas was assessed by a high profile international Visiting Committee, chaired by Nobel Laureate Professor Brian Schmidt. The Committee reported that, "from its inception less than 5 years ago in 2009, ICRAR has quickly emerged as a new major organisation with broad recognition and respect on the World stage. This recognition and respect comes from its broad world--class science program that includes aspects of observational astronomy, simulation, and instrumentation".

CSIRO & ICRAR Strategic Alliance

The Chief Executive Officer (CEO) of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the ICRAR Board Chair established a strategic alliance between the two organizations with the aim of achieving mutual benefit. As part of the process CSIRO and ICRAR held a joint workshop on September 15, 2014 bringing together key people from each organization with Prof Brian Boyle, representing the Australian Government's SKA Office. A memo to Alistair McPherson, Deputy Director General of the SKA Office, is an outcome from that meeting. The intent of the memo is to outline the collective thinking on SKA roles that ICRAR and CSIRO stand ready to fulfil, again with the aim of assisting the SKA Office as it formulates its thinking regarding SKA operations.

ICRAR-CON 2014

The first all-of-ICRAR retreat/conference entitled ICRAR-CON, was held on Rottnest between 3 and 5 September. During the three days, 55 ICRAR staff and 19 students delivered 68 talks on their work at ICRAR. ICRAR-CON was a great opportunity for all staff to meet new staff, share their research results, make new linkages and participate in the ICRAR planning process. Staff from different programs and nodes benefitted from information-sharing and were able to develop new research relationships.

SKA Fremantle Science and Engineering Meeting

Between 29 September and 2 October, some 300 engineers and scientists from 15 countries travelled to Fremantle to participate in the global overview of the status, progress and way forward for the SKA in terms of engineering and management. It is the largest gathering of people working on the SKA ever organised. The official proceedings were opened by the Honourable Colin Barnett, Premier of WA, in the presence of the SKA Organisation Director General, Professor Philip Diamond, as well as the United States (US) Consul General, and representatives from the Dutch and United Kingdom (UK) governments. ICRAR co-hosted a welcoming sun-downer with the WA Office of Science (OoS) on 29 September at the WA Maritime Museum.

Completion of ICRAR I

ICRAR I was launched as a State funded Joint Venture (JV) of Curtin and UWA in 2009 for a first phase of 5 years with a mandate to help Australia win the SKA Project and to strengthen astronomy research in WA. ICRAR achieved both the objectives successfully between 2009 and 2014.

The final Annual Report for ICRAR I

The final Annual Report for ICRAR I and that for the year 2013/14 was submitted to the OoS in September 2014 along with the audited special purpose financial report.

Beginning of ICRAR II

July 2014 marked the beginning of second phase of ICRAR ("ICRAR II"). ICRAR II is tasked by the WA State Government to be the lead WA agency to participate in the SKA project.

ICRAR II Agreements

ICRAR JV and Centre Agent (CA) agreements were signed by the JV parties on 9 September 2014. The WA State Government FAA was finalised in consultation with the JV and also the OoS and was signed by the Premier and Science Minister, Colin Barnett MLA.

SCIENCE

- 177 refereed publications were published in astronomy journals, including 29 chapters in the new SKA Science volume "Advancing Astrophysics with the Square Kilometre Array" (http://pos.sissa.it/cgi-bin/reader/conf.cgi?confid=215). This volume will help define the science goals for SKA phases 1 and 2.

- Members of the science program led efforts to prepare the groundwork for the scientific utilisation of the SKA and were involved in the Scientific Organising Committees for several SKA conferences, including the 2015 OzSKA meeting at the University of Melbourne. Several ICRAR staff are members of the Australia New Zealand SKA Coordination Committee's (ANZSCC) Science Advisory Committee, including Prof Carole Jackson, who replaces Prof Bryan Gaensler as Chair. Prof Staveley-Smith and Drs Meyer, Huynh, Seymour and Macquart have also chaired or co-chaired SKA Science Working Groups in the fields of Galaxy Evolution, Continuum and Transients.
- The Murchison Widefield Array (MWA) project, represented by Prof Steven Tingay (MWA Director), Dr Randall Wayth and Mr Mark Waterson won the Space Science category of the 2015 Thomson-Reuters Citation and Innovation Awards, in recognition of their outstanding contribution to research.
- Success was achieved in external competitive funding including awards from Australian Research Council (ARC) LIEF, DECRA, Future Fellowship and Discovery Projects; and an international MERAC award.
- Two joint appointments shared between ICRAR and CSIRO were signed in order to advance collaborative research on pulsar and low-frequency radio astronomy.
- Six new ongoing staff were appointed by the JV partners, and six new postdoctoral appointments were made in the areas of theory, simulations, galaxies, Neutral Hydrogen (HI), Epoch of Reionisation (EoR) and radio continuum.
- Work on the MWA GaLactic and Extragalactic All-sky MWA (GLEAM) survey progressed significantly, with completion of processing of the first year data covering the whole southern sky. A second year of observations was also concluded. This survey has catalogued 400,000 objects in the southern sky at low radio frequency, providing a unique view of both our Milky Way galaxy and the extragalactic sky.,
- ICRAR scientists demonstrated international leadership in Data Intensive Astronomy (DIA) through science projects with MWA (including GLEAM), Galaxy and Mass Assembly (GAMA), CHILES (Very Large Array (VLA)) and AUDS (Arecibo).
- Dr James Miller-Jones was awarded the WA Young Tall Poppy of the Year Award for 2014. This award from the Australian Institute of Policy and Science is given for excellence in scientific research and communication; Prof Steven Tingay was a finalist in the Scientist of the Year category in the WA Premier's Science Awards 2014.
- PhD student Morag Scrimgeour was winner of the 2015 Charlene Heisler Prize for the best Australian astronomy PhD thesis; PhD student Mr Tom Russell was a finalist in the ExxonMobil Student Scientist of the Year 2014.

ENGINEERING AND PRE-CONSTRUCTION

- ICRAR Engineering, via pre-construction, MRO project management, industry partnerships and MWA-linked initiatives has confirmed the practicality of constructing and operating the LFAA, and by extension SKA-low, in WA. As well as contributions from ICRAR II streams, a large part of ICRAR Engineering pre-construction activities are supported by competitively won Australian Government funds totalling AUD 5M. Building on its pre-construction initiatives, ICRAR will seek central roles in SKA construction consortia when these are formed.

- ICRAR has one of the few groups involved in SKA pre-construction to have produced design insights backed up by astronomically-capable, on-site hardware. The Aperture Array Verification System (AAVS0.5) described in the last Annual Report, has been integrated with the MWA and has produced images used for metrology of the proposed Low Frequency Aperture Array (LFAA) antennas, via new techniques and algorithms. These have been disseminated to mainstream engineering science via publications. In effect ICRAR has produced images of the radio sky using antennas very similar to those to be used for the SKA.

- Professor Peter Hall produced a top-level design for the next-generation LFAA prototype system (AAVS1) and this is now being designed in detail by the Aperture Array Design and Construction Consortium (AADCC). ICRAR will have the key role in constructing, commissioning and characterising AAVS1 in 2016, again giving the Centre high impact outputs and demonstrating ICRAR's unique capacity.

- ICRAR industry partners, associated under LFAA and Central Signal Processor (CSP) preconstruction auspices, have produced seminal studies relating to the design of SKA-low.

These industry studies, especially those in the area of LFAA deployment and power systems, have been central in confirming the feasibility of SKA-low in WA.

- MWA phase 2: A high-level design for the expanded array was developed after national and international consultation workshops and meetings and submissions for funding have been made (ARC LIEF, PI Prof Steven Tingay). The expanded MWA would double the number of MWA tiles (to 256) to significantly enhance the capabilities for key science projects (KSPs). In the ICRAR Engineering laboratory, prototypes of new communication and control systems for long baseline antennas have been developed and are working. The MWA Project Manager continues to work with Perth- and Geraldton-based Small and Medium Enterprises (SMEs) on site power, communications and infrastructure works for MWA phase 2.
- In October 2014 the unique Broadband Instrument for the Glabal HydrOgen ReionizatioN Signal (BIGHORNS) radio telescope developed in collaboration with the ARC Centre of Excellence for All-sky Astrophysics (CAASTRO) was deployed permanently at the Murchison Radio-astronomy Observatory (MRO). BIGHORNS is a custom built conical spiral antenna and receiving system which continuously records the radio spectrum between 50 and 350 MHz. BIGHORNS is a multi-purpose instrument, serving both the astrophysics and engineering community by studying radio emission from the Sun and early Universe, and also the radio interference environment at the MRO.
- LFAA and CSP international SKA pre-construction consortia, in which ICRAR is a leading contributor, passed SKA Preliminary Design Reviews (PDRs). The LFAA design and development progress achieved by the AADCC (of which ICRAR is a foundation and leading member) throughout in Stage 1 of SKA pre-construction was rated highly by the international PDR panel. The review panel made special mention of ICRAR's excellent results in the critical AAVS task and noted that, in their view, the AAVS program would be pivotal in realising the LFAA and SKA-low.
- Industry partner Balance Utility Solutions completed an investigation into the critical question of power supply and distribution to the LFAA. In their report Balance Utility have identified a combination of power strategies, and associated reticulation configurations that broadly satisfy SKA requirements in terms of cost and performance. The report has been very well received by the SKA Organisation (SKAO) in their understanding of the specific requirements, challenges, issues and considerations associated with powering the LFAA.
- Industry partner Kaelus delivered a fully-tested, high specification analogue beamformer in support of SKA pre-construction activities. This system is an excellent demonstration of Australian industry's capacity to meet the stringent demands of radio astronomy instrumentation.
- Industry partner Raytheon Australia, working with ICRAR, produced the first LFAA deployment plan, showing clearly that construction of SKA-low at the MRO is possible within budgets considered feasible by the SKAO.
- Subcontracts with industry partners NVIDIA and CISCO were signed and are in progress. This work explores linkages between the SKA project and major industry partners in high performance computing and networking technologies. This work directly benefits the ICRAR contribution to the CSP work package and ICRAR's data intensive astronomy initiatives.
- A year long process of planning and negotiation between ICRAR, the CSIRO, and the MWA Project, culminated in the execution of the MRO site licence and agreements required to allow the deployment and operation of the AAVS1 system on the MWA site at the MRO. These agreements will ensure that ICRAR can continue the onsite engineering and test program that was identified as vital to a successful outcome by the SKA design review panel.

DATA INTENSIVE ASTRONOMY

- The SKA Science Data Processor (SDP) PDR was passed. PDR is an important milestone in large-scale projects, where the design team has to present a system architecture and design which addresses the high-level requirements for the project, and provides a risk and cost analysis. The ICRAR DIA group together with the rest of the international SDP Consortium prepared some 2000 pages of documentation and discussed the design with an independent, international review panel and the SKA headquarters.

- Support for CHILES data reduction was put into place. CHILES is a groundbreaking deep survey of the HI content of the Universe, spanning over 4 billion years of cosmic time. The huge data volume of this 1000h VLA survey (~1 TB per 10h) required the creation of advanced HPC pipelines to image the data. The DIA group at ICRAR was approached by the CHILES team to implement a solution given the lack of resources available elsewhere. Three parallelized solutions were developed and tested (local cluster, Pawsey supercomputer, and Amazon Web Services), with the Amazon option delivering the first full-sized image cubes for the project.
- The ICRAR DIA group developed, hosted and ran the GLEAM data server, which contains snapshot images and full GLEAM mosaics at all frequencies for all data so far processed (around 1 PB). DIA also runs a catalogue and postage stamp server used internally by the MWA Galactic and extragalactic group. The data is hosted on 300 TB of spinning disk, and will shortly expand to include a similar quantity of resources at Pawsey. Reduced data is automatically copied via Next Generation Archive System (NGAS) to servers in New Zealand and India.
- A core component of the GAMA survey (spectroscopic redshifts + 20 band photometry of ~300,000 galaxies) is the fitting of spectral energy distributions using highly specialized software. Initial processing by the GAMA team took 10-12 weeks. By porting that code to the Magnus supercomputer at the Pawsey Centre, the DIA group was able to reduce this to a single day, enabling the GAMA team to carry out on-the-fly analysis runs during their science busy week.
- The DIA group was actively engaged with industry and partners from other organisations, universities and the CSIRO. In order to further enhance collaborations in this area, a brochure was published, which highlighted the capabilities and expertise of the DIA team. This brochure will be used to inform interested parties about existing projects and the strengths of the ICRAR team.

OUTREACH EDUCATION AND COMMUNICATION (OEC)

- During National Science Week in August 2014, ICRAR staff and students engaged with almost 1,300 school students (including primary and secondary levels) and donated nine 'Universe in a Box' kits to primary schools in and around Perth.
- A new astrophotography themed program for high school students called 'AstroPhotoArt' was trialled at several schools. Students learn how to use digital Single Lens Reflex (SLR) cameras whilst applying and building upon their knowledge of science and astronomy. By the end of the short course students are able to capture images of the night sky for themselves and have a greater understanding and appreciation for the underlying science.
- ICRAR exhibited at the Asia-Pacific International Astronomical Union (IAU) Regional Meeting (APRIM) in Daejeon, South Korea.
- The 2014 SKA Engineering Conference was held in Fremantle from Sept 29 to Oct 2. 300 engineers and scientists from 15 countries attended to take part in a global overview of the status, progress and way forward for the SKA in terms of engineering and management. ICRAR's OEC team assisted with logistics and the successful delivery of the conference.
- Channel 10's children's science program 'Scope' filmed part of an episode at ICRAR, featuring Professor Chris Power's simulations team (Dr Rick Newton and Dr Paul Scott-Taylor). The episode aired in October 2014.
- Using research based simulations; ICRAR's Professor Chris Power, Dr Paul Scott-Taylor and Dr Rick Newton created a live planetarium show called 'Spinning the Cosmic Web in a Supercomputer'. Between October 2014 and February 2015.This show has been delivered three times to public audiences totalling more than 400.
- In December 2014, ICRAR's OEC Manager, Peter Wheeler, spoke about the importance of Outreach and Science Communication at the 'Frontiers of Science' symposium in Canberra, for an audience of Australian based researchers.
- Dr Paolo Ferri and Professor Mark McCaughrean of the European Space Agency came to Perth in February 2015 to deliver a free public lecture in collaboration with ICRAR. Dr Ferri and Professor McCaughrean are the Head of Mission Operations and the Senior Science

Advisor (respectively) for the Rosetta mission to land a probe on Comet Churyumov–Gerasimenko.

- ICRAR in collaboration with Perth's Shire of Kalamunda and the Perth Observatory Volunteer Group put together a world record-breaking event at the end of February. 1,108 people attended and set a new record for the world's biggest science lesson.
- Australia's largest annual astronomy festival Astrofest, coordinated by ICRAR, returned for a fifth time at the end of March, attracting crowds of more than 4,000 people. Optical and radio telescopes, including some of the largest in the State, were available throughout the evening to give festival-goers a fascinating look at some of the wonders of the Universe.
- In May 2015, the Astro-Rocks fest took place in Mt Magnet, the nearest large town to the Murchison Radio-astronomy Observatory. This event has now become a fixture on the annual list of events for the area.
- During this reporting period, ICRAR delivered 9 community programs, activities and events that have engaged more than 2,700 students, 75 teachers and 7,000 members of the public.
- ICRAR produced 23 news articles the ICRAR website and distributed 7 research related media releases. Our media releases and the videos we have created to support them have generated more than 600,000 individuals views of the videos online, almost 900 articles in print, online and television and a potential audience in the hundreds of millions.

SECTION B: GENERAL

B.1 GENERAL DETAILS

B.1.1 Name

International Centre for Radio Astronomy Research (ICRAR)

B.1.2 Recipient/Centre Agent

The University of Western Australia (UWA)

B.1.3 Official contact person

Title:	Ms	Name:	Christine Casey		
Position:	Associate Director, Research Grants and Finance, Office of Research Enterprise				
Address:	UWA, 35 Stirling Highway, CRAWLEY WA 6009				
Telephone:	6488 1776	Mobile:	-	Fax:	6488 1075
Email:	christine.casey@uwa.edu.au				

B.1.4 FAA Commencement Date **1/7/2014**

B.1.5 Length of FAA (years) **5**

B.1.6 Reporting period for this Annual Report (dd/mm/yyyy)

Start date 01/07/2014 Finish date 30/06/2015

B.1.7 Legal due date for this Annual Report (as per the FAA) 30/08/2015

B.1.8 Actual submission date for this Annual Report (dd/mm/yyyy) 28/08/2015

Variance between dates? Yes ☐ No ☒

Detailed reason for variance

SECTION C: ICRAR II PROJECT PROGRESS

C.1 SHORT PROJECT DESCRIPTION (as per the 2014-19 FAA)

The Project is the development and implementation of ICRAR Activities to fulfil ICRAR's role as the agency tasked by the State to lead WA's involvement in the Square Kilometre Array (SKA) Project to maximise the benefits of the SKA for Western Australia (including in research, education, industry and the wider community).

C.2 ICRAR II OBJECTIVES

Summary list of ICRAR II objectives (as per the ICRAR II Plan[1])

Principal Objective – Lay the foundations for a long term future as a sustainable organisation.

1. **Joint Venture Partners: Demonstrated excellence, linkage, output and international profile in scientific, engineering and data intensive research**.
2. **Governments: Success in attaining international and national competitive funding and awards, the development of industrial relationships and returns, and the enrichment of the community at multiple levels.**
3. **The SKA Project: Full delivery of commitments in preconstruction, support of the current planning and decision processes and a proven ability to facilitate the growth of the SKA in Australia during construction and operations.**
4. **Industry: Successful co-invested preconstruction partnerships that lead to successful participation in construction and the identification of opportunities for new players to gain benefit for and from the Project, the State and the Nation**.

[1] The ICRAR II Plan approved by the ICRAR Governing Board and by the Minister for Science (on 26 March 2015).

Progress against ICRAR II objectives (in this reporting period)

Summarise the progress towards achieving each ICRAR II objective.

Please also discuss any encountered difficulties/failures and improvements put or to be put in place.

Principal Objective – Lay the foundations for a long term future as a sustainable organisation

The success of ICRAR from 2009 to 2014 initiated the process of laying the foundation for a long-term sustainable future. In that period ICRAR helped Australia win a major component of the SKA, it contributed to the planning of the SKA project and to the growth of astronomy research and development (R&D) in WA and Australia by attracting the highest calibre staff and students to WA. The process has continued in the reporting period with ICRAR contributing successfully to, and leading, several components of the SKA pre-construction process, leading the scientific utilization of SKA precursors and developing relationships with industry in engineering and data intensive arenas. ICRAR is also successfully charting its path to a long term future in astronomy science and technology R&D through high quality research, research publications and strong academic research collaborations (Appendix A and sections D.6, E.6 and F.6).

1. **Joint Venture Partners: Demonstrated excellence, linkage, output and international profile in scientific, engineering and data intensive research**

The highlights from Sections D, E and F provide details of the excellent progress made by ICRAR against this objective. This is highlighted by ICRAR's success in producing a large number of high quality and impact scientific publications, the quality and number of postgraduate student enrolments, completions achieved, new competitive funding won, improved outcomes from

Excellence in Research Australia (ERA), research collaborations and academic seminars and other activities conducted by ICRAR to fulfil and exceed the JV expectations. Highlights include:

- 177 Publications including 29 ICRAR contributions to the new SKA science case published in the book "Advancing Astrophysics with the Square Kilometre Array' (http://pos.sissa.it/cgi-bin/reader/conf.cgi?confid=215)
- ICRAR scientists are international leaders in data intensive astronomy projects including MWA (GLEAM), GAMA, CHILES (VLA), AUDS (Arecibo) including the development of new cloud technologies approaches to global data analysis and management needs
- AAVS0.5 has been integrated with the MWA and has produced images used for metrology of the proposed SKA-low LFAA antennas, via new techniques and algorithms. These have been disseminated to mainstream engineering science via papers.
- Success with ARC and other external funding as listed in section C.6 and C.7
- International leadership and visibility in the SKA preconstruction program and delivery of commitments as detailed in section E and F.
- Success in profiling the JV universities through media coverage of scientific outcomes of ICRAR as detailed in section G.2 point 4 and 5.
- National and international research collaborations developed in science, engineering and DIA Programs as evidenced in sections D.6, E.6, and F.6.
- National and international collaborations in education and outreach and strategic partnerships as evidenced in section G.6 and H.6
- High calibre staff and students attracted to the JV universities through stringent merit based selection at international and national level. List attached at Appendix B.

2. Governments: Success in attaining international and national competitive funding and awards, the development of industrial relationships and returns, and the enrichment of the community at multiple levels

ICRAR has made excellent progress in at meeting and exceeding this objective. For details see C.6, C.7 and section E and F.

- ICRAR attracted over $9 million in additional competitive funding and actual income from existing grants in the reporting period (Section C.6 and C.7). Major successes include an ARC LIEF grant for a new optical survey (WAVES) to support SKA science and new ARC Discovery, DECRA and Future Fellowship grants.
- An application for a 2017 renewal of CAASTRO (CAASTRO-3D) has been submitted which includes five ICRAR Chief Investigators,
- ICRAR successfully engaged with industry in LFAA, SDP and CSP preconstruction. Details are provided in section E and F. Successful collaboration with industry partners, including Kaelus, Raytheon Australia, Balance Utility Solutions, NVIDIA and CISCO were central to this work.
- ICRAR further developed its engagement with Perth-based technology companies Systemic, ThinkBottomUp and global companies with WA presence Amazon, Fujitsu, ThoughtWorks, Data Direct Networks (DDN), Silicon Graphics Industry (SGI), Intel, IBM, KakaduSoft, Ajilon, Umwelt and Anditi.
- ICRAR progressed its relationships with industry in the area of "Big Data" to enable industry to benefit from ICRAR capabilities in working with data. The DIA group actively engaged with industry and partners from other organisations, universities and the CSIRO to further enhance collaborations in the area. A brochure was prepared highlighting the capabilities and expertise of the DIA team and is being used to inform interested parties about existing projects and the strengths of the ICRAR team. Brochure is attached to this report. Two Letters of Intent (Lois) were signed with industry as listed in section F.
- CISCO, in collaboration with Curtin University and Woodside, announced the launch in July 2015 of the Perth hub of the CISCO Internet of Everything Innovation Centre, to be opened by the Premier.

- ICRAR continues to enrich the community at multiple levels. Between July 1 2014 and June 30, 2015, ICRAR delivered programs, activities and events that engaged more than 2,700 students, 75 teachers and more than 7,000 members of the public. Details provided in Section G.

3. The SKA Project: Full delivery of commitments in preconstruction, support of the current planning and decision processes and a proven ability to facilitate the growth of the SKA in Australia during construction and operations

ICRAR has fully delivered its commitments in the SKA preconstruction phase and received international acknowledgement for its expertise, paving the way for ICRAR's participation in the SKA project during construction and operations. ICRAR passed its delivery milestones in all three WPs as listed below. More information can be seen in section E and F.

- ICRAR's contribution to LFAA passed PDR: The LFAA design and development achieved by the AADCC was rated highly by the international PDR panel. The review panel made special mention of ICRAR's excellent results in the pivotal AAVS task and noted that, in their view, the AAVS program would be pivotal in realising the LFAA and SKA-low. Overall, all milestones were met with all relevant reports being accepted by the SKAO and the Australian Government.
- All project milestones have been met in ICRAR's CSP preconstruction work package. A correlator design and preliminary costing was provided to CSP for PDR. Other architecture, system requirements and design artefacts were also provided and accepted (milestone 1 and 2). See details in section E.2 and E.3.
- In the CSP, subcontracts with NVIDIA and CISCO were signed and actioned. This work will explore linkages between the SKA project and major industry partners in high performance computing and networking technologies. This work directly benefits the ICRAR contribution to the CSP work package. The SDP PDR was passed. The ICRAR DIA group together with the rest of the international SDP Consortium prepared some 2000 pages of documentation and discussed the design with an independent, international review panel and the SKA headquarters.

4. Industry: Successful co-invested preconstruction partnerships that lead to successful participation in construction and the identification of opportunities for new players to gain benefit for and from the Project, the State and the Nation

ICRAR developed several successful partnerships with industry in the preconstruction phase that has contributed to the successful delivery of ICRAR's commitments to the SKA. Some key examples include:

- LFAA industry partners, Balance Utility Solutions, Raytheon Australia and Kaelus have successfully contributed to preconstruction solutions. Balance Utility completed an investigation into the critical question of power supply and distribution to the LFAA. Balance looked at the feasibility of local solar power solutions for antennas, tiles and stations and concluded that these solutions offered whole-of-life cost advantages only for remote stations. The report identified a combination of power strategies, and associated reticulation configurations, that broadly satisfy SKA requirements in terms of cost and performance. The report was very well received and has helped the SKA to understand specific requirements, challenges, issues and considerations associated with powering the LFAA. Raytheon Australia produced the first investigation and report on deploying the LFAA. Raytheon employed advanced operational modelling tools and software to show that, despite the scale of the deployment challenge, variants of known industry practices can produce a deployment program meeting SKA timescale and budget constraints. This work, addressing a significant SKA risk, was a very important milestone in stage 1 of SKA pre-construction. Kaelus delivered a fully-tested, high specification analogue beamformer in support of SKA pre-construction activities. This system is an excellent demonstration of Australian industry's capacity to meet the stringent demands of radio-astronomy instrumentation.
- CSP sub-contracts with NVIDIA and CISCO will lead to exploration of linkages between the SKA project and major industry partners in high performance computing and networking technologies.

- SDP collaboration with DDN, SGI, ThoughtWorks and Systemics has successfully contributed to elements of the SDP Data Layer design. Significant engagement with Amazon on the design and deployment of AWS cloud technologies for radio astronomy data flow and processing has also occurred. The SDP team is engaging with Perth based companies Systemic and ThinkBottomUp, but also globally operating companies having a presence in WA or Australia. This includes Amazon, Fujitsu, ThoughtWorks, DDN, SGI, Intel, IBM, KakaduSoft, Umwelt and Anditi. Some of that engagement involves pre-construction work. In other cases, it involves collaboration on case or cost studies and exchange of information about the SKA requirements on one side and potential technological solutions on the other.

Detailed reason for variance if any

C.3 ICRAR II KEY PERFORMANCE INDICATORS (KPIS)

Summary list of interim ICRAR II KPIs (as per the ICRAR II Plan)

1. **On average, research staff members at ICRAR publish at least two refereed articles per annum, with 90% of all articles to be published in journals with an Impact Factor of 3.0 or greater.**
2. **ICRAR maintains at least 45 enrolments of Masters and PhD students each year, with adequate support provided by the Centre to students to achieve four completions each year.**
3. **ICRAR continues to lead at least three pre-construction phase tasks for the development of SKA Phase 1, and has contractual involvement in the construction of SKA Phase 1.**
4. **ICRAR leads at least three preconstruction tasks for the development of SKA Phase 2 (subject to SKA 2 being approved for design within the five year period 2014-19).**
5. **At least two industry events are delivered by ICRAR each year to update industry on opportunities and requirements for involvement in SKA design, construction and operation. One of the briefings should be held in a regional location of the State.**
6. **ICRAR establishes collaborative relationships with at least three WA based businesses (i.e. organisations with headquarters in WA) between 2014 and 2019.**
7. **Develop a strategy by 2016 for presentation to the Office of Science identifying how ICRAR can be involved in the application of data intensive science to other sectors of the WA economy.**
8. **At least seven community events are delivered by ICRAR each year across WA (including regional areas) to raise awareness of issues relation to data intensive science, astronomy and engineering research relevant to the SKA.**
9. **ICRAR interacts with at least 2,000 school students per year in WA, including in regional areas.**
10. **ICRAR maintains existing agreements for research collaboration with five global corporations (i.e. organisations with headquarters, offices or subsidiaries overseas) between 2014 and 2019.**
11. **ICRAR establishes new collaborative relationships with at least two global corporations (i.e. organisations with headquarters, offices or subsidiaries overseas) between 2014 and 2019.**
12. **The cash investment by the State Government in ICRAR is leveraged at a ratio of at least five to one (including in-kind contributions) over the entire period 2014-19.**

Progress against interim ICRAR II KPIs (in this reporting period)

Summarise the progress towards achieving each interim ICRAR II KPI and milestone.

Please provide details of:

- any encountered difficulties/failures and improvements put or to be put in place;
- refereed journal publications in Appendix A;
- research staff and Masters/PhD students/graduates in Appendix B; and
- successful external research and development (R&D) grants in subsection C.6.

1. **On average, research staff members at ICRAR publish at least two refereed articles per annum, with 90% of all articles to be published in journals with an Impact Factor of 3.0 or greater**

   ICRAR has 65 research staff and 13 technical staff positions. In the reporting period ICRAR has published 177 refereed articles resulting in a metric of 2.7 papers per researcher. This exceeds the required metric of 2 by 35%. Of the papers published, the average impact per

publication, where impact factors are established, is 5.2. Of those papers, 88 are in journals with impact factor exceeding 3.0 representing a 98% achievement on the impact factor metric. Further details about the publications and the associated Impact Factor numbers can be seen in the attached publications list at Appendix A with impact factor numbers listed for each journal indicated in the attached list.

2. **ICRAR maintains at least 45 enrolments of Masters and PhD students each year, with adequate support provided by the Centre to students to achieve four completions each year**

   There were 43 PhD students enrolled during the reporting year giving 96% achievement of this KPI. The students were provided adequate support, with 9 completed in the reporting period leading to a 225% achievement of this KPI. Refer to appendix B for the list of enrolled and completed students. ICRAR is actively working to recruit more high quality students and 6 new students will commence the Science Programs at ICRAR in Q3 2015.

3. **ICRAR continues to lead at least three pre-construction phase tasks for the development of SKA Phase 1, and has contractual involvement in the construction of SKA Phase 1**

   ICRAR led the Data Layer task of the SDP work package, Aperture Array and Verification tasks of the LFAA work package and is involved in the CSP work package. More details can be seen in the Engineering and the DIA Program reports in Section E and F. ICRAR has met and achieved this KPI 100%.

   The procedures, procurement process and start date of SKA Phase 1 construction is not yet defined by the SKAO.

4. **ICRAR leads at least three preconstruction tasks for the development of SKA Phase 2 (subject to SKA 2 being approved for design within the five year period 2014-19)**

   Outside of this reporting period and likely outside the Term of ICRAR II.

5. **At least two industry events are delivered by ICRAR each year to update industry on opportunities and requirements for involvement in SKA design, construction and operation. One of the briefings should be held in a regional location of the State**

   ICRAR hosted 2 events in the reporting period: the ICRAR DIA Program delivered one industry event to update ICT companies on SKA opportunities on 30 March 2015 and ICRAR co-hosted an event with the Australian SKA Office (ASKAO) and Australian SKA Industry Consortium (ASKAIC) on 10 June 2015 at UWA for over 30 participants involving over 12 industries. (100% achievement).

6. **ICRAR establishes collaborative relationships with at least three WA based businesses (i.e. organisations with headquarters in WA) between 2014 and 2019**

   ICRAR established and developed collaborative arrangements with 3 companies in this reporting period: ThinkBottomUP, Ajilon and its subsidiary Anditi, and Umwelt. Two LoIs were signed in June 2015 with Umwelt and Ajilon and its subsidiary Anditi. ICRAR (Curtin University) also partnered with CISCO to launch the “Internet of Everything Innovation Centre” in Perth. ICRAR Engineering program works with Perth and Geraldton area SMEs—including Central Earthmoving, GCo Electrical, GNC Concrete, AFC, NLD Transport, and DeltaCorp Concrete. Details in section E and F. (Qualitative and can be stated as 100% achievement)

7. **Develop a strategy by 2016 for presentation to the OoS identifying how ICRAR can be involved in the application of data intensive science to other sectors of the WA economy**

   Progress has been made towards this KPI with the practical development and distribution of the ICRAR DIA capability statement and announcement of opportunity. Discussions have

been initiated with industry and sister organisations including National Resources Science Precinct (NSRP), CSIRO and Minerals Research Institute WA (MRIWA), to assess the application of DIA capability to other sectors of the WA economy. At the time of reporting collaborative work is being progressed with CSIRO and 2 LOIs have been signed with industry as stated in point 6 above.

8. **At least seven community events are delivered by ICRAR each year across WA (including regional areas) to raise awareness of issues relation to data intensive science, astronomy and engineering research relevant to the SKA**

   During this reporting period, ICRAR has delivered 9 community programs, activities and events that have engaged more than 2,700 students, 75 teachers and 7,000 members of the public. ICRAR has produced 23 news articles the ICRAR website and distributed 7 research related media releases. The media releases and the videos created to support the above have generated more than 600,000 individual views of the videos online, almost 900 articles in print, online and television and a potential audience in the hundreds of millions. See Section G for details. KPI achieved at 129%.

9. **ICRAR interacts with at least 2,000 school students per year in WA, including in regional areas**

   During this reporting period, ICRAR has delivered programs, activities and events that have engaged more than 2,700 students, 75 teachers and 7,000 members of the public. See Section G for details. KPI achieved at 135%.

10. **ICRAR maintains existing agreements for research collaboration with five global corporations (i.e. organisations with headquarters, offices or subsidiaries overseas) between 2014 and 2019**

    ICRAR has collaborative arrangements in place with Raytheon, CISCO, IBM, SGI, DDN, ThoughtWorks and Amazon**.** Discussions in progress with Chevron, BHP and GE to assess any opportunities to collaborate in the area of "Big Data". KPI achieved at 140%.

11. **ICRAR establishes new collaborative relationships with at least two global corporations (i.e. organisations with headquarters, offices or subsidiaries overseas) between 2014 and 2019**

    Process initiated with Fujitsu and KakaduSoft**.** These will be progressed further in the coming years. The KPI is applicable over the term of ICRAR II. ICRAR has signed an Memorandum of Understanding (MoU) with the Large Synoptic Survey Telescope Inc. (LSST) in the USA.

12. **The cash investment by the State Government in ICRAR is leveraged at a ratio of at least five to one (including in-kind contributions) over the entire period 2014-19.**

    The KPI is applicable over the term of ICRAR II. Prorata information for this period is provided based on average committed funds to be received. It may be noted that late Start of ICRAR II from 1 January 2015 instead of 1 July 2014 has impacted the in-kind* contribution.

    Total additional grant income won in reporting period (internal and external) = $9.0M

    Total in kind contribution in the reporting period = $6.8M*

    Average Annual Cash Contribution from the JV partners over the Term = $5.2M

    Total prorata non-State investment = $21.0M

    Total Average Annual State investment = $5.2M

    Current pro rata leverage factor = 4.05

Detailed reason for variance

ICRAR has achieved/overachieved the following KPIs. - 1, 2, 3, 5, 6, 8, 9 and 10. 98% of refereed publications are in Journals with IF greater than 3. Postgraduate enrolment KPI has been achieved 96%.

KPI 4 is out of ICRAR's current Term.

KPI 7 is due in 2016 and very good progress has been made towards achieving it.

KPIs 11 and 12 are over ICRAR's five year term and good progress has been made. ICRAR has made an excellent start with most KPIs and will make all efforts to further achieve any existing gaps.

C.4 BENEFITS TO WA (as per the 2014-19 FAA Schedule 2)

Summary list of ICRAR outcomes for the Term of the FAA

1. **ICRAR has enhanced Western Australia's capability, capacity and reputation for radio astronomy, data intensive science and technology development.**
2. **ICRAR has provided leadership in the SKA pre-construction and construction phases (2014-19), to maximise benefits to Western Australia.**
3. **ICRAR has provided leadership in the planning for the SKA construction and operation phases after the Term, to maximise benefits to Western Australia.**
4. **ICRAR has successfully engaged with local industry to produce studies, prototypes and systems relevant to SKA success and enabled Western Australian industry to contend for SKA work program.**
5. **ICRAR has assisted in development and implementation of a strategy to identify how ICRAR can be involved in the application of data intensive science from ICRAR and SKA activities to other sectors of the Western Australian economy.**
6. **Collaborative agreements with major global companies, including new agreements established during the Term, have delivered benefits to Western Australia.**
7. **ICRAR has increased community awareness, positive attitudes and interest towards SKA and Western Australia's capabilities in radio astronomy, data intensive science and technology development in Western Australia, including in the Mid-West region.**
8. **ICRAR has leveraged the Grant by attracting significant Commonwealth, international or industry research and development funding into Western Australia.**

Progress against ICRAR II outcomes (in this reporting period)

Summarise the progress towards achieving each ICRAR II outcome.

Please also:

- discuss any encountered difficulties/failures and improvements put or to be put in place; and
- provide details of external R&D grants awarded in subsection C.6.

1. ICRAR has enhanced Western Australia's capability, capacity and reputation for radio astronomy, data intensive science and technology development.

ICRAR has successfully enhanced WA's capability, capacity and reputation for radio The research capacity developed at ICRAR has transformed ICRAR into a well-respected hub of Australian and global astronomy, which is able to successfully attract new staff and important SKA and research meetings. astronomy science, engineering and data intensive astronomy since its creation in 2009.

ICRAR has emerged as a world class internationally connected organisation. The independent review of ICRAR by DAE identified ICRAR to be one of the top 5 radio astronomy organisations in the world. ICRAR has attracted through State and external grant funding, 65 world-class research staff and is currently training more than 40 HDR students. Including HDR students, there are 110 researchers conducting world-class research in WA at ICRAR. 177 refereed journal articles were published in the last year, bringing the total output to more than 700 since beginning of ICRAR. ICRAR's high quality publications have improved the ERA rankings of both WA Universities. ICRAR contributes to Science, Technology, Engineering and Mathematics (STEM) training through year 1, 2 and 3 physics and astronomy teaching and coordination. ICRAR also contributes to Honours, Masters and Postgraduate teaching at both UWA and Curtin. ICRAR has significantly contributed to technology development through its participation in the SKA preconstruction activities in the LFAA, CSP and SDP WPs. For details see sections F and G. ICRAR has developed very successful national and international collaborations that have led to more than 700 research scientists and engineers visiting WA in the past years with more than 175 visitors in the

current reporting year. This adds significantly to the international visibility and reputation of WA as a leader in the knowledge economy. This also contributed directly to the WA economy as highlighted by the DAE report. For more details on outcomes, see outcomes listed in sections D.5, E.5, F.5 and G.5. For details of collaborations please see sections D.6, E.6. F.6, G.6 and H.6.

2. ICRAR has provided leadership in the SKA pre-construction and construction phases (2014-19), to maximise benefits to Western Australia.

ICRAR staff have provided scientific, technical and design leadership in the SKA pre-construction activities and also to SKA science planning activities. ICRAR has produced design insights backed up by astronomically-capable, on-site hardware suitable for SKA-low, and has produced images used for metrology of the proposed LFAA antennas, via new techniques and algorithms. A top-level design for the next-generation LFAA prototype system (AAVS1) has been produced, demonstrating innovation and leadership in WA. Pathfinder development with MWA, BIGHORNS, VLA/CHILES continues to demonstrate world-class engineering, scientific and leadership in data intensive science. PDRs for SDP and LFAA were passed – substantial and internationally-recognised contributions having been made by the ICRAR teams. For more details on the SKA pre-construction please refer to sections F.2, F.5 and G.2.

3. ICRAR has provided leadership in the planning for the SKA construction and operation phases after the Term, to maximise benefits to Western Australia.

ICRAR staff have participated in the operations work group for the SKA now advising the new SKA Head of Operations on operations planning and ramp up. ICRAR and CSIRO have proposed a joint operations concept, which includes a regional centre, to the SKA Head of Project and DG. ICRAR has contributed to the planning of the SKA1-low and SKA2-low antenna configuration and topology, and provided advice on radio quiet zones. ICRAR's Science team has actively led major components of the SKA science planning process in the reporting period as outlined in Sections D.2 and E.2. ICRAR staff were part of the Science Organising Committee for the 2014 meeting "Advancing Astrophysics with the Square Kilometre Array" and the 2015 OzSKA meeting. ICRAR staff have led and contributed chapters for SKA science book, chaired international SKA Science Working Groups and SKA KSP planning activities. These contributions will drive the top-level requirements for SKA2. Through its participation in the SKA pathfinder projects, ICRAR has also demonstrated its end to end capacity and capability to work with the pathfinder project MWA and the radio quiet characteristics of the WA's SKA host site. Details in section D, E, F and G.

4. ICRAR has successfully engaged with local industry to produce studies, prototypes and systems relevant to SKA success and enabled Western Australian industry to contend for SKA work program.

ICRAR has very successfully engaged with local industry in the pre-construction phase as already substantially reported in sections F (F.3 and F.4) with reference to LFAA and CSP preconstruction activities. The local and global industries with WA presence involved are Balance Unity Solutions, Kaelus, Raytheon Australia (Perth) and Geraldton based SMEs including Central Earth moving, CGo Electrical, GNC Concrete, AFC, NLD Transport and DeltaCorp Concrete. ICRAR's Engineering team, through these engagements is beginning building of SKA capacity in WA. Further ICRAR through its participation in the SDP WP (see section F.4) has successfully engaged with local companies ThoughtWorks, ThinkBottomUP, Ajilon, Umwelt/ Anditi, and Systemic.

SKA Work programs will not be announced for tender until early 2018 on the current schedule and any further information on ICRAR's ability to contend for, or enable engagement in, the SKA construction work program is out of this reporting period.

5. ICRAR has assisted in development and implementation of a strategy to identify how ICRAR can be involved in the application of data intensive science from ICRAR and SKA activities to other sectors of the Western Australian economy.

ICRAR has taken practical steps to work towards achieving this outcome and has progressed its relationship with other WA economy sectors. ICRAR has strategically developed a capability brochure to inform industry and other WA economy sectors of ICRAR's capability in data intensive science and expertise in dealing successfully with Big Data. The DIA group actively engaged with mining, oil and gas, geoscience and other industry and organisations, including universities, CSIRO, National Resource Sciences Precinct (NRSP), and MRIWA to further enhance collaborations in the area of Big Data. Extensive discussions have been held with industry and the above mentioned organisations to inform these organisations and industry of ICRAR's capability and intent to work with and support sister organisations and industry in the field of Big Data. Two LoIs were signed with industry as listed in section F. In addition to above, active discussions are in progress with several industry partners including Ajilon, Umwelt/Anditi and Chevron. ICRAR in collaboration with Curtin University, Woodside and CISCO, launched the "Internet of Everything" Centre in Perth to further progress this outcome.

6. Collaborative agreements with major global companies, including new agreements established during the Term, have delivered benefits to Western Australia.

Agreements with NVIDIA and CISCO have been signed by the CSP work package. Raytheon has delivered key prototype systems. Amazon has awarded four ICRAR research projects compute credits worth $50k on Amazon Web Services (AWS). A collaborative agreement has been signed with the LSST corporation. CISCO has established the IoE Centre in Perth - this is a major collaboration with a global company likely to benefit WA. ICRAR is also working towards establishing greater collaborations with Amazon, DDN, ThoughtWorks, Western Digital, Fujitsu, Chevron and other mining companies in the area of Big Data.

7. ICRAR has increased community awareness, positive attitudes and interest towards SKA and Western Australia's capabilities in radio astronomy, data intensive science and technology development in Western Australia, including in the Mid-West region.

ICRAR's research staff and students and community volunteers in collaboration with ICRAR's OEC team have successfully increased community awareness and interest towards the SKA through community events, school based activities, exhibitions and public talks conducted in WA, including the Mid-West region. Details can be seen in section G.2. The OEC team, research staff and students have directly reached out to the public through hands-on activities, numerous media releases, video articles and news stories. Staff have also championed ICRAR's extensive Outreach and Education program, which has interacted with more than 80,000 people over the last 5 years. In most visits and programs, OEC staff are accompanied by early career research staff or higher degree students with a passion for outreach. In the reporting period ICRAR delivered programs and events to 7000 members of public, 75 teachers and 2700 students.

8. ICRAR has leveraged the Grant by attracting significant Commonwealth, international or industry R&D funding into Western Australia.

ICRAR staff have been successful in national and international competitive grants. Over $9.0M has been raised in the last 12 months. Major successes have been an ARC LIEF grant to conduct a new optical survey (WAVES) to support SKA science. An application for a 2017 renewal for the ARC Centre of Excellence for All-sky Astrophysics (CAASTRO-3D) has been submitted. Other successful grants include prestigious ARC Discovery, DECRA and Future Fellowships. See Sections C.6 and C.7.

C.5 ICRAR II BUDGET (for this reporting period)

C.5.1 Expenditure of State Government funds (as per the ICRAR II Plan)

Program	Agreed expenditure ($)	Actual expenditure ($)	Variance ($)
ICRAR I carry over funds (includes UWA funds)			
Science Program			
Engineering Program			
DIA Program			
OEC			
Central and Governance			
Centre and Node Management			
Sub-total	*1,070,903*		*1,070,903*
ICRAR II funds			
Science Program	471,900	192,908	278,992
Engineering Program	592,578	383,959	208,619
DIA Program	2,047,524	788,886	1,258,638
OEC	344,439	188,795	155,644
Central & Governance	548,774	348,170	200,604
Centre & Node Management	664,398	394,292	270,106
Sub-total	*4,669,613*	*2,297,010*	*2,372,603*
TOTAL	**5,740,516**	**2,297,010**	**3,443,506**

Expenditure details & reason for variance

Summarise the expenditure of the State Government funds.

ICRAR II expenditure started on 1 January 2015 and not on 1 July 2014. This late start was as approved by ICRAR Finance and Audit Committee and the Board to enable ICRAR I to transition to ICRAR II smoothly. The Carry Forward funds from ICRAR I to ICRAR II of $1.07M have not been expended as these are subject to ICRAR Board approval. A paper on use of carry forward funds will be submitted to the Board in 2015/16. Variance in budgeted expenditure is due to the agreed six month late start of ICRAR II from 1 January 2015 as compared to 1 July 2014. ICRAR II Budget will be revised in 2015/16 to provide for SKA rebaselining outcomes and strategic priorities and will be submitted for approval.

Variance in expenditure? Yes ☒ No ☐

C.5.2 Expenditure of Curtin University and UWA Joint Venture cash contribution (as per the ICRAR II Plan)

Program	Agreed expenditure ($)	Actual expenditure ($)	Variance ($)
Curtin University			
Science Program	1,121,604	503,505	618,099
Engineering Program	397,797	225,460	172,337
Sub-total	*1,519,401*	*728,965*	*790,436*
UWA			
Science Program	1,728,554	927,851	800,703
DIA Program	124,164	55,331	68,833
Centre & Node Management	172,500	42,548	129,952
Sub-total	*2,025,218*	*1,025,730*	*999,488*
TOTAL	**3,544,619**	**1,754,695**	**1,789,924**

Expenditure details

Summarise the expenditure of the Curtin University and UWA Joint Venture cash contributions.

Expenditure of JV cash is in line with ICRAR II Plan Programmatic expenditure. Major expenditure is on salaries. In the Science Program at Curtin appointment offers have been made to new staff but not all have started in the reporting period. Expenditure in the Engineering Program is mainly in the SKA preconstruction effort. Science Program at UWA is fully funded from UWA Cash whereas DIA Program including SDP preconstruction activities are mainly funded from the State Government. Centre and Node Management activities are also mainly funded from the State cash. Variance is due to start date of 1 January 2015 versus 1 July 2014.

Variance in expenditure? Yes ☒ No ☐

Detailed reason for variance in expenditure

Variance in expenditure is due to the agreed six month late start of ICRAR II from 1 January 2015 as compared to 1 July 2014.

C.5.3 Curtin University and UWA Joint Venture in-kind contributions (as per the ICRAR II Plan)

Program	Agreed contribution ($)	Actual contribution ($)	Variance ($)
Curtin University			
Science Program	3,841,488	1,170,367	2,671,121
Engineering Program	2,873,578	662,253	2,211,325
Space		737,685	(737,685)
Sub-total	*6,715,066*	*2,570,305*	*4,144,761*
UWA			
Science Program	5,783,243	1,791,795	3,991,448
DIA Program	1,848,841	1,208,974	639,867
Central & Governance	111,527	0	111,527
Space		1,269,090	(1,269,090)
Sub-total	*7,743,611*	*4,269,859*	*3,473,752*
TOTAL	**14,458,677**	**6,840,164**	**7,618,513**

Contribution details

Summarise the provision of Curtin University and UWA Joint Venture in-kind contributions.

In-kind contributions are for personnel operational support as identified in ICRAR II Plan and for in-kind space contributed by the JV partners. These contributions are in line with ICRAR II Plan and JV agreement.

Variance in contributions? Yes ☒ No ☐

Detailed reason for variance in contributions

Variance in in-kind contribution is due to the agreed six month late start of ICRAR II from 1 January 2015 as compared to 1 July 2014.

C.6 ADDITIONAL EXTERNAL CASH FUNDING RECEIVED (for this reporting period)

Provide details of any additional external R&D cash funding (such as new R&D grants and contract research), including the source (name of funding agency & type of grant or organisation/company name), title of grant or contract project, duration (year or years, e.g. 2015-17) and value.

C.6 ADDITIONAL EXTERNAL CASH FUNDING RECEIVED (for this reporting period)

Source	Chief Investigator	Grant / Project Title	Duration	Administering entity	Value ($)
ARC	Lagos, C	DE150100618 - Australian Research Council ARC/ARC Discovery Early Career Researcher Awards(**) - Lagos, Claudia D - Gas in the Cosmic Web: feeding and feedback of galaxies - RA/1/1639/326	2015-2018	UWA	354,000
ARC	Driver, S	LE150100055 - ARC Linkage Infrastructure Equipment Facilities - Professor Simon Driver - WAVES: Wide Area VISTA Extra-galactic Survey - RA/1/513/129	2015-2016	UWA	560,000
ANU, Macquarie, UOM, SUOT, Monash, UOS, UOQ,CUOT	Driver, S	Australian National University - LE150100055 - Professor Simon Driver - WAVES: Wide Area VISTA Extra-galactic Survey - RA/1/1057/18	2015-2016	UWA	222,500
AAO	Driver, S	Australian Astronomical Observatory - LE150100055 - Professor Simon Driver - WAVES: Wide Area VISTA Extra-galactic Survey - RA/1/2031/2	2015-2016	UWA	80,000
DFAT	Hoh, S	Department of Foreign Affairs & Trade Australia Korea Foundation AKF2014Grant00032 13/11439 Se-Heon Oh: Star Formation & Dark Matter in Dwarf Galaxies RA/1/2401/3	2014-2015	UWA	3,560
ARC	Cattinella, B	How do galaxies in groups run out of gas? Revealing the link between galaxies and their environment	2015-2018	UWA	325,500

Source	Chief Investigator	Grant / Project Title	Duration	Administering entity	Value ($)
ARC	Cattinella, B	Using Australia's next-generation radio telescopes to unveil the gas cycle in galaxies	2015-2016	UWA	177,665
CSIRO	Popping, A	CSIRO ACES joint appointment	2014-2015	UWA	58,638
Various	Various	Income received for existing R & D grants for financial year 2014-2015	2014-2015	UWA	1,428,168
CSIRO	Tingay, S	CSIRO Commissioning Scientist	2014	Curtin	26,175
AFOSR	Tingay, S	AOARD	2014-2015	Curtin	55,000
ARC	Jones, J	Future Fellowship-JMJ	2014-2017	Curtin	647,527
ARC	Seymour, N	Future Fellowship-NS	2014-2016	Curtin	136,525
CSIRO	Tingay, S	CSIRO Joint Appointment	2015-2019	Curtin	496,786
University of Wisconsin	Tingay, S	University of Wisconsin	2014-2015	Curtin	20,000
Various*	Various	Income received for existing R & D grants for financial year 2014-2015	2014-2015	Curtin	3,542,540
				TOTAL ($)	**8,134,584**

* Includes income received in the reporting period from the Federal Government for SKA preconstruction activities in ICRAR's Engineering Program. Federal funds received for LFAA preconstruction (Hall, P $1,454,137) and for CSP (Ord, S $365,816).

C.7 ADDITIONAL INTERNAL CASH FUNDING RECEIVED (for this reporting period)

Provide details of any additional internal R&D cash funding (R&D funding from Curtin University and UWA), in addition to the Joint Venture cash contributions for ICRAR II. Please include the source, Chief Investigator, title of grant, duration (year or years, e.g. 2015-17) and value.

Source	Chief Investigators	Grant/project Title	Duration	Value ($)
UWA	Kafle, P	ECR-RCA 2015 -Kafle-Galaxies Joining a Party: Finding a Group.:RA/1/1200/642	2015-2016	18,726
UWA	Cui, W	ECR-RCA 2015 -Cui-The properties of cosmological structures:RA/1/1200/653	2015-2016	10,000
UWA	Davies, L	ECR-RCA 2015 -Davies-Identifying Low Surface Brightness Galaxies in the Local Universe:RA/1/1200/622	2015-2016	5,847
UWA	Obreschkow, D	ECR-RCA 2015 -Obreschkow-Mysterious Light of Weightless Bubbles.:RA/1/1200/649	2015-2016	19,000
UWA	Power, C	RCA 2015-Power-A new dimension to galaxy modelling for future surveys:RA/1/1200/613	2015-2016	9,463
UWA	Power, C	2014 Mid-Career Research Award - Power	2014-2015	2,000
UWA	Robotham, A	2014 Early Career Investigators Award - Robotham	2014-2015	1,500
UWA	Driver,S	RPF LE150100055 -Driver: RA/1/513/129	2015-2016	50,000
UWA	Various	Income received for financial year 2014-2015.	2014-2015	277,357
Curtin	Tingay, S	CSIRO Joint Appointment	2015-2019	496,786
			TOTAL ($)	**890,679**

SECTION D(i): ICRAR/CURTIN SCIENCE PROGRAM PROGRESS

D(i).1 SHORT PROGRAM DESCRIPTION

Please provide a short summary of the Program (suitable for public release).

The ICRAR/Curtin science program focuses on low frequency radio astronomy and studies a wide range of astronomical phenomena. There are three major areas of focus:

- Studying the properties of the Milky Way and those of external galaxies (extragalactic objects) through the Universe, using new observations from the MWA telescope that Curtin manages and operates on behalf of a major International consortium. Galactic objects include pulsars, HII regions, masers and the interstellar medium, which pervades the Milky Way. Extragalactic studies focus on tracing galaxies via their radio emission and understanding the physical processes including star formation and active galactic nuclei (AGN).

- Analysing the details of the accretion processes that occur in a range of astronomical objects, from stellar-sized compact objects in binary star systems through to the monster black holes in massive galaxies; This group uses a range of multi-wavelength observations and computational models to understand the connection between inflow and outflow around black holes, and the feedback effect they have on their surroundings.

- Detecting the faint signal of the hydrogen spin-flip transition in hydrogen (rest-frame 21cm) at the time of the formation of the first generation of galaxies in the Universe.

D(i).2 PROGRAM OBJECTIVES

Summary list of Program objectives

Please provide a list of Program objectives for the Term of the 2014-19 FAA.

The objectives of the ICRAR/Curtin science program are to build expertise, tools and techniques in readiness for the SKA whilst conducting world-class science. The objectives for the three ICRAR2 projects within this program are summarised as:

- **SC1 MWA Science**
  This five-year project aims to exploit new observations from the MWA telescope, using ICRAR's unique technical and geographical position to extract the maximum high-impact science from this first SKA Precursor telescope. Whilst this project encompasses a range of astronomical research and data, we focus on outputs from the MWA which provide a unique view of the low frequency sky in exquisite detail. Additionally, the MWA is located at the MRO (Australia's SKA site) and provides a clear demonstration of the MRO's superb low radio frequency interference (RFI) environment and its view of the southern sky that covers large regions of our Milky Way and more critically, the Galactic Centre.

  This project is led by Prof Carole Jackson and Dr Nick Seymour.

- **SC2 Accretion Physics**
  This five-year project continues the highly-successful progress established over the past five years of ICRAR, bringing together observations (from a wide range of facilities around the world) and theory to better understand compact astrophysical objects such as neutron stars and black holes, as well as their environments. The aim is to continue to produce very high Impact publications in the world's leading journals and to make discoveries in new areas of astrophysics, such as in the area of Fast Radio Bursts (FRBs).

  This project is led by Dr James Miller-Jones.

- **SC3 Epoch of Reionisation (EoR)**
  This five-year project was introduced to the ICRAR2 plan in Q2 2015. The EoR Project encompasses science, instrument design, and signal processing theory related to detection and estimation of the HI signal from the EoR. It involves research associated with data from the MWA and the low-frequency component of the SKA (SKA-Low).

  This project is led by Dr Cath Trott.

Progress against Program objectives (in this reporting period)

Summarise the progress towards achieving each Program objective.

Please also discuss any encountered difficulties/failures and improvements put or to be put in place.

The ICRAR/Curtin science program objectives are being met through the series of *activities* described in detail in Section D.3. Here we summarise highlights of progress towards the *program objectives*:

1. Develop personnel astronomy expertise, tools & techniques in readiness for the SKA

- **Recruitment success:** ICRAR/Curtin concluded four new postdoctoral appointments in January 2015 to work with Prof Carole Jackson, Dr Nick Seymour and Dr James Miller-Jones. In all cases the top-ranked candidates accepted and are expected to commence later in 2015. A fifth postdoc position to work with Dr Cath Trott will be directed towards further building the EoR team as noted in a following dot point.
- **Strengthening SKA science focus within ICRAR:** Given some flexibility regarding postdoc hires the fifth new postdoc hire was reallocated to MWA EoR science: this justified the creation of the new SC3 science project led by Dr Cath Trott within this program.
- **First joint appointment** with CSIRO Astronomy & Space Science; the appointment of Dr Ryan Shannon strengthens ICRAR/Curtin Science (Pulsars & Transients) and also builds stronger SKA-directed links with CSIRO.
- **Significant contributions to the ongoing development of SKA science planning**, including
  - **Chapters for SKA Science Book**: Following the successful Advancing Astrophysics with the SKA meeting held in June in Sicily, ICRAR/Curtin members contributed to 19 chapters for the new SKA Science Book. This book will be the bible for planning the SKA KSPs as well as a large number of important other science goals.
  - **Chairing international SKA Science working groups (SWG):** during the year Dr Nick Seymour was co-chair of the SKA Continuum Science Working Group (SWG) whilst Dr Jean-Pierre Macquart co-chaired the Transient SWG, and both coordinated the submission and refereeing of numerous chapters for the new SKA Science case as members of the Editorial Board.
  - **SKA development of calibration strategies**: As part of the SKA Calibration Consultation Workshop in April, Dr Cath Trott, Dr Natasha Hurley-Walker and Dr Randall Wayth provided expert input on ionospheric calibration, MWA processing and design: This expertise will influence critical design decisions for SKA-low. Dr Cath Trott and Dr Randall Wayth contributed to the development of an important new mode for EoR science observations on SKA-low.
  - **SKA KSP planning:** August 2015 sees the first of the invite-only KSP Workshop to be held at the Wenner-Gren Centre in Stockholm. Amongst the twenty invited Australian scientists attending, six are members of the ICRAR/Curtin Science program, reflecting the strength of potential KSP leadership across a range of astronomy areas in this cohort.
  - **Further contributions to SKA scientific and design developments are described in D.3, D.5 & D.6.**
- **Develop data analysis expertise for the analyses of data from large-N low frequency arrays:** Whilst our focus is on the scientific (astronomical) results from the MWA in this report, it is of significant note that the ICRAR/Curtin science program has made huge steps in understanding the complexities of data from this new class of instrument. These are captured in the papers by Drs Wayth, Hurley-Walker, Ord, and many others including Prof Hall & Dr Sutinjo (reported in detail in the ICRAR/Curtin Engineering Program). These

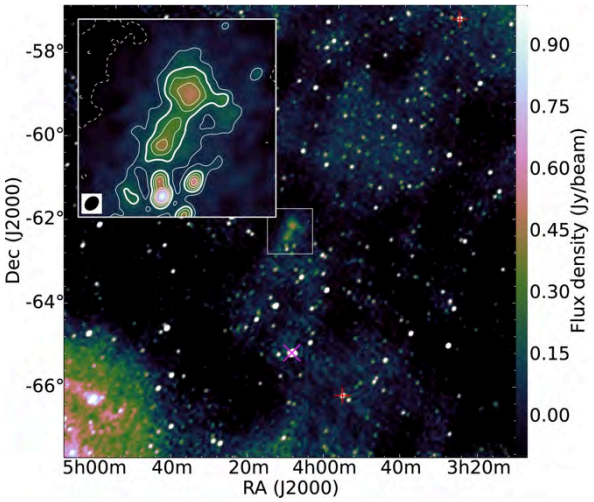
have also fed into important SKA discussions across both science and engineering (design). It has allowed existing, general purpose, radio data processing software packages to be upgraded to handle MWA data. For example, source finding algorithms, such as Aegean (Hancock), are now able to work on MWA data. This means that despite its subtleties, MWA data is evolving to become part of mainstream radio astronomy. This is important for the widespread use of such data in the future by non-expert groups.

2. Produce world-leading science outcomes

- **SC1 MWA Science**

  Deliver new science results from galactic and extragalactic radio astronomy, evidenced from papers delivering important new MWA results and those from other world-leading instruments, some of which we discuss here:

  - The description of the new all-sky GaLactic & Extragalactic MWA sky survey ("GLEAM") (Wayth et al 2015, PASA)
  - The MWA commissioning survey description paper ("MWACS"), provides a first large catalogue of extragalactic sources at 180 MHz (Hurley-Walker et al 2014, PASA).
  - Hurley-Walker et al. (2015) "Serendipitous discovery of a dying Giant Radio Galaxy associated with NGC 1534, using the Murchison Widefield Array", MNRAS, 447, 2468. This paper was the first paper to be published using the new GLEAM survey data.

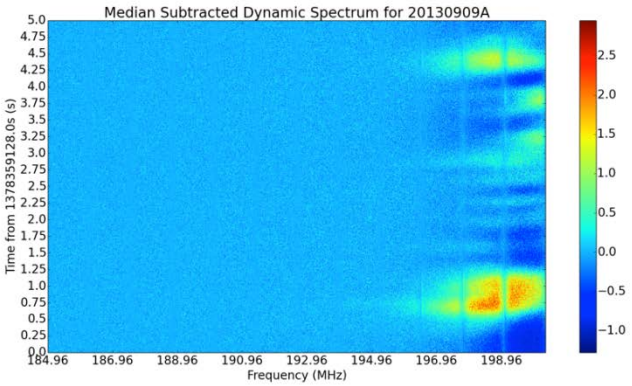


The giant dying radio galaxy discovered with MWA (Hurley-Walker et al, 2014).

  - Tremblay et al. (2015) "The High Time and Frequency Resolution Capabilities of the Murchison Widefield Array", PASA, accepted. This paper presents the commissioning of the high time resolution voltage capture mode of the MWA, crucial for studies of pulsars and fast transients.
  - Hotan et al. (including Jackson) 2014, "The Australian Square Kilometre Array Pathfinder: System Architecture and Specifications of the Boolardy Engineering Test Array", PASA, 31, 41. This paper is the first Australian SKA Pathfinder (ASKAP) engineering design paper.
  - Dannerbauer et al. (including Seymour) 2014, "An excess of dusty starbursts related to the Spiderweb galaxy", A&A, 570, 55. This paper reported an extremely large star formation rate (more than 10,000 times that usually encountered) around the distant, z=2.2, Spiderweb Galaxy Cluster. It was covered in several media outlets including a piece by Dr Seymour in the Conversation: https://theconversation.com/from-galactic-pile-ups-stars-are-born-a-crash-course-in-clusters-32962

Image of the Spiderweb galaxy cluster exhibiting extreme star formation (Dannerbauer et al. (including Seymour) 2014).

- Commissioning has been completed, and first data analysis commenced, from the new MWA voltage capture system (VCS). Dai et al (including Bhat) “A study of multifrequency polarization pulsar profiles of millisecond pulsars” analyses pulse profiles to ever-deeper detail and foreshadows the utility of data below 750 MHz, and Noutsos et al (including Miller-Jones) “Pulsar polarisation below 200 MHz” explores the low frequency behaviour of pulsars using new LOFAR data. Both analyses point to the MWA VCS providing detailed observations for southern pulsars in the near future.

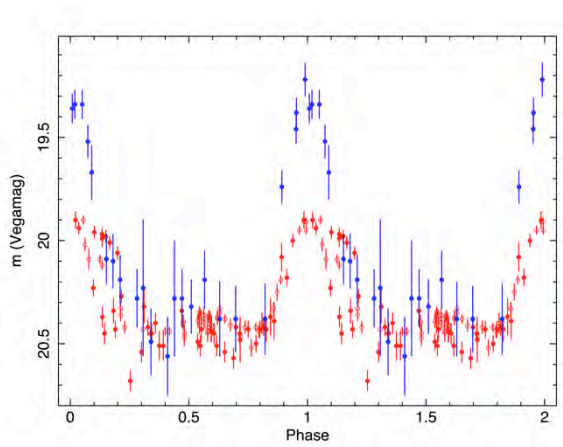


A five second dynamic spectrum from the incoherent sum of all MWA 128 tiles (Tremblay et al. 2015) showing rapid, sub-second solar emission.

- Jordan et al (including Walsh) “MALT-45 a 7mm survey of the southern Galaxy” sets out the techniques and spectral line data obtained from this unbiased, large-scale, sensitive spectral line survey at 45 GHz.
- Ord et al (including Crosse, Emrich, Pallot, Wayth, Tremblay, Bhat, Tingay (and more)) “The Murchison Widefield Array Correlator” details the design and implementation of the MWA’s correlator which now generates more than 8 TB/day during regular MWA observing.

- **SC2 Accretion Physics**
  Deliver new science results from accretion physics, evidenced from papers delivering important new results, some of which we discuss here:
  - **Nature publication on Ultraluminous X-ray (ULX) source:** Roberto Soria was co-author on a Nature paper (Motch et al. 2014, Nature, 514, 198), which solved a long standing question standing question on ULXs. These sources are thought to be powered by accretion onto black holes from companion stars, but the explanation for the intense X-ray luminosity has long been debated: whether it is due to an exceptionally high accretion rate, or to exceptionally massive black holes? In the latter case, these sources could host the long-sought class of ‘Intermediate Mass Black Holes’, which are thought to form the building blocks of supermassive black holes at the centres of galaxies. Using long term monitoring of a ULX in the galaxy NGC 7793 Motch et al. demonstrated that the companion star was a B9 supergiant with a mass of $20\pm2\ M_{\odot}$ and hence that the black

hole had a mass of <15 $M_{\odot}$ (most likely ~10 $M_{\odot}$). This then suggests that the majority of similar sources are not unusually massive, but instead have exceptionally high accretion rates.



Long-term monitoring provides evidence that ULXs are not typically extremely massive black holes, but rather black holes accreting at an extreme rate (Motch et al. (including Soria) 2014, Nature).

- Russell et al (including Miller-Jones, Curran, Soria) "Radio monitoring of the hard state jets in the 2011 outburst of MAXI J1836-194" (MNRAS) presented a comprehensive overview of the behaviour of the jets during an outburst of an accreting black hole system. This student-led paper demonstrates the insights that can be gained by coupling high-resolution VLBI observations with broadband monitoring across the electromagnetic spectrum.
- Macquart & Kanekar 2015, "On Detecting Millisecond Pulsars at the Galactic Center" (ApJ. 805, 172) considered the likely pulsar population at the Galactic Centre along with the scattering properties of the surrounding medium to determine the optimal search strategy for finding millisecond pulsars orbiting the supermassive black hole at the centre of our Milky Way Galaxy. The discovery of even one such system would open the door to testing Einstein's theory of relativity in unprecedented detail, which is one of the key science questions for the SKA.

- **SC3 Epoch of Reionisation (EoR)**
  Deliver new science results relevant to the detection of the EoR, including MWA data analysis, evidenced from papers delivering important new results, some of which we discuss here:
  - A power spectrum analysis methodology developed with Dr Cath Trott enables real-time monitoring of ionospheric conditions, providing direct correction to the astronomical data. Ionospheric calibration is crucial for EoR observations and becomes even more so when we look towards longer baseline instruments such as SKA-low. The power spectrum analysis results have been published in Loi et al (including Trott, Hurley-Walker, Morgan, Hancock, Ord, Emrich, Tingay, Wayth, Williams) "Power spectrum analysis of ionospheric fluctuations with the Murchison Widefield Array" (Radio Science, 2015).

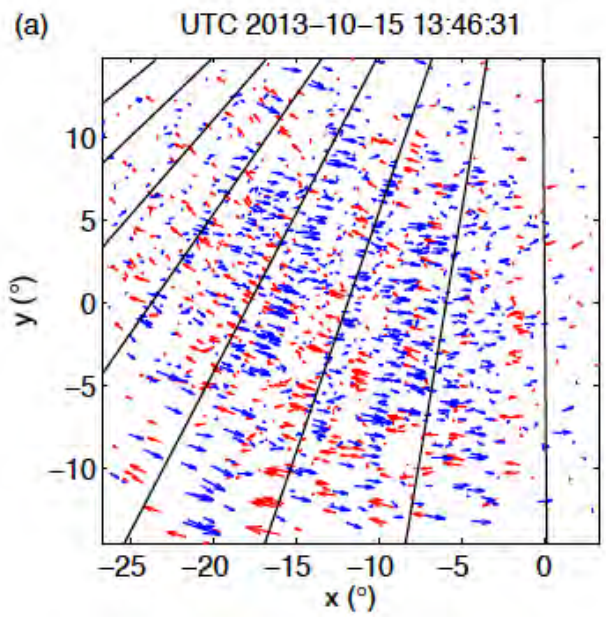


Figure from Loi et al. showing position offsets of extragalactic sources relative to their catalogue position. The apparent shift of the source positions is due to the refractive nature of the ionosphere. Here, offsets to the East and West are encoded with different colours (blue and red, respectively) to aid the eye. Also plotted are geomagnetic field lines, making the connection between these coherent wavelike structures and cylindrical density structures ("ducts") between the plasmasphere and ionosphere

- The first analysis of data from the MWA EoR experiment was published by Dillon et al. (2015, Physical Review D) (including Trott, Hurley-Walker, Wayth, Tingay). This work demonstrated the end-to-end process of obtaining and analysing the data to produce an output that is consistent with expectations given the data set. This work, set among the other research currently being undertaken to test the instrument and our science methods, forms the basis for our confidence to process the remaining data.
- Liu, Trott and Parsons (Physical Review D, 2014a and 2014b) published two studies of the contamination expected within EoR datasets, and presented techniques for assessing and treating these signals. This work demonstrates our thorough approach to this science goal.

D(i).3 PROGRAM ACTIVITIES AND OUTPUTS

Summary list of Program activities and outputs

Please provide a list of Program activities and outputs for the Term of the 2014-19 FAA.

As noted in D.2, the program *activities* within the ICRAR/Curtin Science program are described by three *projects*. The *projects* are each described by a few *project activities*. As SC1 is a large project (in terms of scope and Full Time Equivalents (FTEs)) it is further broken into *sub-activities.*

Project SC1 MWA Science

- Activity 1: Pulsars & Transients, with *sub-activities*
  - AC1.1: Detection and analysis of populations of new & catalogued sources at low frequencies
  - AC1.2: Participating/leading longer-term timing campaigns
  - AC1.3: Analysis of the physical processes within these systems
- Activity 2: Extragalactic Astronomy, with *sub-activities*
  - AC2.1: Individual source and population studies using the Galactic and Extragalactic All-Sky MWA (GLEAM) survey
  - AC2.2: Searching for the highest redshift Active Galactic Nucleus (AGN) into the EoR and the most massive clusters in the early Universe
- Activity 3: Galactic, solar & other science, with *sub-activities*
  - AC3.1: Study of molecular structures revealed by the GLEAM, and other radio, surveys
  - AC3.2: Studies of diffuse and compact Galactic objects detected by the GLEAM survey
  - AC3.3: Interpretation of the MWA Transients target observations
  - AC3.4: Studies of the sun, solar flares, magnetopause and impact on the ionosphere

Project SC2 Accretion Physics

- Activity 1: Accretion-ejection coupling
- Activity 2: Fast radio bursts (FRBs)
- Activity 3: Very Long Baseline Interferometry (VLBI)

Project SC3 EoR

- Activity 1: EoR estimation with the MWA
- Activity 2: Instrument and experiment design for EoR science

Progress against Program activities and outputs (in this reporting period)

Summarise the progress towards achieving each Program activity and output.

Please also discuss any encountered difficulties/failures and improvements put or to be put in place.

In this summary we discuss progress against the specific program *activities*. Other relevant information is provided in Sections D.2, D.5 and D.6 and is not repeated here.

Project SC1 MWA Science

- **Activity 1: Pulsars & Transients**
  - AC1.1: Detection and analysis of populations of new & catalogued sources at low frequencies
  - AC1.2: Participating/leading longer-term timing campaigns
  - AC1.3: Analysis of the physical processes within these systems

Progress in AC1.1 includes the publication of four journal papers, including MWA observations of the bright timing-array millisecond pulsar PSR J0437-4715 (Bhat et al. 2014, ApJL) and a system description paper detailing the new VCS for MWA (Tremblay et al. 2015, PASA). A new processing pipeline has been developed that uses the Pawsey supercomputing facility to coherently combine the recorded VCS data to make a tied-array beam on sources of interest. Other highlights include the discovery of a Fast Radio Burst (FRB) in real time by Petroff (including Bhat) et al. (2015) using the Parkes telescope, and its multi-wavelength follow-ups including low-frequency (GMRT) observations, to search for potential afterglow emission.

Progress in AC1.2 includes the publication of two journal papers using the long pulsar timing database from the Parkes pulsar timing array (PPTA) project; Wang (including Bhat) et al. (2015) reported on a search for gravitational wave memory bursts, and an all-sky search for continuous gravitational wave sources was carried out by Zhu (including Bhat) et al. (2015). The PPTA project makes use of the Parkes telescope, and efforts are underway to develop a pulsar timing capability at the MWA.

Progress in AC1.3 includes the publication of three journal papers, including Shannon & Bhat et al. (2014) that investigated intrinsic pulse jitter noise in radio emission from millisecond pulsars, and a search for radio emission from 17 known exo-planetary systems with the MWA by Murphy (including Ord) et al. (2015). The MWA limits are comparable to the best low-frequency limits available in the published literature. A search for variable and transient radio sources was conducted by Bell (including Hancock) et al. (2015) in the extended Chandra Deep Field South using Australia Telescope Compact Array (ATCA) data at 5.5 GHz, resulting in useful estimates on the surface densities of variable sources.

- **Activity 2: Extragalactic**
  - AC2.1: Individual source and population studies using the Galactic and Extragalactic All-Sky MWA (GLEAM) survey
  - AC2.2: Searching for the highest redshift AGN into the EoR and the most massive clusters in the early Universe

Progress in AC2.1 includes the publication four journal papers, including the MWA Commissioning survey (Hurley-Walker et al, 2014) and the new MWA GaLactic And Extragalactic MWA sky survey (GLEAM) (Wayth et al, 2015), serendipitous discovery of a dying giant radio galaxy (Hurley-Walker et al. 2015) and modelling of the spectral energy distribution of Fornax A (McKinley et al, 2015). Furthermore, significant progress has been made towards publishing the first GLEAM extragalactic source catalogue (Hurley-Walker et al, in progress) and draft catalogues have been circulated to the international MWA team working on Galactic and Extragalactic astronomy. The processing of the Year 1 observations of the GLEAM survey data made significant use of the Pawsey super-computing facility and allowed the team to explore and understand the characteristics of this new low frequency data.

Progress in AC2.2 has included two papers on proto-clusters in the early Universe. Dannerbauer (including Seymour) et al. (2014) presents the intense star formation occurring in a massive proto-cluster when the Universe was only a quarter of its current age (see Section D2 for more). Hatch (including Seymour) et al. (2014) present observations which suggest that proto-cluster environments foster the formation of powerful radio jets explaining why radio surveys can be used to trace proto-clusters in the early Universe. New project collaborations are in place to work on a small high-z sample of radio powerful AGN defined and subject to further observations in the coming year (Seymour et al), and on the bright source sample (Jackson et al). Two new postdoc staff members (White, Drouart) have been hired and will arrive later in 2015.

- **Activity 3: Galactic, solar & other science**
    - AC3.1: Study of molecular structures revealed by the GLEAM, and other radio, surveys
    - AC3.2: Studies of diffuse and compact Galactic objects detected by the GLEAM survey
    - AC3.3: Interpretation of the MWA Transients target observations
    - AC3.4: Studies of the sun, solar flares, magnetopause and impact on the ionosphere

Progress in AC3.1 includes the publication of Jordan et al's paper "MALT-45 a 7mm survey of the southern Galaxy" (including Walsh) which describes the techniques and spectral line data obtained for this unbiased, large-scale, sensitive spectral line survey in this frequency range (45 GHz). Three other papers related to this activity have been published "Accurate water maser positions from the HOPS survey" (Walsh et al. 2015), "Absorption Filaments toward the Massive Clump G0.253+0.016" Bally et al. (including Walsh) 2014 and "Turbulence Sets the Initial Conditions for Star Formation in High-pressure Environments" Rathbone et al. (including Walsh) 2014.
Within AC3.2, studies of diffuse and compact Galactic objects detected by the GLEAM survey

Work is ongoing through a student PhD project to analyse new emissivity measurements from galactic HII regions using the MWA data coupled with a range of other data (radio, infra-red) (Su, Hurley-Walker & Jackson).

Towards AC3.3, all 35 epochs of MWA observations have been calibrated and imaged using the Raijin supercomputer. PhD and Honours projects have been scoped to explore different aspects of variability within this data set. A software pipeline (the VAST pipeline) is in place to extract a first pass set of variable and transient events from this dataset (Hancock).

- **AC3.4 Studies of the sun, solar flares, magnetopause and impact on the ionosphere**

In ionospheric research, two published papers by Loi et al. had significant input from ICRAR researchers (Drs Trott, Hurley-Walker, Hancock & Morgan). These papers beautifully demonstrate the MWA's ability to probe the ionosphere in unprecedented detail. Drs Morgan and Hurley-Walker's research has been a key contribution to producing an accurate GLEAM survey catalogue (ref AC2.1) where it has been important to quantify and remove distortions due to the ionosphere.

Over 1000 hours of Solar observations have been made in the last 12 months with the MWA and analyses are underway. The first dedicated Interplanetary scintillation observations have been performed by the MWA, led by ICRAR/Curtin researchers (Morgan). Early results are extremely promising, initiating a flurry of activity between ICRAR Curtin and collaborators and in India, Japan, the UK and the Netherlands.

Project SC2 Accretion Physics

- **Activity 1: Accretion-ejection coupling**

Progress in Activity 1 has included the publication of 11 papers, including one published in Nature (Motch et al. 2014). Significant progress has been made on data acquisition and analysis for a range of projects, including the completion of a major (400-hour) ATCA survey of southern globular clusters searching for new quiescent stellar-mass black holes, as well as high-cadence, broadband monitoring of an X-ray binary outburst, from the radio through sub-millimetre, infrared, optical and X-ray bands. One PhD student (Russell) has submitted his thesis for examination, and two new postdoc staff members (Plotkin, Anderson) have been hired and will arrive in late 2015.

- **Activity 2: FRBs**

The potential use of FRBs as cosmological probes has made them the top-ranked SKA science goal in the area of Transient Science, driven by the work by Dr Macquart, culminating in his review chapter for the SKA science book. This work also led to a paper on the Galactic latitude dependence of FRBs (Macquart & Johnston; accepted by MNRAS), and ongoing work on the physics of the source counts. Current activities include collaborative work on cosmological simulations to understand the scattering properties of FRBs and their utility as cosmological probes.

- **Activity 3: VLBI**

A large software suite to process pulsar scintillometry data has been constructed, in collaboration with the CITA group at the University of Toronto. Global VLBI data on the Black Widow pulsar (B1957+20) have been acquired and correlated, and analysis is underway. Further data have been acquired on the Crab pulsar, and secondary spectra for two additional pulsar targets. Significant progress has been made in understanding the turbulent properties of the interstellar medium, including two recent publications, a new model for interstellar turbulence, and VLBI observations of an extreme scattering event.

One difficulty encountered within Project SC2 relates to the demonstration of LBA fringes with the space-based VLBI antenna RadioASTRON: This involves significant software effort, and with expert staff approaching the end of their contract, this may not be completed before the departure of these personnel.

Project SC3 EoR

- **Activity 1: EoR estimation with the MWA**

Progress in Activity 1 has been substantial over the reporting period, including the computation of the first EoR power spectrum from MWA data. This power spectrum used an initial test set of 3 hours of MWA data, shared across a number of separate collaborative groups using different analysis methods with the aim of refining each technique and also identifying systematics and errors. Two papers describing these results are in the final stages of preparation before submission for publication. Beyond this 3-hour test set, we have processed and analysed a full week of EoR MWA observations. Two new postdoc staff members are in the process of being hired and will arrive late in 2015.

- **Activity 2: Instrument and experiment design for EOR science**

Progress within Activity 2 has proceeded in concert with Activity 1, in order to test and refine new methods with real datasets. Trott presented two invited presentations at international conferences describing the work to understand the complexities of the MWA instrument, and their impact on EoR science. In the SKA space, Trott led an Engineering Change Proposal to introduce a new observing mode for SKA-low. This mode will be crucial for a robust EoR observing strategy.

D(i).4 PROGRAM KPIS AND MILESTONES

Summary list of interim Program KPIs and milestones

1. **On average, research staff members at ICRAR publish at least two refereed articles per annum, with 90% of all articles to be published in journals with an Impact Factor of 3.0 or greater.**
2. **ICRAR/Curtin maintains at least 20 enrolments of Masters and PhD students each year, with adequate support provided by the Centre to students to achieve two completions each year.**
3. **ICRAR continues to lead at least three preconstruction phase tasks for the development of SKA Phase 1, and has contractual involvement in the construction of SKA Phase1.**
4. **ICRAR leads at least three pre-construction tasks for the development of SKA Phase 2 (subject to SKA 2 being approved for design within the five year period 2014-19).**
5. **The cash investment by the State Government in ICRAR is leveraged at a ratio of at least five to one (including in-kind contributions) over the entire period 2014-19.**

Progress against interim Program KPIs and milestones (in this reporting period)

Summarise the progress towards achieving each interim Program KPI and milestone.

Please also:

- discuss any encountered difficulties/failures and improvements put or to be put in place;
- provide details of refereed journal publications in Appendix A;
- provide details of research staff and Masters/PhD students/graduates in Appendix B; and
- provide details of external R&D grants awarded in subsection C.6.

1. **On average, research staff members at ICRAR publish at least two refereed articles per annum, with 90% of all articles to be published in journals with an Impact Factor of 3.0 or greater**

   ICRAR/Curtin staff members have published 84 unique refereed journal articles, including the 20 AASKA papers included in the special volume “Advancing Astrophysics with the Square Kilometre Array”, published by the Proceedings of Science. For a science research staff complement of 22, this represents 3.9 papers per staff member (195%). Of the 62 papers published in journals with an available impact factor, 49 (or 79%) have an Impact factor greater than 3.

2. **ICRAR/Curtin maintains at least 20 enrolments of Masters and PhD students each year, with adequate support provided by the Centre to students to achieve two completions each yea**

   There were 14 ICRAR/Curtin higher degree students enrolled during this reporting period (70%) with 3 completions (150%) (Lord, Rampadarath and Palaniswamy).

3. **ICRAR continues to lead at least three preconstruction phase tasks for the development of SKA Phase 1, and has contractual involvement in the construction of SKA Phase 1**

   ICRAR/Curtin members contributed to 20 chapters for the new SKA Science Book “Advancing Astrophysics with the SKA. During the year the year Dr Nick Seymour was co-chair of the SKA Continuum SWG whilst Dr Jean-Pierre Macquart co-chaired the Transient SWG. As part of the SKA Calibration Consultation Workshop in April, Dr Cath Trott, Dr Natasha Hurley-Walker and Dr Randall Wayth provided expert input on

ionospheric calibration, MWA processing and design: This expertise will influence critical design decisions for SKA-low. Six Science Curtin (SC) members have been invited to the SKA KSP meeting in Stockholm in August.

4. **ICRAR leads at least three pre-construction tasks for the development of SKA Phase 2 (subject to SKA 2 being approved for design within the five year period 2014-19)**

   N/A for CU1-3

5. **The cash investment by the State Government in ICRAR is leveraged at a ratio of at least five to one (including in-kind contributions) over the entire period 2014-19**

- This KPI is applicable over the Term. See grants list at Section C.6 and C.7.
- An application for a 2017 renewal (CAASTRO-3D) has been submitted which includes two SC Chief Investigators (Tingay & Trott) and three SU Chief Investigators (Driver, Power, Staveley-Smith).

Detailed reason for variance

Excellent progress has been made in achieving the KPIs. Greater efforts are being directed to attract postgraduate students and three students have been enrolled from China under a special SKA China Scholarship program and will join in 2015/16. It may be noted that Programmatic KPIs are monitored internally by ICRAR Executive Director and reported to the Board.

D(i).5 PROGRAM OUTCOMES FOR WA

Summary list of Program outcomes for WA

Please provide a list of program outcomes for WA for the Term of the 2014-19 FAA.

1. **Build expertise, tools and techniques in readiness for the SKA in Western Australia, including**
   a) **exploiting associated facilities (MRO, Pawsey etc)**
   b) **demonstrate this expertise nationally and internationally via e.g. participation at key conferences, on national and international bodies**

2. **Increment the research reputation of the Joint Venture partners and establish a world-class ranking.**

3. **Increase the number of world-class personnel conducting research in WA.**

4. **Increase R&D investment in WA.**

5. **Undertake research that is of major importance, and high impact, and of significant benefit to WA.**

6. **Build and develop new collaborations with national and international partners, including Commonwealth agencies and leverage Commonwealth funding.**

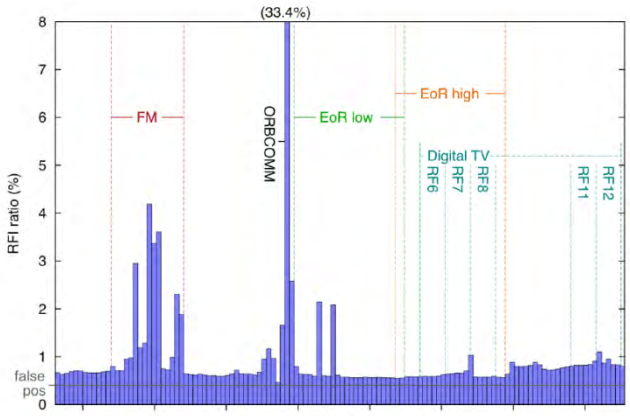
Progress against Program outcomes for WA (in this reporting period)

Summarise the progress towards achieving outcomes for WA.

Please also discuss any encountered difficulties/failures and improvements put or to be put in place.

1. **Build expertise, tools and techniques in readiness for the SKA in Western Australia, including**
   a) **exploiting associated facilities (e.g. MRO, Pawsey etc)**
   b) **demonstrate this expertise nationally and internationally via e.g. participation at key conferences, on national and international bodies**

   - **Demonstrating the radio-quiet characteristics of WA's SKA host site (the MRO)** through the data obtained by the MWA for all active research in this program. This has been published by Offringa et al (including Drs Wayth, Hurley-Walker, Hancock, Ord, Tingay, Trott & Williams "The low-frequency environment of the MWA: RF interference and mitigation". This work also describes the automated RFI detection strategy now routinely implemented for all MWA observations (2014 onwards).



RFI occupancy per subband at the MRO across the MWA observing frequencies. The horizontal grey line represents the false-positives rate of the RFI detection. The RFI fractions are consistently higher than the false-positive rate due to transient broad-band RFI (Offringa et al 2014)

John Morgan explains MWA detection of radio waves to a group of journalists and ministerial advisors visiting MRO in July 2015.

- **The Pawsey supercomputing** facilities have been critical in processing the MWA GLEAM survey, EoR and pulsar (VCS) data. The ICRAR EoR team exclusively use Pawsey resources to calibrate and process all EoR data. There is now >7 Petabytes of MWA data held within Pawsey. The pulsar team has developed a new processing pipeline that runs on the recorded VCS data to coherently combine the voltages to form tied-array beams toward sources of interest.
- **Development of All-sky Virtual Observatory (ASVO)** to include MWA data: An early-phase scoping study to incorporate MWA data into the VO format is underway by Prof Tingay and Drs Morgan & Hancock with the expectation that this will be an ongoing resource for the future (including SKA).
- **Participation in key national and international committees** by members of this program from WA, participating as ICRAR personnel, e.g.
  - Nationally, members of this program are members of AAL's Radio Telescopes Advisory Committee, the Astronomical Society of Australia (ASA), the National Committee for Astronomy (NCA), the Australian National Institute for Theoretical Astrophysics (ANITA) and ANZSCC.
  - International: SKA SWG leadership roles include Dr Trott as a Cosmic Dawn-EoR SWG Management Team member, Dr Macquart as the Transients SWG co-Chair, Dr Seymour as Continuum SWG co-Chair and Dr Miller-Jones as a member of the National Radio Astronomy Observatory (NRAO) Users Committee & the NRAO VLA Sky Survey Review Panel.
- **Hosting a number of key science events increasing participation in high level science activity in WA, e.g.**
  - **ASA 2015**: ICRAR/Curtin Science program team members are the Chairs of this conference (Curtin is the 2015 host institute) and as such Drs Walsh & Trott are major contributors to the Science Organisation of this major national event.
  - **The Inaugural MWA GLEAM Workshop** "Exploiting MWA for AGN and Extragalactic Star Formation Studies", was held at ICRAR/Curtin from 28th to 30th October 2014. Around 35 participants took part including several prestigious international speakers, namely Dr George Heald (Astron) and Dr Rick Perley (NRAO). Talks focussed on the solutions to dealing with low frequency radio data along with exciting plans for current and future MWA extragalactic science from the GLEAM survey. There was plenty of time for fruitful discussions with significant input from the overseas experts on topics such image processing and calibration. There was also a number of presentations and discussion on how MWA data could be used with current and future Australian radio and optical surveys including facilities such as the Australian SKA Pathfinder and Australian Astronomical Observatory (AAO)'s TAIPAN. The coordination of this work, and the long term efforts in survey planning, are vital to maximise the scientific output of surveys from MWA and its enhanced phase over the coming few years.

2. Increment the research reputation of the JV partners and establish a world-class ranking.

- As evidenced in Section D.2, the quantity and quality of papers from this program has boosted the research rankings of both JV partners in a number of important assessments (e.g. Shanghai-Jiao Tong ARWU index). These rankings are vital in the ongoing attraction and retention of world-class staff and HDR students to ICRAR/WA.
- High-impact research has been published in leading peer-reviewed journals and presented at national and international meetings where the reputation of WA as a leading centre for astronomy is further built: specific highlights being
    - National meetings: OzSKA: Radio Astronomy in the Next Decade" meeting was held at Melbourne University from 8-10 April. two invited talks (Seymour & Trott), four contributed talks and Jackson presented the conference summary.
    - Drs Trott, Wayth and Hurley-Walker presented key findings from the MWA to define the design of SKA-low, at the SKA Calibration Workshop in April.

3. Increase the number of world-class personnel conducting research in WA.

- **The ICRAR2 program** has allowed us to attract five new staff to this program; a large number of applications were received and we were able to appoint our first-ranked candidate in each case.

4. Increase R&D investment in WA.

- **Successful external grant applications which commenced late 2014/early 2015 include awards to (see Section C.6 & C.7).**

- **External (ARC) grant applications** have been made this round (2015) including
    - Prof Bland ARC Discovery (inc. Macquart),
    - Dr R Soria, Dr Miller-Jones & Dr Curran ARC Discovery
    - Dr Walsh ARC Discovery,
    - Dr Franzen ARC Early Career ARC (DECRA),
    - Prof Tingay, Prof Jackson et al (ARC LIEF) all leveraging the investment in ICRAR2 by the State Government.
    - Prof Driver et al (including Seymour) ARC LIEF (WAVES year 2)

5. Undertake research that is of major importance, and high impact, and of significant benefit to WA.

Described in the program objectives (D.2).

6. Build and develop new collaborations with national and international partners, including Commonwealth agencies and leverage Commonwealth funding.

- The establishment of new, and strengthening of existing collaborative links with first-ranked national and international partners as described in section D.6 in detail.
- Alignment with new Industry centres & other initiatives: CISCO IOE.

D(i).6 PROGRAM COLLABORATIONS (in this reporting period)

Summarise the Program collaborations between the Joint Venture Participants and externally with local, national and international researchers, and industry, government and other end-users.

Please also:

- discuss any encountered difficulties/failures and improvements put or to be put in place;
- detail the nature, value and any outcomes of each collaboration; and
- include details of any collaborative research undertaken by visiting researchers.

In this reporting period the ICRAR/Curtin Science program activities has involved collaborations with a huge number of national and international partners as evidenced by the content of the detail in other sections of this report (D.2, D.3, D.5).

Here we highlight the most prominent such activities:

- **SC1 MWA Science**

SC1 has worked extremely closely with our JV partner (UWA) on the largest MWA science product, an all-sky wide-band radio survey known as GLEAM. This work includes seven ICRAR/Curtin Science program staff. Amongst this group, Drs Hurley-Walker, Hancock, Wayth & Morgan are considered leading experts in calibration and imaging of MWA data, including the full creation of a significant dataset forming the GLEAM survey. This work has involved close collaboration with a small number of similarly dedicated young researchers at the Universities of Melbourne and Sydney.

Twelve Curtin staff attended the very successful "Early Science From Low-Frequency Radio Telescopes" meeting in Tempe, Arizona (Dec. 2014) of which seven gave presentations. This meeting facilitated key interactions with other MWA consortia members and members of other low radio frequency observatories. This meeting also included a MWA board meeting that was followed up by a productive MWA technical meeting in Melbourne in June 2015.

UWS joined the MWA consortia deepening connections started with Dr Seymour's joint Curtin/UWS student, Tim Galvin. Links with CSIRO remain strong with Dr Seymour's role as ASKAP/EMU Project Scientist as well as co-supervising two CSIRO students. Dr Seymour continued his close collaborative relationships with European Southern Observatory (ESO) in Germany and JPL/Caltech in California with two papers published this year and two more in preparation.

Patti Carroll, a PhD student from University of Washington (Seattle) visited Australia and ICRAR/Curtin for three weeks on a prestigious US fellowship. A new project to analyse the MWA bright source sample has forged active links with UBC (British Columbia, Canada, via Prof Jackson & Wall). High profile visiting researchers included Dr Rick Perley (NRAO, USA) and Dr George Heald (ASTRON, NL) both of which led to technical collaborations regarding low frequency radio collaborations and consistent calibrations between MWA and LOFAR.

The pulsar group (Drs Bhat, Ord & Tremblay) is developing close ties with the Swinburne and CSIRO Astronomy and Space Science (CASS) groups (led by Prof Bailes and Dr Hobbs, respectively) as part of a new collaborative venture to use the MWA for supporting the high-profile PPTA project. The links are now further strengthened through closer involvements of Dr Shannon (a joint Curtin-CASS appointment, commencement: June 2015) and Dr van Straten (Swinburne) to enhance pulsar science capabilities at the MWA. Dr Bhat continues his close collaborative relationships with Swinburne in the ongoing Parkes high time resolution survey for pulsars and FRBs, and undertook extended visits to the National Centre for Radio Astrophysics (NCRA) (Pune) in January 2015 for carrying out Giant Metrewave Radio Telescope (GMRT) observations to support the Parkes project. Dr Bhat gave an invited talk on FRBs at the Transients session at the Annual ASI meeting (Pune) in February 2015.

Collaborations are in place with Dr Rolwinson CSIRO (CASS) to study MWA transients occurring in EoR observational data (Hancock, Miller-Jones, Curran and Tingay) also participated at the meeting "Multiwavelength emission from accreting black holes" in Sydney in Feb 2015 which included a two-day workshop with MWA collaborators on this theme.

The US Air force Office for Scientific Research have funded a project which tests the MWA ability to measure the magnetic field of an Earth-bound Coronal Mass Ejection, a problem which has huge implications for Space Weather readiness. Haystack Observatory (US) leads this project key involvement from ICRAR/Curtin (Prof Tingay & Dr Morgan) and the Smithsonian Astrophysical Observatory (US).

- **SC2 Accretion Physics**

The accretion physics group has maintained productive collaborations with A/Prof Strader and A/Prof Chomiuk of Michigan State University and A/Prof Heinke and A/Prof Sivakoff from the University of Alberta, in the areas of globular cluster black holes and accretion-ejection coupling, respectively. These key collaborations support the work being done under the auspices of Miller-Jones's ARC Future Fellowship.

Dr Soria maintains particularly close links with Professors Pakull and Motch at the University of Strasbourg, working on ULX sources.

In the FRB group, Drs Macquart and Kirsten from this program visited the Canadian Institute for Theoretical Astrophysics (Canada) to work with Prof Ue Li Pen towards their research on pulsar scintillometry: this ongoing collaboration with Prof Pen and his team is making excellent progress towards the highest resolution imaging of pulsars, fulfilling the goals of Macquart's ARC Discovery Grant.

Macquart has established strong links with Prof. Nissim Kanekar (NCRA) and Scott Ransom (NRAO), working on detecting pulsars at the Galactic Centre, which would enable detailed tests of strong-field gravity tests, one of the key science goals of SKA.

Finally, the VLBI team maintains its strongest links with the team at CSIRO (Drs Tzioumis & Phillips).

- **SC3 EoR**

The Curtin-based EoR team has strong links with other ICRAR projects, including the SU3 Computational Theory and Modelling group at the JV partner, UWA.

Within the MWA EoR collaboration, there are strong links with Assoc. Prof. Miguel Morales and his team at the University of Washington and Dr Judd Bowman and his team at Arizona State University. These international connections are maintained with regular virtual and face-to-face meetings to progress the MWA EoR program.

Nationally, we work in strong alliance with the data calibration team at the University of Melbourne, led by Prof. Rachel Webster

D(i).7 PROGRAM BUDGET (for this reporting period)

D(i)7.1 Expenditure of State Government grant

Expenditure type	Agreed expenditure ($)	Actual expenditure ($)	Variance ($)
Salaries	226,900	141,604	85,296
Operating	0	13,662	(13,662)
Capital	0	0	0
Travel	245,000	37,642	207,358
TOTAL	**471,900**	**192,908**	**278,992**

Expenditure details

Summarise the expenditure of the State Government grant.

In line with ICRAR Plan and Budget. Major expenditure is on salaries. New FTE appointed but will commence in 2015/16 period. In the reporting period, Curtin Science Program is mainly funded from Curtin Cash Contribution as shown in Table below.

Variance in expenditure? Yes ☒ No ☐

Detailed reason for variance in expenditure

Variance in expenditure is a timing issue and also due to the agreed six month late start of ICRAR II expenditure from 1 January 2015 as compared to 1 July 2014.

D(i)7.2 Expenditure of Curtin University Joint Venture cash contribution

Expenditure type	Agreed expenditure ($)	Actual expenditure ($)	Variance ($)
Salaries	1,121,604	503,505	618,099
Operating	0	0	0
Capital	0	0	0
Travel	0	0	0
TOTAL	**1,121,604**	**503,505**	**618,099**

Expenditure details

Summarise the expenditure of the Curtin University Joint Venture cash contribution funds.

In line with ICRAR Plan and Budget. Refer to comments in Section C.5.1. Expenditure on salaries is less than budgeted due to late start of ICRAR II and new FTE appointed but will commence in 2015/16 period.

Variance in expenditure? Yes ☒ No ☐

Detailed reason for variance in expenditure

Variance in expenditure is a timing issue and also due to the agreed six month late start of ICRAR II expenditure from 1 January 2015 as compared to 1 July 2014. Staff appointments have been made but not staff commenced in the reporting period. Refer to comments in Section C.5.1

D(i)7.3 Expenditure of UWA Joint Venture cash contribution

Expenditure type	Agreed expenditure ($)	Actual expenditure ($)	Variance ($)
Salaries			
Operating			
Capital			
Travel			
TOTAL			

Expenditure details

Summarise the expenditure of the UWA Joint Venture cash contribution.

Not applicable to ICRAR Science Program at Curtin. See D (ii) 7.3

Variance in expenditure? Yes ☐ No ☐

Detailed reason for variance in expenditure

Not applicable to ICRAR Science Program at Curtin. See D (ii) 7.3

SECTION D(ii): ICRAR/UWA SCIENCE PROGRAM PROGRESS

D(ii).1 SHORT PROGRAM DESCRIPTION

Please provide a short summary of the Program (suitable for public release).

The ICRAR/UWA science program has provided world-leading scientific research in galaxies, focussing on their formation and evolution, and understanding the main physical processes involved. This is being achieved through comprehensive observational studies with the largest Australian and international radio and optical telescopes, including the WA-hosted ASKAP and MWA telescopes, and with ground-breaking supercomputer simulations. Members of the science program are also leading efforts to prepare the groundwork for the scientific utilisation of the SKA.

D(ii).2 PROGRAM OBJECTIVES

Summary list of Program objectives

Please provide a list of Program objectives for the Term of the 2014-19 FAA.

1. **Demonstrate excellence, linkage, output and international profile in scientific research.**
2. **Success in attaining international and national competitive funding and awards, and the enrichment of the community at multiple levels.**
3. **Support of SKA scientific planning and decision processes.**

Progress against Program objectives (in this reporting period)

Summarise the progress towards achieving each Program objective.

Please also discuss any encountered difficulties/failures and improvements put or to be put in place.

1. The ICRAR/UWA SU science program has published 107 refereed papers in high-profile international journals in 2014/15. Over 90% of the papers have involved national and international collaboration. In its latest Excellence in Research Australia report, the Australian Research Council (ARC) gave the highest possible ranking to ICRAR/UWA in the field of research of Astrophysics and Space Science.
2. The SU science program has been awarded approximately $3.3M in national and international competitive funding; science staff have been involved in numerous media releases and have engaged in outreach activities such as Astrofest, theSkyNet and Radio Galaxy Zoo.
3. Group members lead two SKA Science Working Groups, have received invitations to numerous SKA-related science meetings, and have published numerous SKA science papers including 16 refereed papers in “Advancing Astrophysics with the Square Kilometre Array”, seven of which were led by SU group members.

D(ii).3 PROGRAM ACTIVITIES AND OUTPUTS

Summary list of Program activities and outputs

Please provide a list of Program activities and outputs for the Term of the 2014-19 FAA.

1. **Recruit, train and retain high-calibre research staff**
2. **Research activities falling under SU1 "Gas and Feedback with Radio Surveys"**
3. **Research Activities falling under SU2 "Multiwavelength and Spectroscopic Surveys"**
4. **Research Activities falling under SU3 "Computational Theory and Modelling"**
5. **HDR and STEM training activities**
6. **National and International grant applications**
7. **Scientific contribution to outreach activities**
8. **Strategic SKA and other strategic international astronomical activities**

Progress against Program activities and outputs (in this reporting period)

Summarise the progress towards achieving each Program activity and output.

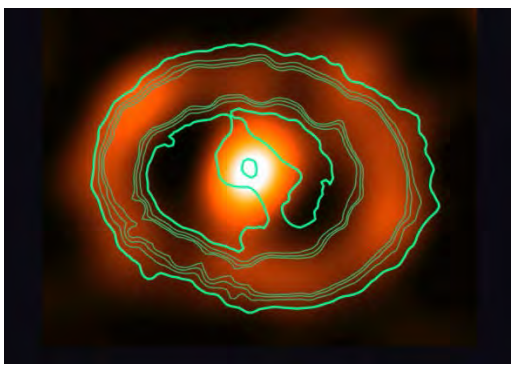
Please also discuss any encountered difficulties/failures and improvements put or to be put in place.

1. Appointments

Following a rigorous international search, two new ICRAR Senior Research Fellows, Drs Barbara Catinella and Luca Cortese, were appointed. 56 applications were received. UWA has also offered the new appointees an ongoing position at the end of ICRAR2. In addition, three existing ICRAR2 staff members, Drs Danail Obreschkow, Martin Meyer and Aaron Robotham, have been appointed Senior Research Fellows and awarded ongoing positions by UWA, demonstrating the leverage afforded by the State Government's funding. Other recent appointments include DECRA Fellow Dr Claudia Lagos, the second Jim Buckee Fellow, Dr Charlotte Welker, and two CAASTRO postdocs, Drs Dan Taranu and Cullan Howlett.

2. Research activities falling under SU1 "Gas and Feedback With Radio Surveys"

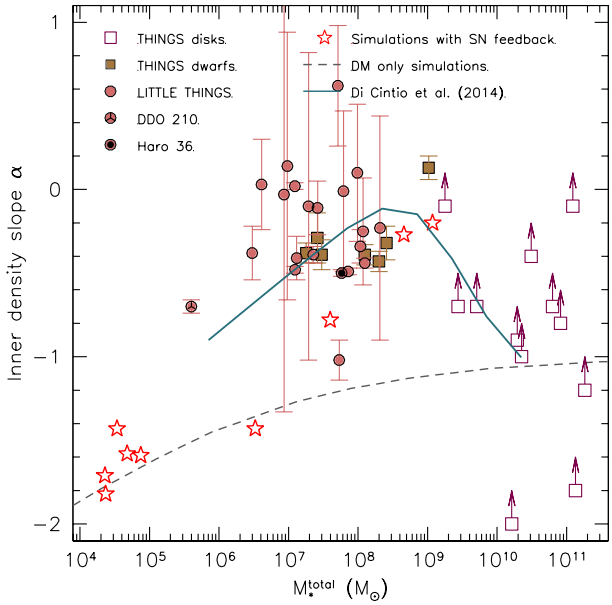
- **SUPERNOVA 1987A:** The latest SN1987A observations with the Atacama Large Millimetre Array (ALMA) and ATCA (Zanardo et al. 2014) were published in the Astrophysical Journal. The corresponding media release (*Astronomers dissect the aftermath of a Supernova*) resulted in more than 30 stories in at least 10 countries that mentioned ICRAR, including significant coverage in India and the United States. The coverage was of a high quality and Giovanna Zanardo was interviewed by journalists from ABC Science and ScienceNetwork WA, as well as on 6PR radio.



New ALMA observations of SN1987A (Zanardo et al. 2014, ApJ, 796, 82)

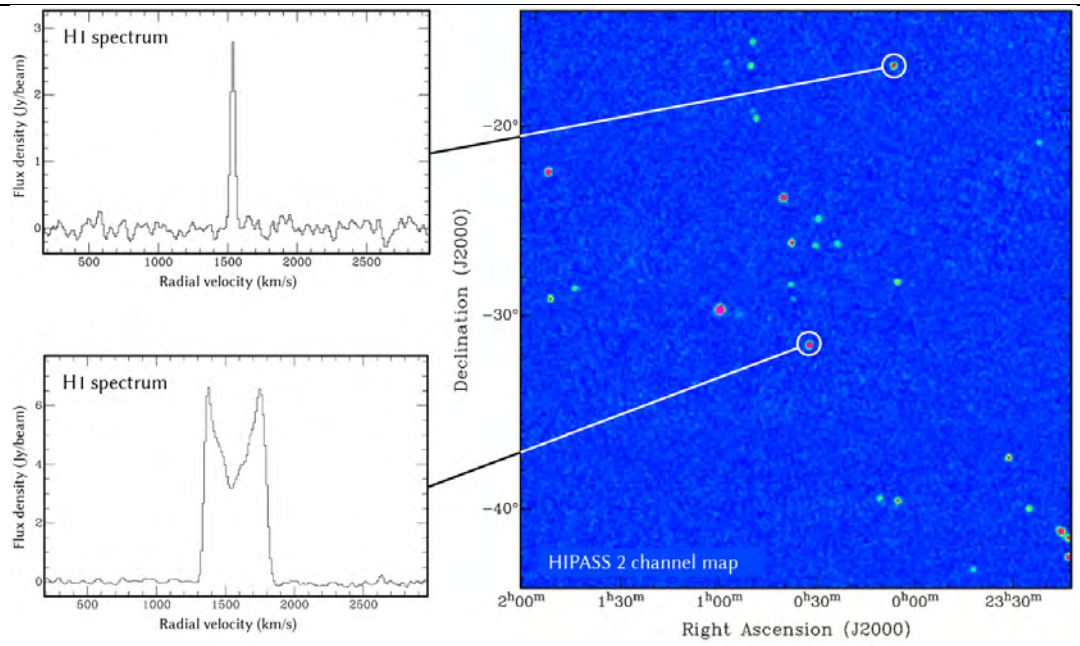
- **GALAXIES - NGC 2915:** Bruzzese, Meurer, Lagos, et al. (Bruzzese et al. 2015, MNRAS, 447, 618) have introduced a new technique for constraining the distribution of birth masses of stars by using colour-magnitude diagrams of nearby galaxies. The technique works when there are good constraints on its star formation history. They showed that the outer disk is producing less of the highest mass stars than expected for a standard stellar mass distribution, and hence there is more star formation in what had appeared to be a gas disk devoid of new stars.

- **GALAXY SURVEYS - LITTLE THINGS:** High-resolution (20 – 300 pc) mass models have been developed by Se-Heon Oh for 26 dwarf galaxies from LITTLE THINGS project, a VLA nearby galaxy HI 21cm survey. He quantified the degree of the central dark matter concentration by measuring the logarithmic inner slopes of their dark matter density profiles (Oh et al. 2015, AJ 149, 180). The mean value of the inner slopes of the sample galaxies is -0.32, which indicates a mass distribution with a sizeable constant density-core towards the centres of the galaxies. However, notwithstanding the dominant trend of core-like dark matter distribution in the LITTLE THINGS (The HI Nearby Galaxy Survey) sample galaxies, a few of them, such are equally well fitted by core- and cusp-like halo models in describing their dark matter rotation curves. This work demonstrates the cosmological importance of low mass dwarf galaxies for testing LCDM cosmology, bringing our attention to the lower mass systems in the local Universe.



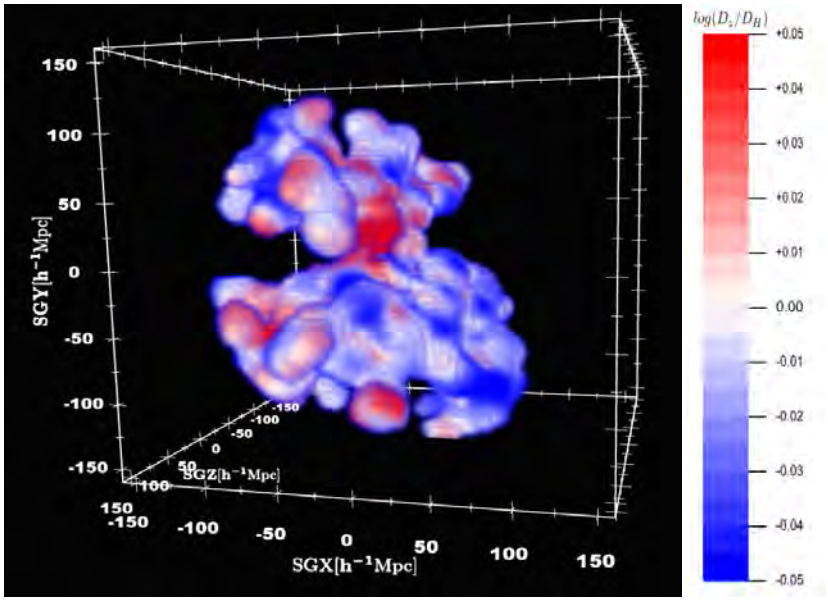
The inner dark matter density slope of the LITTLE THINGS galaxies versus their stellar mass, from Oh et al. (2015)

- **GALAXY SURVEYS - HIPASS2:** After fixing the last remaining data reduction issues, reprocessing of the HI Parkes All-Sky Survey (HIPASS) has now been completed by a team led by Westmeier and Meyer. The new version, called HIPASS2, has a lower noise level than its predecessor and comes with fewer artefacts thanks to the use of improved data processing techniques. These improvements are expected to result in an increase in the number of galaxies detected by the survey and will enable advanced data analysis techniques such as HI stacking.



The image on the right shows a single channel map from HIPASS 2 with HI emission from numerous galaxies, while the integrated HI spectra of two galaxies are shown on the left, illustrating the excellent data quality of HIPASS 2.

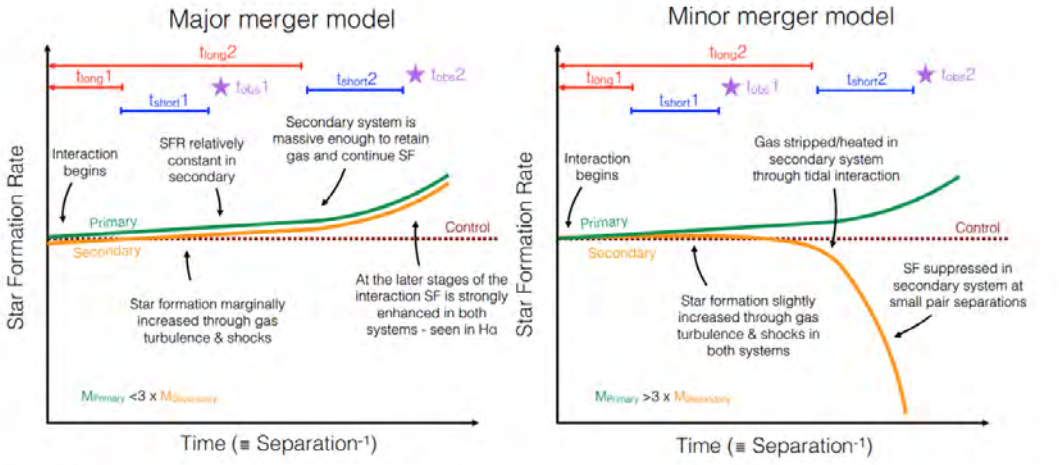
- **GALAXY SURVEYS – GROUPS**: Meurer and collaborators (Sweet et al. 2014, ApJ, 782, 35) sought to find rare "Tidal Dwarf Galaxies" in gas rich galaxy groups. These galaxies are interesting because they are thought to contain little or no dark matter, and are expected to have high metallicity. The paper found that dwarf galaxies in groups have a wide range of metal contents, and found three candidate Tidal Dwarf Galaxies.
- **GALAXY SURVEYS – 6dFGS:** A new cosmographic analysis of the local Universe using 9,000 galaxies from the 6dFGS survey has been published (Springob et al. 2014, MNRAS, 445, 2677). The paper is accompanied by the 6dFGSv data release and a three-dimensional figure. This figure can be downloaded from http://www.6dfgs.net/vfield/figure11.pdf but you must use Adobe Reader version 8.0 or higher for interactive 3D views.



The smoothed 6dFGSv peculiar velocity field in 3D, plotted on a grid in supergalactic Cartesian coordinates. Adobe Reader version 8.0 or higher enables interactive 3D views of the plot, allowing rotation and zoom (Springob et al. 2014, MNRAS, 445, 2677).

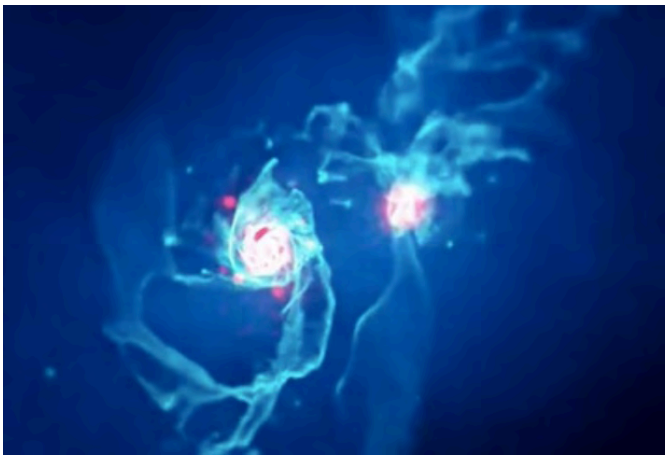
3. Research activities falling under SU2 "Multiwavelength and Spectroscopic Surveys"

- **GALAXY SURVEYS - GAMA:** Davies et al. have concluded a study demonstrating that star-formation is significantly suppressed in the minor partner of a minor merger event but generally enhanced for participants of major mergers. In this work a variety of star-formation indicators were used each of which is sensitive to a different timescale. This allows one to reconstruct the progression of star-formation during the merger process and the size of the GAMA dataset allows one to explore both major and minor mergers. A press release has been drafted and will be put out following acceptance. GAMA has also been selected for ABC Citizen Science project during National Science Week.



A toy model for the evolution of SF in major (left) and minor (right) merger systems. The purple stars highlight two possible observation epochs during the merger. These are proceeded by the likely timescales over which long duration and short duration SFRs are measured at each epoch (red and blue horizontal bars respectively - note red bars would extend off the left edge of the plot). These models are consistent with our observations of SF in pair systems and can potentially explain the seemingly contradictory previously obtained results for SF in close pairs as SF is enhanced in all merger scenarios, except in the secondary galaxy in minor mergers at close separation. As such, our measure of how SF is affected in galaxy interaction is dependent on pair mass ratio and primary/secondary status within the pair.

- **GALAXY SURVEYS – GAMA:** A new study of 22,000 galaxies published in MNRAS (Robotham et al. 2014) has investigated the stellar mass accretion rate of massive galaxies more accurately than previously possible. The corresponding media release (*Monster galaxies gain weight by eating smaller neighbours*) resulted in more than 130 stories in at least 27 countries that mentioned ICRAR, including significant coverage in the United States, United Kingdom, India, Russia, France, Spain and Romania. A simulation of Andromeda and the Milky Way colliding that accompanied the release was used widely by online media and often led the story. The video resulted in extended media coverage, with articles recorded more than a month after the original release.



Simulation of the merging of galaxies (Robotham et al. MNRAS, 444, 3986; image credit Chris Power).

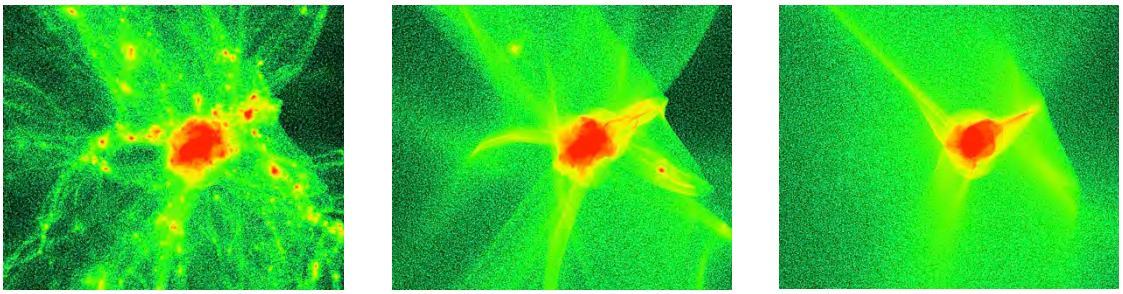
- **GALAXIES – MILKY WAY**: Prajwal Kafle and collaborates have published a new study of the mass of the Milky Way in the Astrophysical Journal. The corresponding media release (*Dark matter half what we thought*) resulted in 50 stories in at least 12 countries that mentioned ICRAR, including significant coverage in Australia, India, the United Kingdom and the United States. Prajwal was interviewed by ABC Radio National and a number of media organisations in Nepal, and was featured on the front page of the Nepal Republic Media newspaper. The media coverage has opened up the opportunity for high level discussions with research organisations in Nepal.

Artist's impression of the Milky Way galaxy and its massive dark matter halo in blue (Kafle et al. 2014, ApJ, 794, 59).

4. Research activities falling under SU3 "Computational Theory and Modelling"

- **SIMULATIONS - DARK MATTER:** galaxy simulations have been conducted by Power et al. to investigate the growth of angular momentum and the assembly of the stellar halo in the presence of Cold Dark Matter (CDM) and Warm Dark Matter (WDM). Image (a) shows the underlying dark matter in the progenitor of Milky Way-mass halo, identified at z~3, when its virial mass is about 8×10^{11} h^{-1} solar masses. Images (b) and (c) show the underlying dark matter in 1 and 0.5 keV/c^2 WDM models. There is a potential signature of dark matter physics in the radial structure of the stellar halo around galaxies. Because there are more low-mass satellites in CDM, they deposit their stripped stars at large radii and so the stellar halo will look more extended. This has implications for future telescopes being designed to search for extended emission from galaxies.

(a) (b) (c)



The formation of a Milky Way galaxy with different forms of dark matter (a-c: CDM and 1 and 0.5 keV/c^2 WDM, respectively). Image credit: Power.

5. Higher Degree Training

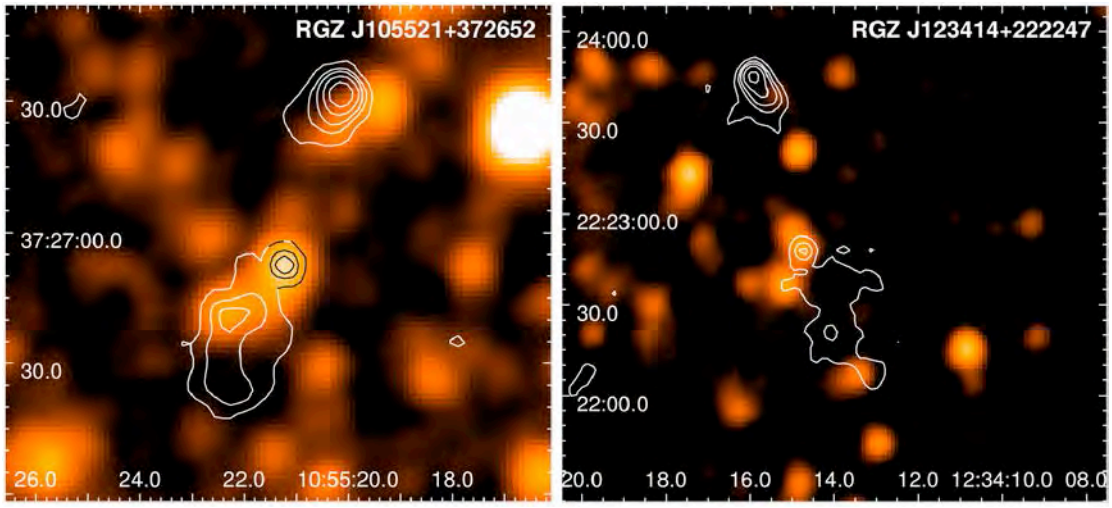
Four PhD students have been enrolled (Andrew Butler, Kamran Ali, JT Malarecki, Katharine Kelley) in the last year, and three PhD students have completed (Laura Hoppmann, Giovanna Zanardo, Stefan Westerlund). 16 PhD students and six Masters students are currently enrolled. PhD students Morag Scrimgeour, who graduated in 2014, won the 2015 Charlene Heisler Prize for the best Australian astronomy PhD thesis.

6. Grant Applications

Numerous UWA (RCA), ARC (DP, DECRA, LIEF, Laureate, CoE) and non-ARC (MERAC, SIEF) applications have been submitted, or are in preparation. Significant successes announced so far are detailed in Section D4.

7. Scientific Contribution to Outreach Activities

Wong and Kapinska are active members of Radio Galaxy Zoo, a citizen science project to classify the morphology of radio galaxies in the FIRST radio survey and identify their counterparts in the mid-infrared Wide-field Infrared Survey Explorer (WISE) survey. The project description paper (Banfield, Wong, et al.) and the first science paper (Kapinska et al.) have both been submitted and publication is expected in the next few months. In the first science paper by Kapinska et al. the team searched for hybrid morphology radio galaxies (HyMoRS or hybrids). In general, hybrids show different Fanaroff-Riley radio morphology on either side of the active nucleus, that is FRI type on one side and FRII on the other side of their infrared host galaxy. They found 14 objects with Radio Galaxy Zoo that satisfy their criteria.

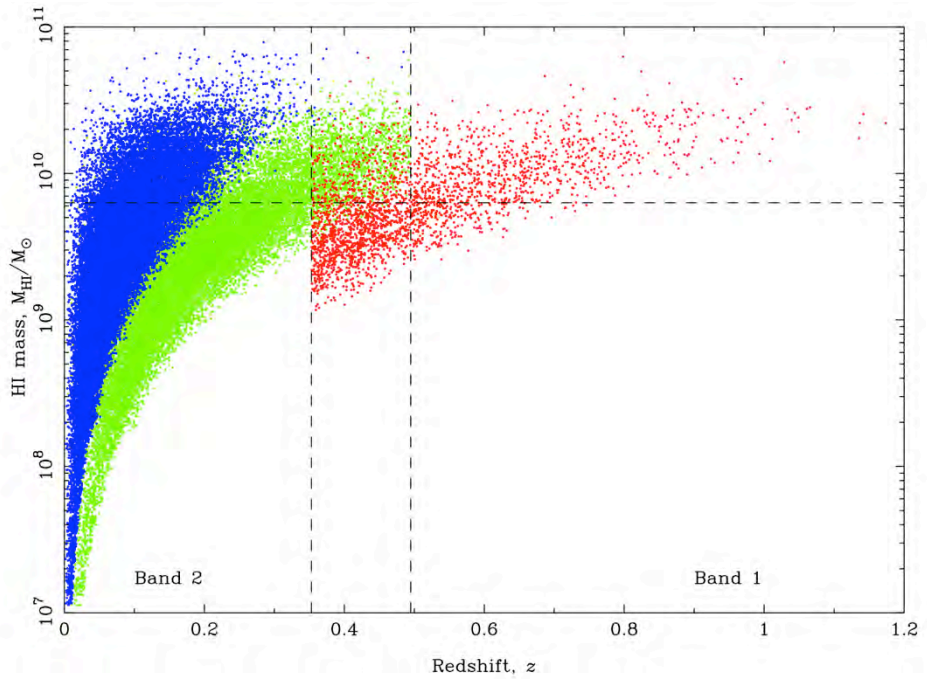


Examples of newly identified hybrid morphology radio galaxies (Kapinska et al. 2015). FIRST contours are shown in white overlaid on WISE 3.4μm images.

8. Strategic SKA and other strategic international astronomical activities

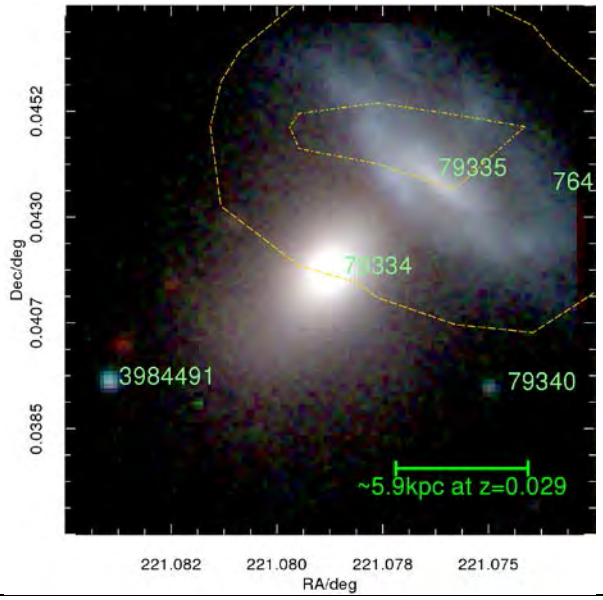
- **SKA SCIENCE:** this year's annual Pathfinders HI Science Coordination Committee meeting was held at Rutgers University in the US from March 16-18 2015. ICRAR staff met with many US colleagues, especially from the CHILES and ALFALFA consortia. Eight ICRAR staff and students gave presentations at the meeting on topics ranging from galaxy groups, HI stacking, CHILES, galaxy kinematics, multi-wavelength science, AUDS and HI lensing. Staveley-Smith concluded his two-year term as co-chair (with Oosterloo) of the SKA HI and Galaxy Evolution Science Working Group, and has been replaced by Martin Meyer (with de Blok). Following the publication of seven SU-led SKA science chapters (and nine others co-authored by SU staff), Staveley-Smith has submitted to the SKA Office a post-re-baseline overview chapter for all nine SKA HI chapters which outlines a suite of HI surveys likely to meet the combined science needs of the group.

- **WAVES:** 500k Euros and 5 FTEs have been approved by Hamburg University to join 4MOST and participate in the ICRAR-led WAVES project. Luke Davies has also been appointed as the WAVES-Deep project scientist in a position to be co-funded by UWA Physics.



A simulation of the distribution in HI mass and redshift of galaxies likely to be detected in a suite of three band 1 and 2 HI surveys with the re-baselined SKA phase 1 (Staveley-Smith and Oosterloo 2015, HI Science with the SKA).

- **END USER TOOLS:** we are developing several on-line tools for use by the broad astronomical community:
  - Online cosmology calculator tool: http://cosmocalc.icrar.org
  - GAMA online image cutout tool: http://ict.icrar.org/cutout
  - A Virtual Observatory server has been developed to distribute MWA GLEAM data to the MWA Galactic and Extragalactic (GEG) collaboration and the international astronomy community.



An example from the recently revamped GAMA on-line cutout tool (see http://ict.icrar.org/cutout

D(ii).4 PROGRAM KPIS AND MILESTONES

Summary list of interim Program KPIs and milestones

1. **On average, research staff members at ICRAR publish at least two refereed articles per annum, with 90% of all articles to be published in journals with an Impact Factor of 3.0 or greater.**
2. **ICRAR/UWA maintains at least 20 enrolments of Masters and PhD students each year, with adequate support provided by the Centre to students to achieve two completions each year.**
3. **ICRAR continues to lead at least three preconstruction phase tasks for the development of SKA Phase 1, and has contractual involvement in the construction of SKA Phase1.**
4. **ICRAR leads at least three pre-construction tasks for the development of SKA Phase 2 (subject to SKA 2 being approved for design within the five year period 2014-19).**
5. **The cash investment by the State Government in ICRAR is leveraged at a ratio of at least five to one (including in-kind contributions) over the entire period 2014-19.**

Progress against interim Program KPIs and milestones (in this reporting period)

Summarise the progress towards achieving each interim Program KPI and milestone.

Please also:

- discuss any encountered difficulties/failures and improvements put or to be put in place;
- provide details of refereed journal publications in Appendix A;
- provide details of research staff and Masters/PhD students/graduates in Appendix B; and
- provide details of external R&D grants awarded in subsection C.6.

1. **On average, research staff members at ICRAR publish at least two refereed articles per annum, with 90% of all articles to be published in journals with an Impact Factor of 3.0 or greater**

   ICRAR/UWA SU staff members have published 107 unique refereed journal articles, including the 16 AASKA papers included in the special volume “Advancing Astrophysics with the Square Kilometre Array”, published by the Proceedings of Science. For a science research staff complement of 25, this represents 4.3 papers per staff member. Of the 91 papers published in journals with an available impact factor, 81 (or 89%) have an Impact factor greater than 3.

2. **ICRAR/UWA maintains at least 20 enrolments of Masters and PhD students each year, with adequate support provided by the Centre to students to achieve two completions each year**

   ICRAR has 25 ICRAR/UWA higher degree students enrolled; three completions (Westerlund, Zanardo, Hoppmann)

3. **ICRAR continues to lead at least three preconstruction phase tasks for the development of SKA Phase 1, and has contractual involvement in the construction of SKA Phase 1**

   The ICRAR/UWA SU1-3 team has contributed to 16 refereed journal papers for the updated SKA science book. Team members Staveley-Smith and Meyer have also led the SKA Galaxy Evolution SKA Science group. They and SU1 leader Huynh, and CAASTRO/UWA scientist Popping have been invited to the SKA KSP meeting in Stockholm.

4. **ICRAR leads at least three pre-construction tasks for the development of SKA Phase 2 (subject to SKA 2 being approved for design within the five year period 2014-19)**

   N/A for SU1-3

5. **The cash investment by the State Government in ICRAR is leveraged at a ratio of at least five to one (including in-kind contributions) over the entire period 2014-19**

   List of grants can be seen in Section C.6 and C.7.

Detailed reason for variance if any

Excellent progress has been made in achieving the KPIs. Though Science Program at UWA has the required postgraduate enrolments, greater efforts are being directed to attract more postgraduate students. Three new students to join under the SKA China Scholarship Program in 2015/16. It may be noted that Programmatic KPIs are monitored internally by ICRAR Executive Director and reported to the Board.

D(ii).5 PROGRAM OUTCOMES FOR WA

Summary list of Program outcomes for WA

Please provide a list of program outcomes for WA for the Term of the 2014-19 FAA.

1. **Increased capability, capacity and reputation in astronomy (and STEM in general)**
2. **Leadership in SKA project**
3. **Increased engagement of community**
4. **Application of data intensive science**
5. **Successful leverage of ICRAR grant**

Progress against Program outcomes for WA (in this reporting period)

Summarise the progress towards achieving outcomes for WA.

Please also discuss any encountered difficulties/failures and improvements put or to be put in place.

1. **Increased capability, capacity and reputation in astronomy (and STEM in general)**

   ICRAR-funded science staff, and other grant-funded staff in the SU team number about 25. Combined with HDR students, there are around 50 researchers. 107 refereed journal articles were published in the last year. This group contributes to STEM training through year 1, 2 and 3 physics and astronomy teaching and coordination (the astrophysics courses are ranked the highest amongst Physics courses at UWA). We also contribute to Honours, Masters and Postgraduate teaching at both UWA and Curtin.

2. **Leadership in SKA project**

   SU staff (Huynh, Meyer, Staveley-Smith) led two of the SKA Science Working Groups during 2014/15 (Galaxy Evolution and Continuum Surveys). SU staff have also been members of the higher-level international Science Working Group and part of the Science Organising Committee for the 2014 meeting “Advancing Astrophysics with the Square Kilometre Array” and the 2015 OzSKA meeting. SU research staff authored 16 papers in the recently-published SKA science book and have contributed to the success of WA in securing a significant portion of the SKA.

3. **Increased engagement of community**

   Research staff have directly reached out to the public through numerous media releases, video articles and news stories. For example, Robotham’s media release on 19 September 2014 “Monster galaxies gain weight by eating smaller neighbours” generated 130+ news stories. Staff have also championed ICRAR’s extensive Outreach and Education program which has interacted with more than 80,000 people over the last 5 years. In most visits and programs, OEC staff are accompanied by early career research staff or higher degree students with a passion for outreach.

4. **Application of data intensive science**

   Many of the current large surveys and simulations being conducted by ICRAR/UWA staff (e.g. GAMA, AUDS, GLEAM, XXL, CHILES, theSkyNet) involve 10s to 1000s of Terabytes of data. These are not easy data sets to deal with as they are well beyond the capacity of desktop computers. The application of data intensive science through collaboration with the DIA group, the Pawsey Centre and Amazon Web Services has enabled each of these to proceed with a large degree of success.

5. **Successful leverage of ICRAR grant**

   ICRAR/UWA staff have been very successful in national and international competitive grants. Around $3.3M has been raised in the last 12 months. Major successes have been an ARC LIEF grant to support a new optical survey (WAVES) to support SKA science and the current ARC Centre of Excellence, CAASTRO. An application for a 2017 renewal (CAASTRO-3D) has been submitted which includes three SU Chief Investigators (Driver, Power, Staveley-Smith) and two SC investigators (Trott and Tingay).

D(ii).6 PROGRAM COLLABORATIONS (in this reporting period)

Summarise the Program collaborations between the Joint Venture Participants and externally with local, national and international researchers, and industry, government and other end-users.

Please also:

- discuss any encountered difficulties/failures and improvements put or to be put in place;
- detail the nature, value and any outcomes of each collaboration; and
- include details of any collaborative research undertaken by visiting researchers.

- **SC Program**

There exists a significant collaboration with the ICRAR/Curtin Science program around GEG science with the MWA with at least five SU1 staff collaborating on the GLEAM survey. Seven joint refereed papers have been written.

- **SU DIA Program**

Collaboration with the DIA program (D2, D3) has also facilitated rapid processing of GLEAM, CHILES, AUDS and MAGPHYS science projects.

- **National and International**

Over 90% of SU refereed papers have involved collaboration with national and international collaborators. Detailed Collaboration are:-

o European Southern Observatory (ESO)(AUDS team)

Following the acceptance for publication of the second Arecibo Ultra Deep Survey (AUDS) paper by ICRAR PhD student Hoppmann, members of the team, including Freudling and Zwaan from ESO gathered at ICRAR from May 4-8 to continue their analysis of the deepest HI survey ever conducted on the world's largest radio telescope. The emphasis of the "busy week" was on methods of large-scale flagging and gridding.

o GLEAM

GLEAM is one of the top-ranked MWA projects and consists of an international team of over 60 scientists led by SU1 (Staveley-Smith) and SC1 (Wayth, Hurley-Walker) ICRAR staff. Tremendous progress in analysis has occurred over the last 12 months, and detailed scientific studies by other SU1 and SC1 staff is now well underway.

o Wallaby

Wallaby is one of the two top-ranked ASKAP projects. It has already published its first paper from Boolardy Engineering Test Array (BETA) data, and is due to begin its early science phase in 2016. Over 100 international scientists are involved, with SU1 staff having key science and leadership roles. Activities over the last year have focussed around scientific software pipelines (source-finding and kinematics), BETA science and other ancillary science studies. Much activity was put into international activities at the annual Pathfinders HI Coordination Committee meeting at Rutgers University in March.

o DINGO

DINGO (Deep Investigations of Neutral Gas Origins) is a reference deep field study of neutral atomic hydrogen to be carried out on ASKAP, one of ten key supported survey science projects. This international project is led by Meyer at ICRAR, along with a team of local researchers including Popping, Staveley-Smith, Driver, and Westmeier. In the last 12 months, DINGO has carried out its first test observations with the 6-antenna BETA array, along with pilot HI observations using the JVLA of the GAMA equatorial fields. The project is currently planning for a 200 hr HI stacking experiment to be carried out as part of the 12 antenna ASKAP Early Science program. Meyer presented DINGO at a number of

conferences over the past 12 months (e.g. GAS2014, Sarawak, Borneo; PHISCC, Rutgers, New Jersey; OzSKA, Melbourne; Southern Cross, Sydney; ASA, Perth).

- CHILES

  The Cosmos HI Large Extragalactic Survey (CHILES) is studying the evolution of neutral hydrogen in the Universe 5 billion years back in time. The Jansky Very Large Array (VLA) in New Mexico (USA) is being used to observe an area in the sky for a total integration time of thousand hours and this is the most sensitive survey for distant gas that has ever been undertaken. Popping, Meyer and Wicenec are current members of this international collaboration which is being led by Columbia University in New York (PI: van Gorkom). Scientists at ICRAR have been leading the imaging pipeline of the survey and are responsible for producing the data cubes. Popping and Meyer have visited Columbia University in April 2015 and Popping has presented the first results of the survey at several national and international conferences.

- Zagreb (XXL team)

  The X-Ray Multi-mirror Mission (XXM) Extragalactic Survey (XXL) is the largest XMM-Newton (ESA X-Ray telescope) observing program ever. Huynh is a member of the XXL collaboration and works closely with the group at the University of Zagreb (Vernesa Smolcic) to follow up the XXL survey fields in the radio bands. Huynh and collaborators obtained 240 hours of ATCA time in late 2014. Huynh and ICRAR PhD student Butler are leading the analysis of the ATCA data, which forms the bulk of Butler's thesis. Huynh and Butler visited the University of Zagreb and presented preliminary results at the annual XXL collaboration meeting in May 2015. The first paper from pilot data collected in 2012 has recently been accepted for publication.

- Leiden University (KiDS team)

  Robotham, Driver and Moffet work closely with a large number of researchers in Leiden (Konrad Kuijken, Massimo Viola and Jelte de Jong) on science projects that use data from GAMA and the Kilo-Degree Survey (KIDS) that Kuijken is leading. On ICRAR's side the focus is on using the KiDS data to better deconstruct the components of GAMA galaxies and to uncover faint satellite members of GAMA groups using photo-z techniques. On the Leiden side the focus is on using the GAMA groups to do stacked weak lensing analysis using the KiDS data. The first weak lensing science has recently been accepted for publication and was the focus of a large ESO sponsored press release. Robotham has visited Leiden twice in the last 18 months, with one of the trips funded by a grant from Leiden.

- Cardiff and Edinburgh (H-ATLAS team)

  Driver, Robotham, Davies and Wright work closely with researchers in Cardiff/Edinburgh (Loretta Dunne and Steve Maddox) on science projects combining GAMA data with imaging from the Herschel space telescope. These projects probe the warm and cold dust content of local galaxies using the far-infrared data from Herschel combined with a further 15 bands of imaging from GAMA to fully explore the energy output of galaxies. This collaboration has led to 30+ joint publications over the past 5 years, and is a large part of the focus of Wright's PhD. We recently hosted a large multi-wavelength meeting which Dunne attended.

- Birmingham, Liverpool, Bristol (XXL project)

  Robotham has become involved with a new project that will combine his GAMA group data with deep X-ray data obtained as part of the XXL project. This will investigate the hot gas component of galaxy groups over the largest range of halo mass ever attempted. The collaboration is in its early phases, but tasks have recently been allocated and Robotham should be meeting with other project members face-to-face in September during his visit to the UK.

- Warwick, Bistol, Sussex (High-redshift galaxies)

  Davies works with a team of researchers in the UK on science projects probing high redshift (z~5) galaxies and their local analogues, led primarily by Stanway (Local analogues) and Bremer (z~5 galaxies). Recent projects involve the identification of local analogue systems (Stanway & Davies, 2014), radio observations of local GRB host galaxies (potential Lyman-break type systems, Stanway, Levan & Davies, 2014), emission line modelling of starburst systems (Stanway et al, 2014) and searches for high redshift

proto-cluster systems (Husband et al 2013). Davies has visited the UK to meet with the team twice in the last 18 months as part of an RCA award.

- Swinburne (MAGPHYS)

  Elisabete Da Cunha is key collaborator, being the driving force behind the hugely popular Multi-wavelength Analysis of Galaxy Physical Properties (MAGPHYS) energy balancing Spectral Energy Distribution (SED) fitting code. She visited ICRAR in late February 2015 in order to attend our multi-wavelength meeting. GAMA makes extensive use of this code, since it is the largest mutli-wavelength survey that covers the large range of wavelength (UV to FIR) required to properly constrain the energy properties of galaxies. Robotham in particular is working closely with Da Cunha on updates and improvements to MAGPHYS, and we expect her to be a regular visitor to ICRAR over the coming years.

- Waterloo (merging galaxies)

  James Taylor visited Robotham for a 2.5 week period in April. This was funded by Robotham's UWA RCA, and was ostensibly to work on simulations of merging galaxies that Robotham initiated. Power (SU3) is also involved in this project, and we will have a joint B-Phil student working on extending these simulations in the near future. In the meantime Taylor's 3rd PhD student is using the simulation software to assist in interpreting some theoretical results for the final chapter of his thesis.

- Carnegie, Manchester, Spain, Nottingham, Sussex (Mocking Astrophysics Collaboration)

  Power is a core member of the Mocking Astrophysics international collaboration of galaxy formation simulators and modellers that is coordinating and running workshops to compare the results of state-of-the-art supercomputer models and also with observations, to refine models, and to calibrate model parameters. Since 2010 there have been several workshops, including in 2015 ones at ICRAR/UWA in March and at the Carnegie Observatories in Pasadena, USA in July, with further workshops planned in Cape Town and Zurich in 2016. Over 20 papers have been published based on these workshops, already with a few hundred citations. Key collaborators are Dr Andrew Benson (Carnegie Observatories, USA), Dr Scott Kay (U Manchester, UK), Prof Alexander Knebe (UAM, Spain), Prof Frazer Pearce (U Nottingham, UK), Prof Peter Thomas (U Sussex, UK).

- Durham (GALFORM)

  Power and especially Lagos work extensively with the Galaxy Formation (GALFORM) simulation code collaboration, the world-leading team of galaxy formation modellers based primarily at Durham University (UK). Key collaborators are Professors Carlos Frenk, Carlton Baugh and Cedric Lacey (Durham University), Dr. Violeta Gonzalez-Perez (University of Portsmouth), and Hansik Kim (U Melbourne). In this collaboration the focus to date has been on predicting the properties of cold gas in galaxies, but Lagos is now focused on developing state-of-the-art models of supernovae feedback, considering the fate of the outflow gas. This collaboration is about to submit a major paper that is expected to be of very high impact (in the lines of Baugh et al. 2005 and Bower et al. 2006, which have each 462 and 1314 citations, respectively).

- Strasbourg, Sydney, Leicester, Swinburne (Dynamical Models)

  The ICRAR team of Diakogiannis, Obreschkow, Power, & Taranu works on projects related to dynamical models of star clusters and galaxies. Diakogiannis leads a collaboration of Prof Rodrigo Ibata (Strasbourg), Prof Geraint Lewis (U Sydney), and Dr Mark Wilkinson (U Leicester) on reconstructing mass models of globular clusters and dwarf galaxies that has so far produced 3 publications and will be applied to Local Group dwarf galaxies. Obreschkow collaborates with Prof Karl Glazebrook (Swinburne UT) on the DYNAMO survey to look at the structure of clumpy galaxies. Obreschkow, Power and Taranu are all actively collaborating with the SAMI galaxy survey team, exploiting both observational data and providing theory support. For example, Taranu works on dynamical models of SAMI spiral galaxies by simultaneously fitting the stellar velocity moments (luminosity, velocity, velocity dispersion, possibly h3/h4) to extract structural parameters for the bulge, disk and halo components with a full Bayesian MCMC approach; this will be used to study correlations between structural parameters, galaxy scaling relations and the connection between morphology and angular momentum. Key collaborators are Dr Lisa Fogarty (U Sydney) and Prof John Dubinski (U Toronto), and this work is producing code.

- Leiden, Durham, Chile (EAGLE)

  Lagos works with the Evolution and Assembly of GaLaxies and their Environments (EAGLE) simulation collaboration to study the evolution of the interstellar medium of galaxies from integrated properties, such as mass in the atomic and molecular gas phases, to structural properties, such as radial distribution, angular momentum, velocity dispersion, among others. In this project Dr. Lagos is closely working with Prof. Joop Schaye (Leiden Observatory), Prof. Tom Theuns (Durham University), post doctorates Michelle Furlong and Matthieu Schaller (Durham University) and Lecturer Robert Crain (Liverpool). There is already one paper in press on this subject led by Lagos. Lagos also co-supervises students Enrique Paillas and Sergio Conteras in Pontificia Universidad Catolica de Chile, together with Professors Nelson Padilla (Pontificia Universidad Catolica de Chile) and Patricia Tissera (Universidad Andres Bello in Chile), to study the properties of voids and the large scale structure under the influence of baryonic physics using the EAGLE simulations.

- Sydney, Spain, Heidelberg, Durham, UQ (Alternative Cosmologies)

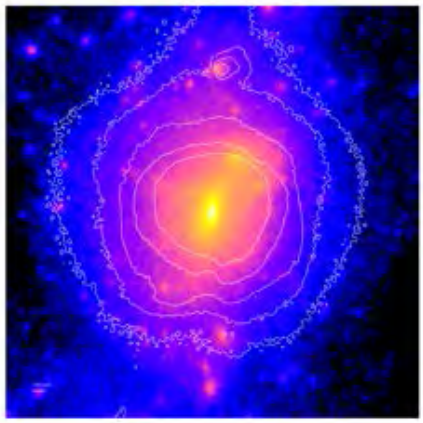
  Cui and Power collaborate with Dr Pascal Elahi (U Sydney), Prof Alexander Knebe (UAM, Spain), Dr David Parkinson (U Queensland), Dr Baojiu Li and Prof Carlton Baugh (Durham University, UK), and Prof Volker Springel (Heidelberg ITS, Germany) on modelling structure formation and galaxy formation in non-standard dark matter and dark energy models. Power has written papers on halo structure and observational tests of the nature of dark matter and papers on gravitational lensing and assembly histories of galaxies in Warm Dark Matter models; Cui and Power have written papers on non-standard gravity and dark energy models and the structure of galaxy clusters.

- Swinburne, AAO, Trieste (Galaxy Groups & Clusters)

  Bekki and Meurer collaborate with Dr Virginia Kilborn (Swinburne UT) on the origin of metal-rich dwarf galaxies discovered recently by Dr Sarah Sweet (ANU) for nearby groups, comparing the observed high metallicities of the dwarfs with corresponding simulations and discussing them in the context of tidal dwarf formation in interacting galaxies. Bekki also collaborates with Prof Warrick Couch (AAO) on the formation and evolution of group galaxies, in particular, transformation from late-type to S0s based on the comparison between SAMI data and simulations. Cui and Power collaborate with Prof Stefano Borgani, Dr Veronica Biffi and Dr Giuseppe Murante (Observatory of Trieste, Italy) on simulating statistical samples of galaxy clusters, to understand how the observable spatial and kinematical structure of gas and stars within clusters can be used to constrain their assembly history.

- The Perth Simulated Galaxy Clusters Workshop

  This successful international workshop was held at ICRAR/UWA during the week of March 23-27, when we had 9 visitors (from institutions in Spain, UK, South Africa, Germany and Canada) as well as several from interstate. Three papers from the week are in advanced stages of preparation and will be submitted shortly. The workshop was funded primarily by UWA Research Collaboration Awards (Weiguang Cui and Chris Power) and co-sponsored by a 10% contribution from CAASTRO (all overseas participants had at least their accommodation covered; productive participants had flights and local costs also covered).



Simulations of galaxy cluster formation were the subject of a workshop during March 23-27.

D(ii).7 PROGRAM BUDGET (for this reporting period)

D(ii)7.1 Expenditure of State Government grant

Expenditure type	Agreed expenditure ($)	Actual expenditure ($)	Variance ($)
Salaries			
Operating			
Capital			
Travel			
TOTAL			

Expenditure details

Summarise the expenditure of the State Government grant.

Not applicable to Science program at UWA. This is applicable only to ICRAR Science Program at Curtin and see Section (D (i) 7.1

Variance in expenditure? Yes ☐ No ☐

Detailed reason for variance in expenditure

Not applicable to Science program at UWA. This is applicable only to ICRAR Science Program at Curtin and see Section (D (i) 7.1

D(ii)7.2 Expenditure of Curtin University Joint Venture cash contribution

Expenditure type	Agreed expenditure ($)	Actual expenditure ($)	Variance ($)
Salaries			
Operating			
Capital			
Travel			
TOTAL			

Expenditure details

Summarise the expenditure of the Curtin University Joint Venture cash contribution funds.

Not applicable to Science program at UWA. This is applicable only to ICRAR Science Program at Curtin and see Section (D (i) 7.2

Variance in expenditure? Yes ☐ No ☐

Detailed reason for variance in expenditure

Not applicable to Science program at UWA. This is applicable only to ICRAR Science Program at Curtin and see Section (D (i) 7.2

D(ii)7.3 Expenditure of UWA Joint Venture cash contribution

Expenditure type	Agreed expenditure ($)	Actual expenditure ($)	Variance ($)
Salaries	1,378,054	755,919	622,135
Operating	167,750	77,964	89,786
Capital	25,000	8,297	16,703
Travel	157,750	85,672	72,078
TOTAL	**1,728,554**	**927,851**	**800,703**

Expenditure details

Summarise the expenditure of the UWA Joint Venture cash contribution.

Expenditure is in line with ICRAR II Plan and Budget. Over 81% expenditure is on salaries as planned followed by travel and operating. Science Program at UWA has most FTEs in place. Variance is mainly due to late start of ICRAR II as stated below and also in section C.5.1.

Variance in expenditure? Yes ☒ No ☐

Detailed reason for variance in expenditure

Variance in expenditure is due to the agreed six month late start of ICRAR II expenditure from 1 January 2015 as compared to 1 July 2014.

SECTION E: ENGINEERING PROGRAM PROGRESS

Including the SKA Pre-construction work packages, LFAA and CSP.

E.1 SHORT PROGRAM DESCRIPTION

Please provide a short summary of the Program (suitable for public release).

ICRAR is one of a small number of radio astronomy institutes in the world to bring together strong radio astronomy, engineering and ICT capabilities. This capability mix enables ICRAR to apply an end-to-end system perspective of radio astronomy instrumentation and make well-informed, high-impact contributions on the international stage, including into the SKA Project.

The ICRAR Engineering Program includes four projects scoped and resourced to facilitate the broad range of laboratory, workshop and site based activity that supports ICRAR's end-to-end contribution to the development of innovative, world leading radio astronomy instrumentation.

E.2 PROGRAM OBJECTIVES

Summary list of Program objectives

Please provide a list of Program objectives for the Term of 2014-19 FAA.

1. **Project E1—Astronomical instrumentation: Encompasses major ICRAR Engineering activities not directly associated with SKA pre-construction. Will engage ICRAR engineers and associates in leading-edge engineering science and deliver new capabilities for ICRAR astronomers.**
2. **Project E2—SKA LFAA pre-construction: Represents a substantial co-investment into an AUD 4M Australian Government grant awarded to ICRAR/Curtin to support high-level involvement in the SKA pre-construction phase. ICRAR is leading prototyping and verification, and local infrastructure activities, for the SKA-low AA and is responsible for all on site activity in support of the engineering design process. In large measure ICRAR milestones and deliverables mirror formal preconstruction artefacts contracted to the Australian Government and the SKA Organisation.**
3. **Project E3—SKA Central Signal Processing pre-construction: Represents a substantial co-investment into an AUD 1M Australian Government grant awarded to ICRAR/Curtin to support high-level involvement in the SKA pre-construction phase. ICRAR leads two high-visibility and high-impact tasks, the Requirements and Architecture packages, and a physical implementation prototype for SKA-low. In large measure ICRAR milestones and deliverables mirror formal preconstruction artefacts contracted to the Australian Government and the SKA Organisation.**
4. **Project E4—MRO projects management: A variety of ICRAR projects, activities and tasks depend on having access to the MRO and use of the infrastructure and facilities that enable operations at the site. Project E4 provides for the effective and efficient planning, coordination and execution of ICRAR's field program.**

Progress against Program objectives (in this reporting period)

Summarise the progress towards achieving each Program objective.

Please also discuss any encountered difficulties/failures and improvements put or to be put in place.

1. **Project E1 - Progress**

   MWA phase 2 expansion: Milestone 1.1 (high-level design) complete. The LIEF funding application for phase 2, led by ICRAR/Curtin Science Director Tingay, was submitted in March 2015. Results are expected in late 2015.

MWA correlator enhancement: Milestone 3.1 (design) complete. A prototype system for development of enhanced features of the MWA correlator has been set up in the ICRAR engineering laboratory.

Integration of AAVS/external data with MWA: a prototype data capture system has been implemented in the ICRAR engineering laboratory to test the capabilities of the MWA correlator to ingest digital data from external instruments. This will allow data from BIGHORNS and AAVS1 (for instance) to be correlated with the entire MWA.

2. Project E2 - Progress

AAVS0.5: ICRAR successfully completed the test and evaluation of AAVS0.5 which was a major contributor to the successful LFAA preliminary design review. We continue to lead verification and prototyping efforts in key areas such as Radio-over-Fibre (RFoF), fibre optic cable characterization and antenna calibration techniques.

AAVS1: ICRAR continues to provide critical inputs to Aperture Array Design and Construction Consortium (AADCC) in the specification, design and test methodology for AAVS1, the primary LFAA prototype designed at the top level by ICRAR Director Hall. We recently delivered key design and test documentation to AADCC. Overall AAVS1 progress is occurring slightly more slowly than originally planned due to AAVS1 management re-structuring in Europe, which includes a new effort in formalising system definition and design. We expect that this exercise will lead to improvement in AADCC work structure leading to long-term AAVS1 project gain such that the late-2015 construction start date will hold.

Local INFRA: ICRAR's contributions to the LFAA Preliminary Design review process were widely acknowledges as being high quality and high impact, and were explicitly noted as such by the independent review panel appointed by the SKAO. ICRAR Local Infrastructure studies, conducted in association with Raytheon Australia and Balance Utility Solutions, and presented in the form of comprehensive written reports, addressed a number of key risks associated with LFAA through stage-1 of SKA preconstruction, breaking down a number of pre-conceptions by bringing a practical focus to previously unaddressed questions and issues. ICRAR has taken a leading role in ongoing discussions about SKA construction and deployment, leveraging its unique end-to-end instrumentation expertise and experience.

Overall, all Project E2 milestones have been met with all relevant reports being accepted by the SKA Organisation and the Australian Government. It is important to note that preconstruction effort is funded through the Federal Governments SKA preconstruction grants along with the State and JV funds. For the LFAA and CSP total $5.0M were won under the Federal Government's SKA preconstruction grants scheme in 2013 and in the current reporting period $1.9M of those funds has been received as stated in Section C.6.

3. Project E3 - Progress

All project milestones have been met. A correlator design and preliminary costing was provided to CSP for PDR. Other architecture, system requirements and design artefacts were also provided and accepted (milestone 1 and 2)

Milestones 3 and 4 pertain to the finalisation of contracts between ICRAR/Curtin and two industry partners: NVIDIA and CISCO Systems. Both of these have been met and work has begun.

Milestones 5 and 6 are Australian Government reporting milestones. Both have been met. The reports have been submitted and accepted.

4. Project E4 - Progress

The rationale underpinning the creation of this project was to remove the administrative overhead associated with site licence compliance and logistics from E1 and E2 project resources in order that they can be focused on delivery of their key outputs. This approach has been validated by the outputs of projects E1 and E2 through stage 1 of SKA pre-construction and in support of ICRAR's various astronomical instrumentation development initiatives. Project E4 has also supported a variety of Government, SKAO and industry site visits, taking each opportunity to showcase ICRAR's outstanding record of delivery. All milestones to date have been met.

Final year Curtin Electrical and Computer Engineering student Mia Walker is assisted by ICRAR engineer Mr David Emrich in the roof-top installation of an interferometer designed for learning and outreach purposes.

E.3 PROGRAM ACTIVITIES AND OUTPUTS

Summary list of Program activities and outputs

Please provide a list of Program activities and outputs for the Term of the 2014-19 FAA.

1. **E1—Astronomical instrumentation**
   - MWA expansion, part 1
   - MWA expansion, part 2
   - MWA correlator enhancement
   - Integration of AAVS1 analogue output into MWA signal path
   - Integration of AAVS1 digital output into MWA signal path
   - Integration of BIGHORNS output into MWA signal path
   - ICRAR Laboratory
   - Student Projects
2. **E2—SKA LFAA pre-construction**
   - Prototyping and verification
   - Local infrastructure
3. **E3—SKA CSP pre-construction**
   - Software Correlator Development
   - Industry Engagement
   - Systems Engineering Supporting Correlator Design
4. **E4—MRO projects management**
   - SLA Management
   - SLA Compliance
   - Site Infrastructure
   - Site Logistics
   - Site Safety
   - MRO Development

Progress against Program activities and outputs (in this reporting period)

Summarise the progress towards achieving each Program activity and output.

Please also discuss any encountered difficulties/failures and improvements put or to be put in place.

1. E1—Astronomical instrumentation

MWA expansion, part 1

- Milestone 1.1 (high-level design) complete. Outcomes of ARC LIEF grant application are expected in 2015 November. Prototypes of beamformer controllers for new long baseline times are working in the ICRAR laboratory.

MWA expansion, part 2

- Preliminary investigations into potential hardware for MWA phase 3 have been made and a session for MWA expansion phases was included in the June MWA project meeting in Melbourne.

MWA correlator enhancement

- Milestone 3.1 (high-level design) complete. Software engineering work on expansion will commence in 2015 July.

Integration of AAVS1 analogue output into MWA signal path

- Milestone 4.1 (design) for AAVS1 analogue integration with the MWA: complete. A prototype based on using Signatec data capture cards is working in ICRAR laboratory.

Integration of AAVS1 digital output into MWA signal path

- Conceptual design complete and some parts of the digital signal chain have been tested in the ICRAR laboratory using the Netherlands Institute for Radio Astronomy (ASTRON) Uniboard as a proxy for SKA-low. Results of these signal processing prototypes were presented at international AAVS1 design reviews.

Integration of BIGHORNS output into MWA signal path

- Milestone 6.1 (deployment) complete. Signal chain integration with MWA (milestone 6.2) is in progress and uses the same design and hardware as integration with AAVS1 analogue activity. Deployment will be in the second half of 2015.

ICRAR Laboratory

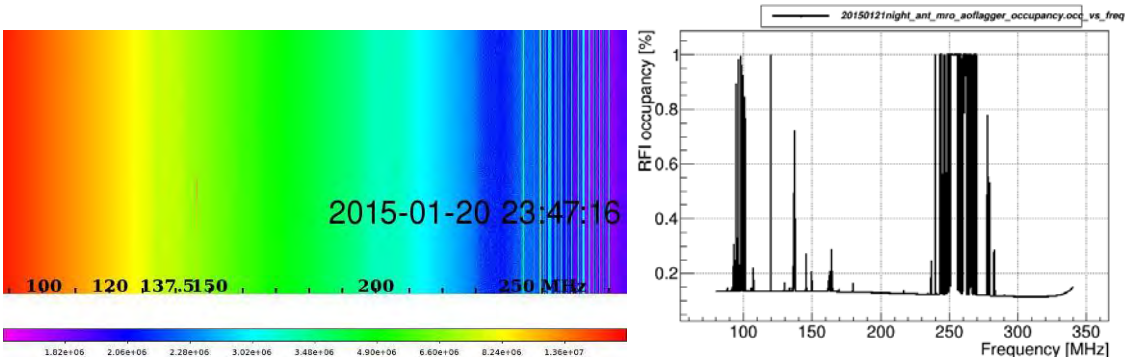
- The ICRAR laboratory is providing essential support for development and testing equipment over all ICRAR Engineering programs and activities. Testing and software development for the Kaelus analogue beamformer is progressing with substantial work being performed by visiting Dutch interns. The internship program has been a great success. Installation of rooftop test equipment and dipoles for Radio Frequency (RF)-over-fibre environmental testing and student interferometry projects is complete.

Student Projects

- There are two student projects in progress, both involving Curtin University final-year students from the Department of Electrical and Computer Engineering (ECE). One is using the rooftop antennas to build an outreach scale interferometer using inexpensive, portable USB TV tuner dongles. The other project is using the BIGHORNS equipment at the MRO to study the RFI environment at the MRO.

Journal publications

1. Ord, S.M. et al., The Murchison Widefield Array Correlator, Publications of the Astronomical Society of Australia, Volume 32, March, 2015
2. Sokolowski, M. et al., BIGHORNS - Broadband Instrument for Global HydrOgen ReioNisation Signal, Publications of the Astronomical Society of Australia, Volume 32, February, 2015



Top: Drs Wayth and Sokolowski from ICRAR/Curtin installing the BIGHORNS cone antenna at the MRO. The completed cone is also shown in Perth, prior to receiving its protective fibreglass painting. Bottom: The left spectrogram shows frequency from 50 – 350 MHz on the horizontal axis, with about 1 hour of time on the vertical axis. Very low RFI in the SKA-low bands are apparent to the eye, and are confirmed by the spectral occupancy plot on the right. However, the effects of known military communications satellites around 250 MHz are obvious. The ICRAR monitoring system runs continuously, producing data at time and frequency resolutions of 50 ms and 100 kHz and, apart from its scientific application, is invaluable in monitoring and containing RFI at the radio-quiet MRO.

2. E2—SKA LFAA pre-construction

Prototyping and verification

- SKA Preliminary Design Review deliverables:
  - Array Prototypes Specific and Overall Design Report, SKA-TEL.LFAA.PROT.MGT-AADC-R-002, 2014-10-30
- Other:
  - Field Test Result at the MRO to Assess Gain & Phase Variation of Fibre-optic Cable, SKA-TEL.LFAA.RE.AST-AADC-R-001, 2015-2-15
- AAVS1 design deliverables:
  - Aperture Array Verification System1, A Brief Overview, Professor Peter Hall, January 21, 2014 (and subsequent updates), SKA.TEL.LFAA.PROT.AAVS1.SDD-AADC-PLA-001
  - AAVS1 Commissioning Test Plan, SKA-TEL-LFAA-0800002, 2015-22-05
  - AAVS1 EMI Requirements and Example, SKA-TEL-LFAA-0800006, 2015-05-22
  - Proposed layout of AAVS1 stations, SKA-TEL-LFAA-0900001-AAVS1-proposed-station-layout-Rev-1-1, 2015-05-25
  - Evaluation of AAVS1 Calibration (Southern Hemisphere), SKA-TEL-LFAA-0800003, 2015-05-22
- Journal publications:
  1. Sutinjo, A., J. O'Sullivan, E. Lenc, R. B. Wayth, S. Padhi, P. Hall, and S. J. Tingay (2015), Understanding instrumental Stokes leakage in Murchison Widefield Array polarimetry, Radio Sci., 50, 52–65, doi:10.1002/2014RS005517.

2. Sutinjo, A.T.; Hall, P.J., "Antenna Rotation Error Tolerance for a Low-Frequency Aperture Array Polarimeter," Antennas and Propagation, IEEE Transactions on , vol.62, no.6, pp.3401,3406, June 2014, doi: 10.1109/TAP.2014.2312201

3. A. Sutinjo and T. Colegate, et. al., “Characterization of Aperture Array Verification System 0.5: Radio Astronomy Interferometry and Full-Wave Simulation,” submitted to IEEE Trans. Antennas Propagat. (in revision)

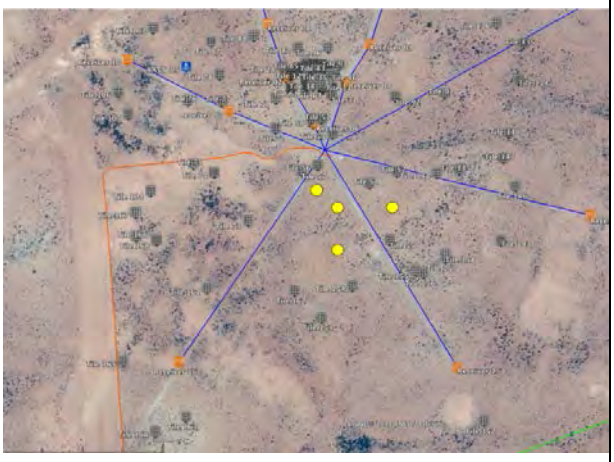
Local infrastructure

- Interim deliverables to AADCC and SKAO
  - Balance Utility Solutions, LFAA Preliminary Power Investigation, SKA-TEL-LFAA-0000013-LINFRA.PWR-RE
  - Raytheon Australia, LFAA Initial Deployment Plan
  - Central Earthmoving, A comparison of SKALA installation techniques

- SKA Preliminary Design Review deliverables:
  - LFAA Schedule Estimate for Construction, SKA-TEL-LFAA-0000005-LINFRA-MGT-AADC-PL, 2014-10-30
  - LFAA Preliminary Deployment Report, SKA-TEL-LFAA-0000011-LINFRA.DEM-RE, 2014-10-30
  - LFAA Preliminary Power Design Report, SKA-TEL-LFAA-0000012-LINFRA.PWR-RE, 2014-10-30
  - LFAA Local Infrastructure Preliminary Design Report, SKA-TEL-LFAA-0000019-LINFRA.MGT-RE, 2014-10-30
  - LFAA Preliminary Health, Safety and Environment Plan, SKA-TEL-LFAA-0000024-SE.MGT-PL, 2014-10-30
  - LFAA Preliminary WBS for Construction, SKA-TEL-LFAA-0000033-LINFRA.MGT-SOW, 2014-10-30
  - LFAA EMI Pre-scan Guide for AAVS1 Equipment, SKA-TEL-LFAA-0000045-PROT.SE-PR, 2014-10-30
- AAVS1 design deliverables:
  - AAVS1 Site Preparation, SKA-TEL-LFAA-0700002, 2015-05-22
  - AAVS1 Preliminaries, SKA-TEL-LFAA-0700003, 2015-05-22
  - AAVS1 Logistics, SKA-TEL-LFAA-0700005, 2015-05-22
  - AAVS1 Local Infrastructure Design, SKA-TEL-LFAA-0700007, 2015-05-22

Industry Engagement

Half of the AUD 4M Australian Government LFAA preconstruction grant awarded to ICRAR/Curtin is expended via industry partners. In the reporting period Kaelus, Raytheon Australia and Balance Utility Solutions have all delivered key prototypes and systems in pivotal LFAA development areas, effectively confirming the feasibility of siting SKA-low in WA and building SKA capacity in Australian and WA industry.



Proposed location and layout of AAVS1 at the MRO. The four stations (yellow dots), containing a total of 400 antennas, form a 2-dimensional array, with E-W and N-S maximum baselines of > 200 m. The blue radials depict MWA trenches. Black and orange squares are MWA tiles and receivers, respectively. The orange line is the existing access road, running for some distance at the side of the airstrip.

3. E3—SKA CSP pre-construction

SKA Preliminary Design Review deliverables

- SKA-TEL.CSP.CBF.LOW-CUR-PIP-001 – the design document
- SKA-TEL.CSP.CBF.LOW-CUR-DVP-001 – the development plan
- SKA-TEL.CSP.CBF.LOW-CUR-CST-001 – the design costing
- The Low, Mid and Survey correlator requirements specifications (SKA-TEL.CSP.CBF.LOW-CUR-SRS-001, SKA-TEL.CSP.CBF.MID-CUR-SRS-001, SKA-TEL.CSP.CBF.SUR-CUR-SRS-001)
- The Low, Mid and Survey correlator architecture documents (SKA-TEL.CSP.CBF.LOW-CUR-ADD-001, SKA-TEL.CSP.CBF.MID-CUR-ADD-001, SKA-TEL.CSP.CBF.SUR-CUR-ADD-001)

Industry Engagement

- Two sub-contracts, funded by the Australian Government via an ICRAR/Curtin preconstruction grant have been finalised. These are each extensive ~AUD 1M contracts covering the design and development of technologies supporting the SKA software correlator. These not only provide ICRAR with extensive insight into industry capability, but also provide these same industries with access to the SKA project. The heavily promote industry engagement with the SKA.

4. E4—MRO projects management

SLA Management

- ICRAR/Curtin's MRO Site Licence Agreement was amended to include the construction and operation of the AAVS1 on the MWA site as an authorised activity.
- A Memorandum-of-Understanding between ICRAR/Curtin (on behalf of the AADC Consortium) and the MWA Project was completed.

SLA Compliance

- There have been no SLA compliance breaches or issues during the reporting period.
- ICRAR/Curtin's current MRO site licence will expire early in CY2016. Discussion of the terms of a new licence have commenced with the Site Authority.

Site Infrastructure

- Site infrastructure for the 'BIGHORNS' installation was completed in the reporting period and 'BIGHORNS' was successfully deployed and commissioned.
- Site infrastructure planning for AAVS1 was completed and procurement activity commenced. This infrastructure will be in place ahead of the required schedule.
- Scoping and resourcing of general site infrastructure maintenance was completed during the reporting period. Funding has been allocated and a range of site maintenance activities will commence in FY2015/16.

Site Logistics

- All site activities were executed effectively with respect to site logistics.
- o Detailed logistics planning for AAVS1 was completed (AAVS1 Logistics, SKA-TEL-LFAA-0700005, 2015-05-22)
- A number of logistics procedures were reviewed with a view to reducing dependencies on external organisations, including the CSIRO. A number of new procedures will be implemented subject to finalisation of implementation and budgetary issues.

Site Safety

- No safety issues occurred during ICRAR's on-site activities conducted through the reporting period.

- A comprehensive review of ICRAR's field-work risk assessment and safety protocols was conducted—triggered by changes to Curtin Universities risk management regime.
- A preliminary health, safety and environment plan for AAVS1 was developed as part of ICRAR's contribution to the LFAA Preliminary Design Review process (SKA-TEL-LFAA-0000024-SE.MGT-PL)

MRO Development

- ICRAR continues to proactively engage with the MRO Site Authority (CSIRO) on site management and development issues.

Publications

1. C. Choeysakul, F. Schlagenhaufer, and P. Hall, "EMC Applications for the Navy: Reverberation Chamber Tests," Royal Thai Naval Academy Journal of Science and Technology, Issue Number 1, Aug. 2014.
2. C. Choeysakul, F. Schlagenhaufer, P. Rattanakreep, and P. Hall, "EMC Applications for Military: Reverberation Chamber Tests," The 20th Asia-Pacific Conference on Communications; APCC, Pattaya, Oct. 1-3, 2014

ICRAR is in the front-line of organising many MRO visits for international radio astronomy staff and dignitaries. Here, a VIP group is shown the MWA and AAVS0.5 installations. From left to right the group is Prof. Deborah Terry (Curtin University Vice-Chancellor); Prof. Peter Hall; Mr Sem Fabrizi, Ambassador and Head of EU Delegation to Australia and New Zealand; Mr Brett Hiscock, CSIRO; Ambassador Mrs Annemieke Ruigrok, Embassy of the Kingdom of The Netherlands; Prof. Steven Tingay; and Mr Rolf Karst, Policy Officer, Trade & Economic Affairs, Embassy of the Kingdom of The Netherlands

E.4 PROGRAM KPIS AND MILESTONES

Summary list of interim Program KPIs and milestones

1. **On average, research staff members at ICRAR publish at least two refereed articles per annum, with 90% of all articles to be published in journals with an Impact Factor of 3.0 or greater.**
2. **ICRAR maintains at least 45 enrolments of Masters and PhD students each year, with adequate support provided by the Centre to students to achieve four completions each year.**
3. **ICRAR actively engages with the SKA project.**
4. **ICRAR effectively engages with local industry.**
5. **ICRAR leverages research in Data Intensive Science.**
6. **ICRAR raises the community awareness of science.**
7. **ICRAR raises the profile of WA to major global companies.**
8. **ICRAR builds a financially sustainable organisation.**

Progress against interim Program KPIs and milestones (in this reporting period)

Summarise the progress towards achieving each interim Program KPI and milestone.

Please also:

- discuss any encountered difficulties/failures and improvements put or to be put in place;
- provide details of refereed journal publications in Appendix A;
- provide details of research staff and Masters/PhD students/graduates in Appendix B; and
- provide details of external R&D grants awarded in subsection C.6.

1. **On average, research staff members at ICRAR publish at least two refereed articles per annum, with 90% of all articles to be published in journals with an Impact Factor of 3.0 or greater**

   Engineering peer-review journal publication since September 2014:

   - 1 published in Radio Science
   - 2 published in Publ. Astron. Soc. Aust.
   - 1 in-press in Publ. Astron. Soc. Aust.
   - 1 submitted to Institute of Electrical and Electronic Engineers (IEEE) Trans. Antennas and Propagation.

   In addition, several conference papers have been produced, as outlined in the ICRAR publication list.

2. **ICRAR maintains at least 45 enrolments of Masters and PhD students each year, with adequate support provided by the Centre to students to achieve four completions each year**

   One new PhD student commenced, with an electrical power engineering project co-supervised by Professor Hall and a Curtin Electrical and Computer Engineering (ECE) colleague.

   A co-tutelle agreement was signed between Curtin University and the University of Twente in The Netherlands as part of a campaign to attract very high-calibre candidates to PhD programs in radio astronomy engineering in WA. An associated pilot internship program for first-rank students from U. Twente and Technical University Eindhoven has produced outstanding results and likely follow-on enrolments in WA.

ICRAR is expanding its engagement in mainstream engineering courses, including Increased ECE teaching engagement and recruitment of two local high-achieving fourth-year students for ICRAR summer projects, with a view to subsequent engineering PhD program enrolment.

3. ICRAR actively engages with the SKA project

The ICRAR Engineering program is heavily geared toward direct participation in and indirect support of SKA preconstruction activities. All four Engineering projects have milestones associated with the SKA and all are progressing as anticipated.

ICRAR's end-to-end instrumentation expertise and experience have been recognised by the SKA community and have seen ICRAR take a clear lead in the prototyping and verification, and system level construction and deployment planning, for the SKA-low.

4. ICRAR effectively engages with local industry.

ICRAR Engineering has had successful engagements with a number of industry partners in support of its participation in SKA preconstruction activity.

- Kaelus (Brisbane) has designed and delivered a fully tested, high-specification analogue beamformer to support AAVS1 and other ICRAR astronomical instrumentation.
- Balance Utility Solutions (Perth has made a high-impact contribution to key discussions concerning generation and distribution of power for the LFAA specifically and the SKA generally.
- Raytheon Australia (Perth) made a high-impact contribution to the understanding and constraining of the LFAA deployment via advanced operational simulation and modelling.
- ICRAR have leveraged the experience of Perth and Geraldton area SMEs—including Central Earthmoving, GCo Electrical, GNC Concrete, AFC, NLD Transport, and DeltaCorp Concrete—to build realistic cost models and inform system trade-offs through SKA pre-construction, and to begin building SKA capacity in WA SMEs.

5. ICRAR leverages research in Data Intensive Science

The ICRAR/Curtin CSP preconstruction contracts involve collaborations with large players such as NVIDIA and CISCO in the development of specialised computing hardware for extremely large data rates and volumes. In addition, ICRAR will use data products from prototype CSP systems to feed demonstration software and data processing supercomputing prototypes, further establishing the Centre's reputation in Data Intensive Science.

6. ICRAR raises the community awareness of science

ICRAR Engineering is a full participant in Centre student programs, including summer studentships and schools – particularly the Australian Indigenous Engineering Summer School and the Curtin University Engineering Summer School. ICRAR also holds industry and community briefings on its LFAA and MWA projects, with the next session planned for Geraldton in late 2015.

7. ICRAR raises the profile of WA to major global companies

In addition to its pre-construction work with NVIDIA and CISCO, ICRAR has collaborated in the LFAA domain with Raytheon Australia and Kaelus, Australian arms of two large international companies with an interest in SKA-low in WA.

8. ICRAR builds a financially sustainable organisation

ICRAR Engineering is a large part of the Centre's strategy in establishing its indispensability in the era of SKA construction and operations. Many of the current Engineering emphases give ICRAR easy segues into, or leadership of, important construction and commissioning contract work. When construction funds begin flowing in Australia, ICRAR will be uniquely placed to capture a significant fraction of them, most likely via construction consortia yet to be formed.

Dutch engineering interns with their ICRAR supervisors. From left to right are Prof. Peter Hall, Mr Robert Grootjans (Technical University Eindhoven), Mr Rene Baelemans (University of Twente), Dr Adrian Sutinjo and Dr Randall Wayth. The interns spent four months at ICRAR/Curtin working on advanced radio astronomy projects as part of their professional Masters qualifications.

Detailed reason for variance if any

Excellent Progress has been made towards achieving the KPIs, in particular the SKA preconstruction related KPIs and industry engagement KPIs. Engineering Program is focussed currently on SKA preconstruction and design efforts and is a global leader in that field. The publications and postgraduate enrolment KPIs are flowing from ICRAR's organisational KPIs may need to be updated in the revision of ICRAR II KPIs in 2015/15 for the Engineering Program. It may be noted that Programmatic KPIs are monitored internally by ICRAR Executive Director and reported to the Board.

E.5 PROGRAM OUTCOMES FOR WA

Summary list of Program outcomes for WA

Please provide a list of Program outcomes for WA for the Term of the 2014-19 FAA.

- Enhanced scientific performance and capability for the MWA; the formation of collaborative industry links with at least two companies during the MWA upgrade process; the completion of at least four PhD projects; the support of undergraduate and postgraduate engineering projects; and the effective development and operation of the ICRAR Laboratory.
- The delivery of designs and prototypes for the LFAA and its prototype and verification systems – including specialist local infrastructure – to be built at the MRO.
- The delivery of pre-construction designs and prototypes for the CSP, including provision of a software correlator to be used in conjunction with the ICRAR verification systems.
- The delivery of appropriate site licenses for Astronomical Instrumentation Project (E1) MWA expansion and E2 prototyping and verification systems; planning and administration of specialized local infrastructure contracts relating to MWA and LFAA verification systems; effective health and safety systems for ICRAR Engineering projects; and MRO access planning and administration for ICRAR staff and collaborators.

Progress against Program outcomes for WA (in this reporting period)

Summarise the progress towards achieving outcomes for WA.

Please also discuss any encountered difficulties/failures and improvements put or to be put in place.

The significant Engineering achievements outlined previously have a number of important outcomes for WA; those listed below are especially relevant for the first year of ICRAR II operation.

1. Confirmation of the practicality of constructing and operating the LFAA, and by extension SKA-low, in WA.
2. The showcasing of WA as the centre of technically advanced, and most-progressed, SKA prototyping.
3. Development of productive industry partnerships, helping ICRAR to deliver pivotal information and prototypes to the SKA Organization.
4. Operation, maintenance and upgrade planning of the highly successful MWA radio telescope, the only operating SKA precursor.
5. An increased push by ICRAR to use SKA-related activities to (a) engage more with mainstream WA engineering education and (b) attract the best engineering research students (local, national and international) to WA universities, building on the earlier successes of ICRAR.

E.6 PROGRAM COLLABORATIONS (in this reporting period)

Summarise the Program collaborations between the Joint Venture Participants and externally with local, national and international researchers, and industry, government and other end-users.

Please also:

- discuss any encountered difficulties/failures and improvements put or to be put in place;
- detail the nature, value and any outcomes of each collaboration; and
- include details of any collaborative research undertaken by visiting researchers.

A number of significant collaborations are central to the Engineering undertaken by ICRAR. These have been discussed in previous Sections but the list below captures the main partners.

1. Collaborations in the context of prominent SKA pre-construction consortia, namely the AADCC, and the CSP Consortium. These Consortia are described in Section E.2 and E.3 but, in the essence, they require ICRAR Engineering researchers and professionals to meet or exceed the standards of partners such as U. Cambridge, U. Oxford, ASTRON (Netherlands) and INAF (Italy). The Consortia are the channels to the SKA Organization for much of ICRAR's SKA-related work. Regular two-way exchanges of Consortia personnel occur and ICRAR hosted a number of working meetings associated with the 2014 SKA Engineering Meeting held in Perth.

2. Collaborations in the MWA Consortium context requires ICRAR engineers to interact with a variety of international science and engineering colleagues at institutions such as Harvard, Massachusetts Institute of Technology (MIT) and Ramen Research Institute (RRI) (India). This has been, and remains, one of ICRAR's key collaborations and ICRAR Engineering will be the group responsible for designing and implementing an expanded MWA. MWA is the only operating SKA precursor and, as described in Section D, is already producing ground-breaking science.
3. Collaboration with CAASTRO enabled ICRAR Engineering to fund and deploy the BIGHORNS radiometer, shown in Figure on page 67.
4. Collaboration with the CSIRO is the lynch-pin of ICRAR's activities at the Murchison Radio-astronomy Observatory. These activities include the MWA, BIGHORNS, AAVS0.5 and AAVS1 systems.
5. Collaboration with industry partners, including Kaelus, Raytheon Australia, Balance Utility Solutions, NVIDIA and CISCO are central to SKA pre-construction work undertaken by ICRAR Engineering, and in stage 1 pre-construction, have enabled ICRAR to produce pivotal studies for the SKA Organization.
6. Collaboration with universities outside WA helps raise the profile of ICRAR researchers, a number of whom supervise students from institutions such as U. Sydney, T. U. Eindhoven and U. Twente (Netherlands).

E.7 PROGRAM BUDGET (for this reporting period)

E7.1 Expenditure of State Government grant

Expenditure type	Agreed expenditure ($)	Actual expenditure ($)	Variance ($)
Salaries	311,459	309,894	1,565
Operating	36,119	40,699	(4,580)
Capital	0	0	0
Travel	245,000	33,366	211,634
TOTAL	**592,578**	**383,959**	**208,619**

Expenditure details

Summarise the expenditure of the State Government grant.

The Engineering Program is actively engaged with the SKA preconstruction activities and expenditure on salaries and operating is higher in this period and a timing issue (given late start of ICRAR II) and will be addressed in the next budget period.

Variance in expenditure? Yes ☒ No ☐

Detailed reason for variance in expenditure

The expenditure in operating higher than anticipated and is a timing issue and will even out over the next budget period.

E7.2 Expenditure of Curtin University Joint Venture cash contribution

Expenditure type	Agreed expenditure ($)	Actual expenditure ($)	Variance ($)
Salaries	397,797	225,117	172,680
Operating	0	343	(343)
Capital	0	0	0
Travel	0	0	0
TOTAL	**397,797**	**225,460**	**172,337**

Expenditure details

Summarise the expenditure of the Curtin University Joint Venture cash contribution.

Expenditure is in line with the budget.

Variance in expenditure? Yes ☒ No ☐

Detailed reason for variance in expenditure

Variance in expenditure due to the agreed six month late start of ICRAR II expenditure from 1 January 2015 as compared to 1 July 2014. Variance is a timing issue.

E7.3 Expenditure on SKA preconstruction work packages

Expenditure type	Agreed expenditure ($)	Actual expenditure ($)	Variance ($)
E2 LFAA pre-construction			
Salaries – Curtin University funded	238,676	157,449	81,227
Salaries – State Government grant funded	124,518	127,083	(2,565)
E3 CSP pre-construction			
Salaries – Curtin University funded	55,254	67,667	(12,413)
TOTAL	**418,448**	**352,199**	**66,249**

Expenditure details

Summarise the expenditure of the State Government grant and the Curtin University Joint Venture cash contribution.

The Engineering Program is actively engaged with the SKA preconstruction activities. Higher expenditure in State funded salaries in LFAA and Curtin funded salaries CSP (despite late start of ICRAR II) is a timing issue and will be addressed in the next budget year.

Variance in expenditure? Yes ☒ No ☐

Detailed reason for variance in expenditure

Variance in expenditure is a timing issue.

SECTION F: DIA PROGRAM PROGRESS

including the SKA preconstruction work package Science Data Processor (SDP)

F.1 SHORT PROGRAM DESCRIPTION

Please provide a short summary of the Program (suitable for public release).

The DIA Program at ICRAR is focussed on three main areas:

1. **The design and architecture of the data system of the SKA**
2. **The support of survey science projects in the area of data management, data handling and data analysis.**
3. **General support of ICRAR computing infrastructure, including a DIA computing laboratory.**

F.2 PROGRAM OBJECTIVES

Summary list of Program objectives

Please provide a list of Program objectives for the Term of the 2014-19 FAA.

1. Improve the State's global capability and capacity for astronomy, data intensive science and engineering research.
2. Actively engaging with the SKA project.
3. Effectively engaging local industry.
4. Leveraging research in data intensive science.

Progress against Program objectives (in this reporting period)

Summarise the progress towards achieving each Program objective.

Please also discuss any encountered difficulties/failures and improvements put or to be put in place.

1. **Improve the State's global capability and capacity for astronomy, data intensive science and engineering research.**

   The DIA team is very well recognised around the world for its capabilities in large-scale data management for astronomical observatories. We have extended this reputation by engaging with several global science survey teams in particular CHILES (VLA, USA) and GLEAM (MWA, WA). More recently we are also connecting with Chinese facilities like FAST and the Chinese Virtual Observatory.

2. **Actively engaging with the SKA project.**

   The DIA team is dedicating about 75% of its resources into the SKA SDP pre-construction consortium, to architect and design the SKA data system. During the reporting period we have delivered all the milestones and document in a timely fashion. The most prominent milestone was the Preliminary Design Review.

3. **Effectively engaging local industry.**

   In particular related to the SKA activities we are engaging with Perth based companies, like Systemic and more recently ThinkBottomUp, but also globally operating companies having a presence in WA or Australia. This includes Amazon, Fujitsu, ThoughtWorks, DDN, SGI, Intel, IBM, KakaduSoft, Umwelt and Anditi. Some of that engagement involves actual pre-construction work being conducted, in other cases we are collaborating on case or cost studies or exchange information about the SKA requirements on one side and potential technological solutions on the other.

4. **Leveraging research in data intensive science.**

   We have started discussions about potential collaborations with several parties in the resources sector. This includes CSIRO, MRIWA, EMI, NRSP and Woodside.

F.3 PROGRAM ACTIVITIES AND OUTPUTS

Summary list of Program activities and outputs

Please provide a list of Program activities and outputs for the Term of the 2014-19 FAA

1. **SKA Science Data Processor Project: The ICRAR DIA team is the main responsible for the SDP Data Layer task and is contributing to the consortium management as well as to the overall SDP architecture, the Local Monitoring and Control and the Compute tasks.**
2. **Science Survey Support Project (S3P): Innovation for Survey Science in data management, algorithms and the usage of supercomputing, cloud computing and distributed computing (citizen science).**
3. **System Support Project (S2P): Support and administration of the ICRAR@Fairway compute infrastructure.**

Progress against Program activities and outputs (in this reporting period)

Summarise the progress towards achieving each Program activity and output.

Please also discuss any encountered difficulties/failures and improvements put or to be put in place.

1. **SKA Science Data Processor Project:** The DIA team has delivered the various inputs for the Preliminary Design Review of the SKA SDP on time. The SDP complete documentation set consisted of more than 2000 pages and is a major milestone achieved by the consortium. The Review panel and the SKAO came up with a list of almost 700 comments and questions, which had to be addressed before the review meeting. About 50 of these were then selected to be of high relevance or controversial to be discussed during the meeting. The SDP PDR meeting then took place at the SKA headquarters in Jodrell Bank 18/19 March 2015. The SDP consortium proposed already before the PDR to work towards a delta PDR, mostly because a whole set of operational and calibration requirements as well as the details of the re-baselining were not available to be taken into account for PDR. Almost everybody in the DIA team is involved in the SDP design and architecture work and also the on-going prototyping activities. We have developed a prototype Data Flow Management System in order to derive the detailed design and requirements for that part of the SDP. The prototyping system had been used to process the CHILES data (see below) as well and that gives us confidence that it is working as anticipated and it also provides cross-utilisation of resources, expertise and experience.
2. **The Survey Science Support Project (S3P)** went through a phase of consultation with scientists all around ICRAR in order to collect requirements for concrete projects. Some of the S3P projects, like CHILES and GLEAM, were already well underway, some others are quite exciting new ones. The main S3P themes are:
   a. Methods for delivering survey support, includes pipelines and workflows
   b. Data Object Storage approaches
   c. Methods of reducing data volumes, including `smart' averaging, compression and layered approaches (e.g. JPEG postage stamps)
   d. Distributed solutions, such as cloud computing (such as the projects on POGS and Amazon)

We have dedicated 2.25 FTE to support the projects. For the CHILES project we have run the processing of the data of the first observing campaign on three different platforms including Pawsey (Magnus), the Amazon cloud and our ICRAR cluster. In order to achieve this, the existing reduction pipeline and in-particular the pipeline control code had been re-developed to allow for a flexible deployment. By doing this, the efficiency and throughput had been improved significantly.

For the GLEAM survey (on MWA), we have developed the archiving system of the final products. This system is fully compliant with the International Vertical Observatory Alliance (IVOA) standards. We have also developed a pipeline to produce short movies from the GLEAM observations.

As part of the Survey Science Report Project (SSSP) we were awarded four grants from the AstroCompute in the Cloud Grants program (see https://aws.amazon.com/blogs/aws/new-astrocompute-in-the-cloud-grants-program/ and https://www.skatelescope.org/ska-aws-astrocompute-call-for-proposals/):

1. A continuation of CHILES, "CHILES - Part II Return of the Jalapeño", ICRAR, NRAO and Pawsey.
2. A harvesting of the ATCA archive, "The Narrabri [Cloud] Mine: Accessing the ATCA Archive on Amazon", ICRAR and CSIRO
3. A continuation of POGS,"Data mining theSkyNet results on AWS", ICRAR and Johns Hopkins University.
4. An exploration for high-resolution Deep Investigation of Neutral Gas Origins ASKAP Survey (DINGO) processing, "Seeing Sharp through the Cloud, a high resolution imaging pipeline for ASKAP", ICRAR and CSIRO

Using the Magnus supercomputer and some improvement of the processing we had been able to improve the processing speed of one of the core GAMA algorithms from several months to one day.

theSkyNet project continues to grow and a number of improvements have been implemented. This also includes the support of the Android platform, the implementation of a virtual machine based compute framework to be run within BOINC, and the porting of one of the codes to use Graphic Processing Units (GPUs).

3. **The System Support Project (S2P)** is quite small, but very important for the scientists in particular at ICRAR Fairway. S2P is supporting the various servers and small clusters as well as the storage and networking installations at ICRAR Fairway. During the reporting period we have installed additional storage servers and performed various Operating Systems (OS) upgrades. We are also providing virtual machines for specific services. The biggest project was the setup and configuration of a backup system for the server user's home directories. This system is now up and running and fully operational.

F.4 PROGRAM KPIS AND MILESTONES

Summary list of interim Program KPIs and milestones

1. **Deliver active and pointed support around data management and processing for data intensive science projects carried out at ICRAR.**
2. **Deliver assigned SDP pre-construction milestones within ICRAR resources and according to the overall SKA plans.**
3. **Plan and engage with global, federal and local activities to ensure that the DIA Program stays involved in the SKA construction and operational phases.**
4. **Expand the expertise of ICRAR in the area of data intensive science by identifying and carrying out research projects in areas like advanced data management, large scale processing, scalable computing and data mining.**
5. **Maintain and expand engagement of local industry with the SKA project and data intensive science by actively promoting collaborations and opportunities.**
6. **Maintain and expand the collaborations with global companies such as Amazon, CISCO, DDN, Intel, SGI and ThoughtWorks.**

Progress against interim Program KPIs and milestones (in this reporting period)

Summarise the progress towards achieving each interim Program KPI and milestone.

Please also:

- discuss any encountered difficulties/failures and improvements put or to be put in place;
- provide details of refereed journal publications in Appendix A;
- provide details of research staff and Masters/PhD students/graduates in Appendix B; and
- provide details of external R&D grants awarded in subsection C.6.

1. **Deliver active and pointed support around data management and processing for data intensive science projects carried out at ICRAR**

   As described above the S3P project continues to deliver solutions to CHILES and GLEAM as well as GAMA.

2. **Deliver assigned SDP pre-construction milestones within ICRAR resources and according to the overall SKA plans**

   As described above, the milestones leading to the SDP PDR had been delivered and the PDR concluded. We are actively engaging with the SDP partners to improve communication and work relationships inside the consortium.

3. **Plan and engage with global, federal and local activities to ensure that the DIA Program stays involved in the SKA construction and operational phases**

   Meetings with SKA Office and CSIRO to plan the future outline of SKA regional activities in Australia

4. **Expand the expertise of ICRAR in the area of data intensive science by identifying and carrying out research projects in areas like advanced data management, large scale processing, scalable computing and data mining**

   Meetings with NRAO, CSIRO and AWS as well as a number of industry partners

5. **Maintain and expand engagement of local industry with the SKA project and data intensive science by actively promoting collaborations and opportunities**

   We keep collaborating with Systemic as well as the Perth based people from ThoughtWorks and AWS and have just started a new collaboration with ThinkBottomUp a small company in Perth providing database solutions and software consulting to the mining sector. We have also held an industry update meeting to keep our partners informed about the progress of the SKA. In addition we had a meeting with people from Woodside to explore possible future projects.

6. **Maintain and expand the collaborations with global companies such as Amazon, CISCO, DDN, Intel, SGI and ThoughtWorks**

   We had a meeting with AWS in Seattle to talk about global activities and got an excellent overview of current and future plans for AWS services. Another meeting with DDN to discuss a new collaborative project around one of their software products to be used as a testbed for the SDP data flow management. We also had a meeting with Intel to receive updates of their technology roadmaps for the next few years.

   We have performed a 'Hackathon' on a cluster of Ethernet Drives from HGST (a Western Digital Company). This storage technology is very promising in terms of power consumption and scalability. We have produced a report together with HGST.

Detailed reason for variance if any

ICRAR's DIA Program is a global leader in the SKA SDP Data layer design task and efforts are focussed in that area. Excellent progress has been made towards achieving the KPIs and greater efforts to develop collaborations are in progress. It may be noted that Programmatic KPIs are monitored internally by ICRAR Executive Director and reported to ICRAR Board.

F.5 PROGRAM OUTCOMES FOR WA

Summary list of Program outcomes for WA

Please provide a list of the Program outcomes for WA for the Term of the 2014-19 FAA.

1. Significant and accountable contributions to the SDP PDR and engagement with local and Australian based industries to promote SKA opportunities.
2. The maintenance of the availability of ICRAR's server and storage infrastructure for all ICRAR users as well as planning of required updates, upgrades and replacements.
3. Active engagement and support for national and international survey science projects.

Progress against outcomes for WA (in this reporting period)

Summarise the progress towards achieving outcomes for WA.

Please also discuss any encountered difficulties/failures and improvements put or to be put in place.

1. Significant and accountable contributions made to the SDP preliminary and critical design review document sets as well as to the management of the SDP consortium. Costed, high quality design and architecture of the SDP Data Layer. Active engagement maintained with local and Australian based industries to promote SKA opportunities and enable successful and competitive bids
2. Effective maintenance of the availability of ICRAR's server and storage infrastructure for all ICRAR users as well as planning of required updates, upgrades and replacements. This is essential to enable ICRAR to function well and contribute to the successful SKA preconstruction and Science Program activities.
3. Active engagement and support for survey science projects like GLEAM and CHILES demonstrating the scientific productivity increase by applying data intensive techniques to large scale astronomy projects. Cross-fertilisation of ideas, concepts and implementations between S3P and the SDP project. Active engagement with industry, such as Amazon to work on practical solutions for globally distributed survey teams.

F.6 PROGRAM COLLABORATIONS (in this reporting period)

Summarise the Program collaborations between the Joint Venture Participants and externally with local, national and international researchers, and industry, government and other end-users.

Please also:

- discuss any encountered difficulties/failures and improvements put or to be put in place;
- detail the nature, value and any outcomes of each collaboration; and
- include details of any collaborative research undertaken by visiting researchers.

DIA collaborations with JV partners: The S3P project has several direct connections across the JV partners. DIA continues to support the MWA data flow and archive.

DIA collaborations with local partners: As mentioned above the active involvement of people from Systemic continued during the reporting period, with Eric Bastholm to work on the SysML model for the Data Life-Cycle component of the SDP. This model is part of the SDP PDR delivery. With ThinkBottomUp we signed a Letter of Intent and had a technical meeting and are starting to exchange technical documents. The plan is to work towards a Statement of Work and work on a small project using their product.

DIA collaborations with global partners With NRAO we have agreed to work on an integration of our JPEG2000 technologies into the new Common Astronomy Software Applications *(*CASA) viewer. We have also agreed to work together on technical guidelines for users as well as actual projects using the AWS for radio astronomy. One such project is now covered with an AWS AstroCompute grant (see above). In addition we have also agreed to expand our collaboration in the usage of NGAS at NRAO.

We keep our involvement in the International Virtual Observatory Alliance (IVOA) up and do also support the local organisation of the IVOA interoperability meeting 1-3 Nov, 2015 in Sydney and we are part of the technical working group discussing the next All Sky Virtual Observatory (ASVO) projects.

Dongwei Fan from NAOC visited us for two months to work on two projects, one to improve our implementation of a JPEG2000 client and server for radio astronomy data cubes and another one to get our data management system, NGAS, up and running on the China-VO cloud. The latter activity had been undertaken to improve the visibility of this system in China, since we do see opportunities for further collaborations in this space for the future FAST telescope data flow and also in the extension of the MWA and the work towards the SKA.

F.7 PROGRAM BUDGET (for this reporting period)

F7.1 Expenditure of State Government grant

Expenditure type	Agreed expenditure ($)	Actual expenditure ($)	Variance ($)
Salaries	1,694,071	728,133	965,938
Operating	142,953	15,689	127,264
Capital	56,250	0	56,250
Travel	154,250	45,064	109,186
TOTAL	**2,047,524**	**788,886**	**1,258,638**

Expenditure details

Summarise the expenditure of the State Government grant.

Expenditure in the DIA program is mainly in the SKA SDP preconstruction effort with over 80% expenditure on salaries. FTE budgeted for industry participation have yet to be appointed and paid and this is a timing issue. The expenditure is in line with ICRAR Budget on items listed above. Variance is timing issue including late start of ICRAR II as stated below.

Variance in expenditure? Yes ☒ No ☐

Detailed reason for variance in expenditure

Variance in expenditure is due to the agreed six month late start of ICRAR II expenditure from 1 January 2015 as compared to 1 July 2014. Low rate of expenditure is a timing issue and will change in 2014/15 as payments are made to industry.

F7.2 Expenditure of UWA Joint Venture cash contribution

Expenditure type	Agreed expenditure ($)	Actual expenditure ($)	Variance ($)
Salaries	124,164	55,331	68,833
Operating	0	0	0
Capital	0	0	0
Travel	0	0	0
TOTAL	**124,164**	**55,331**	**68,833**

Expenditure details

Summarise the expenditure of the UWA Joint Venture cash contribution.

Expenditure is in line with ICRAR Budget on salary as listed above.

Variance in expenditure? Yes ☒ No ☐

Detailed reason for variance in expenditure

Variance in expenditure is due to the agreed six month late start of ICRAR II expenditure from 1 January 2015 as compared to 1 July 2014.

F7.3 Expenditure on SKA preconstruction work package

Expenditure type	Agreed expenditure ($)	Actual expenditure ($)	Variance ($)
D1 SDP preconstruction			
Salaries – UWA funded	55,331	55,331	0
Salaries – State Government grant funded	1,097,941	373,993	723,948
Travel – State Government grant funded	71,250	33,725	37,525
Operating – State Government grant funded	41,175	13,696	27,479
TOTAL	**1,265,697**	**476,745**	**788,952**

Expenditure details

Summarise the expenditure of the State Government grant and the UWA Joint Venture cash contribution.

Please see Section F5.7.1.

Variance in expenditure? Yes ☒ No ☐

Detailed reason for variance in expenditure

Variance in expenditure is due to the agreed six month late start of ICRAR II expenditure from 1 January 2015 as compared to 1 July 2014. Low rate of expenditure of State funds on salaries is a timing issue and will change in 2014/15 as appointments of the 2 industry FTE budgeted in the SDP Budget are yet to be made.

SECTION G: OUTREACH, EDUCATION & COMMUNICATIONS PROGRESS

G.1 SHORT DESCRIPTION

Please provide a short summary (suitable for public release).

Each year our researchers and our postgraduate students, supported by a small team of professional science communicators, give back to the community through a plethora of OEC programs throughout the State and beyond.

Whether it's the person on the street, the teacher in the classroom or the student about to head off to university, our public lectures, community observing events, school programs and extensive online presence help us to reach people, wherever they are and however they prefer to engage.

Between July 1 2014 and June 30, 2015, ICRAR has delivered programs, activities and events that have engaged more than 2,700 students, 75 teachers and more than 7,000 members of the public.

Key highlights for this year have been a significant presence in National Science Week, delivering the international SKA Engineering conference in Fremantle, a successful work record attempt for the 'world's biggest science lesson', another successful Perth Astrofest, the creation and delivery of a live planetarium based show and a free public lecture in collaboration with the European Space Agency shortly after they landed a probe on a comet.

In our first five years, more than 85,000 people have interacted with our outreach programs, with hundreds of thousands more connecting with us through our growing online presence. Our media releases, and a commitment to communicating only the best research stories that capture the imagination of our audiences, has generated thousands of articles and a potential global readership in the millions.

ICRAR has achieved this level of outreach success because of the passion, creativity and level of excitement our researchers and science communicators bring to their work, and through the collaborative relationships we've been able to establish with like-minded organisations and individuals working in this important domain.

G.2 OBJECTIVES

Summary list of objectives

1. **Maintain a high level of visibility and activity in WA.**
2. **Continue to design and deliver a suite of programs that inspire interest and participation in science, astronomy, engineering, high performance computing (HPC) and the SKA.**
3. **Promote ICRAR research to mainstream media through stories that excite, inspire and fire the imagination.**
4. **Support ICRAR researchers in their work, particularly when it comes to activities that have the potential to promote ICRAR, Curtin University and UWA to external audiences.**
5. **Grow ICRAR's international profile through key conferences, sponsorship opportunities, collaborations with other institutes and ICRAR's online presence.**
6. **Play a leading role in international astronomy outreach by supporting the IAU and SKA Headquarter (HQ) programs and initiatives.**
7. **Grow ICRAR's distributed computing citizen science project theSkyNet, by increasing the number of active members; processing more data for more institutions around the world; and developing and implementing an educational component for high schools.**

8. **Grow and develop ICRAR's online presence around the ICRAR website, theSkyNet project, social media platforms such as Twitter, and multimedia sharing platforms such as Vimeo.**
9. **Design and produce communications materials that promote ICRAR and ICRAR research.**
10. **Collaborate with other groups to design and deliver astronomy themed educational resources that align with the new Australian Curriculum.**

Progress against objectives (in this reporting period)

Summarise the progress towards achieving each objective.

Please also discuss any encountered difficulties/failures and improvements put or to be put in place.

1. Maintain a high level of visibility and activity in WA.

During this reporting period, ICRAR has delivered programs, activities and events that have engaged more than 2,700 students, 75 teachers and 7,000 members of the public.

This has included several major events such as the delivery of live planetarium shows at SciTech, Astrofest in Perth and Mt Magnet educational programs in the far north Kimberley, the Mid-West and Albany, and a free public lecture in collaboration with the European Space Agency.

Our media releases and news articles have generated significant interest from WA based print, radio, online and TV media.

Collaborating with others is important when it comes to maintaining a high level of visibility and activity. Our WA based collaborators in the Outreach and Education space include:

- SciTech
- Aspire
- UWA's School of Indigenous Studies.
- SPICE
- The CSIRO
- The Astronomy WA Collective
- Gingin Observatory
- Perth Observatory
- The Gravity Discovery Centre
- The Science Teachers Association of WA
- The Astronomical Group of WA
- The Astronomical Society of WA
- iVEC

2. Continue to design and deliver a suite of programs that inspire interest and participation in science, astronomy, engineering, HPC and the SKA.

Each year, we deliver a whole range of programs that engage the community, school students, teachers and online audiences. In everything we do, we strive to maintain an extremely high level of quality and take the road less travelled through a creative and innovative approach. Some of our more innovative and impactful offerings include:

- **Astrofest**

  Coordinated by ICRAR and supported by a host of other organisations and groups, Astrofest takes place at Curtin Stadium and Edinburgh Oval. Each year more than 3,000 people of all ages attend to enjoy, learn and experience the largest event of its kind in

the country. Astrofest is a free event featuring an astrophotography exhibition, inflatable planetariums, science shows, public talks, static displays, night sky tours and a host of telescopes. Based on this successful model, regional Astrofest events have sprung up outside of metropolitan Perth, with annual and biennial events now established and supported to some degree by ICRAR in Carnarvon, Mt Magnet and the Murchison settlement.

- **theSkyNet**

  TheSkyNet is a distributed computing citizen science initiative raising the public profile of science and radio astronomy while simultaneously creating a research grade data processing resource for scientists. At any given time, day or night, almost 6,500 computers around the world are now contributing to theSkyNet. This adds up to a distributed network capable of performing more than one million processing tasks per day, placing theSkyNet on par with a supercomputer with between 40 and 60 TFlops of compute power.

- **Online telescopes**

  The SPICE-Physics-ICRAR Remote Internet Telescope (SPIRIT) initiative comprises of a pair of research grade optical telescopes being used by high school and university students to conduct surveys and take precise measurements of galaxies, star clusters, near-Earth asteroids and other objects.

- **AstroPhotoArt**

  This program targets underprivileged students in low socio-economic schools and regions. Students are taught the basics of photography and astronomy before using digital SLR cameras and purpose built tracking mounts to image objects such as stars, nebulas, the Milky Way and nearby galaxies.

- **Guerrilla Astronomy**

  Guerrilla Astronomy is about setting up telescopes in unusual places and inviting unsuspecting passers-by to observe the night sky. These events are not advertised and no attempt is made to gather an audience. Instead telescopes are taken to where people already are; the side of a bike path, a shopping centre or an outdoor event.

- **Astrophotography exhibitions**

  WA has a wealth of talent when it comes to astrophotography and each year we draw this out and put it on show by holding a competition. The best work is then turned into an exhibition for display at events like Astrofest and at schools and museums during important periods such as National Science Week.

3. Promote ICRAR research to mainstream media through stories that excite, inspire and fire the imagination.

Since July 1, 2014 we have had 23 news articles posted on the ICRAR website and distributed 7 research related media releases.

Our media releases and the videos we have created to support them have generated more than 600,000 individuals views of the videos online, almost 900 articles in print, online and television and a potential audience in the hundreds of millions.

4. Support ICRAR researchers in their work, particularly when it comes to activities that have the potential to promote ICRAR, Curtin University and UWA to external audiences.

The OEC team support ICRAR researchers in several ways. Firstly, we provide opportunities for our researchers and students to participate in outreach and education programs for schools.

Recently we have initiated a series of annual workshops that help researchers professionally develop when it comes to interacting with the media, presenting to audiences and engaging through social media.

At conferences (local and international) we support logistical preparations and delivery and where it's important to do so, attend as an exhibitor to promote awareness of ICRAR and the work of our researchers. In August ICRAR exhibited at the 2014 Asia Pacific Regional IAU meeting, and in October we helped deliver and had a presence at, the SKA Engineering conference held in Fremantle.

Our researchers and students are busy people, who still want to do their bit for engaging schools, students and the community. However, liaising and making the necessary arrangements is time consuming. The OEC alleviates this burden and ensures that the time of researchers is efficiently and optimally spent.

As a research organisation supported by Australian taxpayers, an important part of what we do is communicating the work our researchers do back to the local, national and international community via the media. Our media releases and the videos we have created to support them have generated more than 600,000 individuals views of the videos online, almost 900 articles in print, online and television and a potential audience in the hundreds of millions.

5. Grow ICRAR's international profile through key conferences, sponsorship opportunities, collaborations with other institutes and ICRAR's online presence.

In August ICRAR sponsored and exhibited at the 2014 Asia Pacific Regional IAU meeting, and in October we sponsored, helped deliver and had a presence at, the SKA Engineering conference held in Fremantle.

Growing our online presence is a key objective for ICRAR. To this end we are creating more videos and animations than ever before to help drive our online presence and sharing what we create via social media platforms. In this reporting period these videos have generated more than 600,000 individual views.

Also, we have recently engaged an external company to completely rebuild the ICRAR website which will include a range of new features that will make ICRAR's online presence shine.

6. Play a leading role in international astronomy outreach by supporting IAU and SKA HQ programs and initiatives.

2015 is the International Year of Light (IYL) and is being supported by the IAU. ICRAR has contributed by raising the profile of the year by incorporating IYL themes into the promotion and delivery of our activities and events this year.

ICRAR is also participating in the IAU's Name an 'Exo World' initiative and ensures that resources being made available by the IAU find their way into WA schools to support science education in the classroom.

OEC Manager, Pete Wheeler, is a member of the SKA Communications and Outreach network, chaired by SKAO in Manchester, and regularly meets with other members via video con to assist with planning and delivery of activities. In this reporting period the most significant activity centre around 'rebaselining' and the development of a media strategy to ensure that as Phase 1 of the SKA was reduced in scope, this did not lead to negative media and instability for the project which would have put it at risk.

7. Grow ICRAR's distributed computing citizen science project theSkyNet, by increasing the number of active members; processing more data for more institutions around the world; and developing and implementing an educational component for high schools.

TheSkyNet now has more than 6,500 members active at any one time, up from 4,600 twelve months ago. In addition, we have almost 130,000 members signed up to theSkyNet's projects (up from 30,000 twelve months ago), 32,000 of which have earned credit for processing astronomy data for us.

Currently theSkyNet's 'SourceFinder' project is being rebuilt ready to tackle an enormous cube of simulated ASKAP data and the processing of observations made for the CHILES survey.

TheSkyNet's future is dependent on funding beyond January 2016 to retain the project's

programmer. If successful in this regard the project will continue to grow and eventually come to include an education component that will help high school students learn programming and use these skills to create algorithms to process large data sets as part of an online competition for WA schools.

8. Grow and develop ICRAR's online presence around the ICRAR website, theSkyNet project, social media platforms such as Twitter, and multimedia sharing platforms such as Vimeo.

We have recently engaged an external company to completely rebuild the ICRAR website, incorporating new features and giving our online presence a much-needed update. This new website will launch by the end of 2015.

In addition, ICRAR's social media audience continues to grow on both Facebook and Twitter, in part due to a strong partnership with the international SKA social media channels. Our digital communications are also expanding, with a new educational video series 'Science Snippets' just beginning, and many of our press releases in the past year accompanied by animations to support and fuel distribution and uptake.

9. Design and produce communications materials that promote ICRAR and ICRAR research.

During this period we have produced a number of materials to help communicate to, and engage with our audiences. These include:

- A DIA brochure to assist in engaging and developing new strategic partnerships in this space.
- The 2013-2014 Year Book - a biennial publication providing a comprehensive overview of the organisation, our researchers and our research.
- Several SKA Factsheets for school and public audiences. The Department of Industry is now relying on ICRAR to produce these materials for distribution throughout the country.
- SKA Posters for schools.
- Planispheres to help people find the constellations in the night sky.
    - Novel items such as an ICRAR boomerang which we have used as a VIP gift for international visitors, and also to attract media attention for some recent experiments done on board a Zero G flight. Channel 10 ran a news piece on this, primarily because of the boomerang.

10. Collaborate with other groups to design and deliver astronomy themed educational resources that align with the new Australian Curriculum.

We have collaborated with SPICE on the delivery of educator workshops, the SPIRIT initiative, which puts Internet based, research grade telescopes in the hands of school students, and on various programs for schools located in regional areas.

We collaborated with Astronomy Education Services, Aspire and UWA's School of Indigenous in the design and delivery of the 'AstroPhotoArt' program for high school students in metropolitan and regional areas.

Detailed reason for variance if any

Kalamunda World's Largest Astronomy Lesson Guinness World Record.

Derby SHS students with their stunning astrophotos after participating in a week-long ICRAR program 'Astro Photo Art'.

A special presentation at the Scitech Planetarium with custom animations made by ICRAR's simulations team.

A packed out audience ready for the opening of Astrofest 2015.

Enthusiastic volunteers help build a display MWA tile at Mount Magnet Astrofest in May 2015.

ICRAR PhD student Tom Russell leads visiting high school students as well as ICRAR's summer scholars in measuring the temperature of the Sun using a radio telescope.

G.3 ACTIVITIES AND OUTPUTS

Summary list of activities and outputs

Please provide a list of Program activities and outputs for the Term of the 2014-19 FAA.

(Please enlarge box as required.)

1. Deliver education and outreach programs, activities and events.
2. Write and distribute news articles, website articles and media releases.
3. Create an online presence for ICRAR.

Progress against activities and outputs (in this reporting period)

Summarise the progress towards achieving each Program activity and output.

Please also discuss any encountered difficulties/failures and improvements put or to be put in place.

1. **During this reporting period, ICRAR has delivered programs, activities and events that have engaged more than 2,700 students, 75 teachers and 7,000 members of the public.**
2. **We have written 23 news articles the ICRAR website and distributed 7 research related media releases.**
3. **Our media releases and the videos we have created to support them have generated more than 600,000 individuals views of the videos online, almost 900 articles in print, online and television and a potential audience in the hundreds of millions.**

G.4 PROGRAM KPIS AND MILESTONES

Summary list of interim KPIs and milestones

1. **At least seven community events delivered by ICRAR each year in WA with outcomes aligned to the Program objectives.**
2. **At least 2,000 WA metropolitan and regionally based school students engaged in ICRAR OEC programs each year.**

Progress against interim KPIs and milestones (in this reporting period)

Summarise the progress towards achieving each interim Program KPI and milestone.

Please also discuss any encountered difficulties/failures and improvements put or to be put in place.

1. **At least seven community events delivered by ICRAR each year in WA with outcomes aligned to the objectives**

   Since July 1 2014 we have delivered or been involved in 11 community events:

   - Profs & Pints (Jul)
   - National Science Week launch (Aug)
   - Geraldton's 'Goodness Festival' (Aug)
   - 'Spinning the Cosmic Web' planetarium show (Oct & Feb)
   - Professor Peter Quinn at SciTech's Planetarium (Oct)
   - Rosetta Mission Public Lecture at UWA (Feb)
   - World's Biggest Science Lesson (Feb)

- Perth Astrofest (Mar)
- Big Data Week presentation at SciTech's Planetarium (Apr)
- Albany Science Awareness festival coordinated by SciTech (May)
- Mt Magnet 'Astro-Rocks Fest' (May)

2. **At least 2,000 WA metropolitan and regionally based school students engaged in ICRAR OEC each year**

   Since July 1 2014 we have delivered programs for more than 2,700 school students, including programs for students in regional areas throughout WA.

Detailed reason for variance if any

G.5 OUTCOMES FOR WA

Summary list of outcomes for WA

Please provide a list of outcomes for WA for the Term of the 2014-19 FAA.

1. Increased participation in science themed opportunities for school students.
2. Greater awareness of the big science projects happening in WA by teachers.
3. Increased public understanding and awareness of the SKA and radio astronomy, and the important support of this from the WA State Government.

Progress against outcomes for WA (in this reporting period)

Summarise the progress towards achieving outcomes for WA.

Please also discuss any encountered difficulties/failures and improvements put or to be put in place.

1. Thanks to ICRAR's outreach and education programs several thousand WA school students have been engaged in a range of innovative and impactful STEM themed programs in this reporting period alone. These programs are designed to generate interest in science and increase students' aptitude and desire to study STEM related subjects at a tertiary level. Our programs also create awareness of SKA and other big science that are extremely relevant to WA's school students and highlight the WA State Government's role in investing and supporting such projects.
2. Increased awareness of the SKA and WA's involvement among WA teachers, educators, and access to resources and opportunities that help them to better understand the big science projects that are happening in WA and bring this into the classroom as a motivator and context for learning for their students. Increased collaboration amongst science outreach and education providers. ICRAR is a key collaborator in WA, creating and driving innovative events and activities that others are keen to be involved in and which generate significant outcomes for the providers and the WA community.
3. ICRAR outreach and communications is increasing public understanding and awareness of the SKA and radio astronomy and helping WA to be visible on the world stage as the new global hub for radio astronomy research. We contribute to this ambitious objective through our media releases, our online presence, the conferences we attend and support, and the projects we undertake with our counterparts around the world. Several spin-off regional Astrofests now exist due to the success of the Perth Astrofest and ongoing support from ICRAR. Also, Astrofests are planned for Sydney and Melbourne based on the WA model.

G.6 KEY PERSONNEL

(Please add rows as required.)

Title	Name	Position	Level	% FTE	ICRAR location	Existing/New
Mr	Pete Wheeler	OEC Manager	9.1	100	UWA	Existing
Ms	Kirsten Gottschalk	Online and Outreach Coordinator	7.2	100	UWA	Existing

G.7 COLLABORATIONS (in this reporting period)

Summarise the collaborations between the Joint Venture Participants and externally with local, national and international researchers, and industry, government and other end-users

Please also:

- discuss any encountered difficulties/failures and improvements put or to be put in place; and
- detail the nature, value and any outcomes of each collaboration.

The following is a growing list of our key collaborators.

- **State**
  - UWA
  - Curtin University
  - SPICE
  - SciTech
  - The Astronomy WA Collective
  - Perth Observatory
  - The Science Teachers Association of WA
  - The OoS
  - The Astronomical Group of WA
  - iVEC
  - Aspire and UWA's School of Indigenous Studies
  - Astronomy Education Services
- **National**
  - The Department of Industry
  - CSIRO & ATNF
  - Questacon
  - RiAus
  - The Australian Science Media Centre
  - The Astronomical Society of Australia
  - Cosmos
  - Refraction Media
- **International**
  - SKA Organisation (Manchester, UK)
  - The IAU
  - Johns Hopkins University (Baltimore, US)

G.8 BUDGET (for this reporting period)

G8.1 Expenditure of State Government grant

Expenditure type	Agreed expenditure ($)	Actual expenditure ($)	Variance ($)
Salaries	230,939	124,780	106,159
Operating	93,500	55,887	37,613
Capital	10,000	0	10,000
Travel	10,000	8,129	1,871
TOTAL	**344,439**	**188,796**	**155,643**

Expenditure details

Summarise the expenditure of the State Government grant.

Budget is in line with ICRAR Plan. Operating expenses are related to the outreach activities delivered nationally, internationally and in the regional areas of the State. There has been no capital expenditure in the reporting period as funds will be expended to buy new equipment and upgrade existing outreach items.

Variance in expenditure? Yes ☒ No ☐

Detailed reason for variance in expenditure

Variance in expenditure is due to the agreed six month late start of ICRAR II expenditure from 1 January 2015 as compared to 1 July 2014.

G.9 ADDITIONAL CASH FUNDING RECEIVED (for this reporting period)

Provide details of any additional cash funding secured by the for its activities, including the source (name of funding agency & type of grant or organisation/company name), title of grant or funded activity, duration (year or years, e.g. 2015-17) and value.

Source	Grant/activity title	Period	Administering Entity	Value ($)
Lotterywest	Astrofest 2015	2015	UWA	20,000
Lotterywest	Astrofest Strategic Review	2015	UWA	10,000
Curtin University	Astrofest Strategic Review	2015	UWA	5,000
SciTech	Astrofest Strategic Review	2015	UWA	2,500
Office of Science (via SciTech)	Astrofest Strategic Review	2015	UWA	2,500
Curtin University	Astrofest 2015 Venue Hire	2015	UWA	3,900
CSIRO	Astrofest 2015 speaker travel	2015	UWA	608
			TOTAL	**44,508**

SECTION H: CENTRAL OFFICE PROGRESS

Including “Central & Governance” and “Centre & Node Management”

(but **not** including “Outreach, Education & Communications” which is to be reported on in section G).

H.1 SHORT DESCRIPTION OF CENTRAL OFFICE

Please provide a short description of the Central Office (suitable for public release).

ICRAR is a JV of Curtin and UWA and its activities are governed by three agreements, the JV agreement, the FAA and the CA Agreement. UWA is the Center Agent of ICRAR. ICRAR is governed by a WA State Government appointed Governing Board. The Board has independent members and also representative members from the JV Universities and the WA State Government. The Board meets on a quarterly basis. Functions of the Board are described in the JV agreement of ICRAR. The Governing Board appoints the CEO and also appoints ICRAR Committees. Currently ICRAR has two Committees, the Finance and Audit Committee meets on a quarterly basis and the Strategy Committee meets annually.

The Head Quarter of ICRAR and the Central Office are based at UWA and work with both the nodes of ICRAR. ICRAR is headed by the ICRAR Executive Director (ED) who is also the CEO of ICRAR. The roles and responsibilities of the CEO are defined in the ICRAR JV agreement. The ED chairs and works with two ICRAR Executive teams that collectively form the ICRAR Executive. The Science and Technology Executive consist of the three ICRAR Directors (Engineering Director, Science/Curtin Director and Science/UWA Director). The Management Executive comprises the Directors, the Chief Operating Officer (COO)/Associate Director (AD) and the Head of the DIA Program. Collectively they form ICRAR Executive Team. ICRAR holds the Management Executive Meetings (MEM) where in along with the ICRAR Executive team the pre-construction project leads and other Program and Project leads are also invited to report on their Program and Project progress.

The Central Office is responsible for administration of ICRAR activities; human resource planning, recruitment and support; financial planning, budget preparation, internal controls and financial reporting; legal and contractual responsibilities; logistics and facilities management and other functions including overall management, compliance and reporting of ICRAR activities across both nodes. Central office works closely with the CA for Head Quarter functions. The Central Office also oversees the OECs functions and any other related areas. The Central functions are managed within a Central Office under the responsibility of a COO. The Central Office along with the two node administration teams works closely with the Governing Board, ICRAR Committees, JV partners, State Government, national and international collaborators.

H.2 CENTRAL OFFICE OBJECTIVES

Summary list of Central Office objectives

1. **Manage and support a world class high performing organisation that is diverse, inclusive and equitable.**
2. **Recruit and develop highest quality staff and students.**
3. **Create an innovative and supportive culture to strengthen research and development activities of ICRAR staff, students, visitors and collaborators including industry.**
4. **Provide and maintain high quality infrastructure.**
5. **Ensure accountability, compliance and transparency in all transactions.**
6. **Support, promote and strengthen the ICRAR brand internationally as a symbol of excellence.**

Progress against Central Office objectives (in this reporting period)

Summarise the progress towards achieving each Central Office objective.

Please also discuss any encountered difficulties/failures and improvements put or to be put in place.

1. **Manage and support a world class high performing organisation that is diverse, inclusive and equitable**

   ICRAR has developed into a world class high performing organisation and this was independently assessed and reported by Deloitte Access Economics (DAE). DAE reported ICRAR to be one of the top 5 performing astronomy organisations in the world in 2014. Performance of ICRAR may also be seen in the highlights section A.1. In the reporting period ICRAR attracted over 9.0 million external grants, published 177 refereed publications and 177 national and international visitors and of these 74% were male visitors and 26% were female visitors and 58% were international visitors from 24 counties and 42% were national visitors. In the reporting period ICRAR had 92 staff members and recruited 14 staff and provided tenure to 6 staff members. Not all recruited staff have joined and new staff will join in later part of 2015. All research jobs were advertised and recruited internationally on a merit basis. ICRAR is an inclusive and diverse organisation with systems and process in place to support a world class well performing organisation. ICRAR won the ASA Pleiades Bronze medals for both the nodes for its performance as an inclusive organisation that supports diversity and equity. Diversity Equity and Inclusivity (DEI) and Development Committees have been established at both the nodes to ensure ongoing support for staff and students.

2. **Recruit and develop highest quality staff and students**

   All research jobs were advertised internationally and recruited through merit based assessment process based on written applications, interviews and where required, presentations by applicants. ICRAR received very high quality applications and though a rigorous merit based selection process has selected and offered positions to 14 staff. The offers have been made and accepted but not all have joined in the reporting period. Further details can be seen in the Programmatic sections. ICRAR through the University merit based selection process was successful in attracting 14 PhD and Master's students in the reporting period. In the period 43 students were enrolled in Masters or PhD programs through the two nodes and of these 9 completed their degree. 26% of enrolled students are women. ICRAR is a strong supporter of professional development of staff and students and staff and student support budget is built into the budgeting process to enable their professional development. Professional development of staff was also supported through the annual performance and development review process and through ongoing interactions and feedback.

3. **Create an innovative and supportive culture to strengthen research and development activities of ICRAR staff, students, visitors and collaborators including industry**

   ICRAR has a very innovative environment and the R&D culture is fostered through series of regular activities that stimulate intellectual scientific discussions and knowledge sharing. During the reporting period activities conducted to foster this environment included weekly Journal Clubs and Astro-Morning Tea, Radio Galaxy Zoo discussions, Seminars, workshops, busy weeks, colloquia, student discussions and interactions with invited visitors. ICRAR hosted 61 Seminars in the reporting period with 50 % of seminars delivered by international speakers from more than 24 organisations. ICRAR hosted 177 visitors. In addition to these, ICRAR worked with more than a dozen industries, interacted with CSIRO, MERIWA, different departments in the JV universities and developed academic collaborations as seen in sections D.6, E.6 and F.6.

4. **Provide and maintain high quality infrastructure**

   Buildings at ICRAR Fairway and at ICRAR Brodie Hall are very high quality buildings with offices, labs, teaching and seminar rooms, video con and audio facilities for international and national collaboration. Total floor space is well over 3000 sqm. ICRAR works regularly with the facilities and maintenance departments of the JV universities to ensure high quality of infrastructure.

5. **Ensure accountability, compliance and transparency in all transactions**

   ICRAR complied with the policies of the JV and as required in line with the three ICRAR agreements requirements. The Finance and Audit Committee keeps an oversight of ICRAR

and there are internal control mechanisms in place at ICRAR and also JV universities and CA to ensure compliance and transparency. It is also maintained through the MEM, Finance & Audit (F&A) and Board meetings. ICRAR accounts are audited annually by an external auditor and the current statement will be attached to the report once received from the Auditors. In the reporting period four Board meetings, four F&A meetings and two Strategy Committee meetings were held. In addition, external audit was conducted by KPMG.

6. **Support, promote and strengthen the ICRAR brand internationally as a symbol of excellence**

   ICRAR Brand is an internationally well recognised brand and this was ascertained in the DAE independent review report and also the ICRAR Visiting Committee report. . Presentations by ICRAR staff and students are done using templates specifically created with ICRAR brand and logos of the JV and State Government. Staff and students in the reporting period were supported to represent and further strengthen ICRAR brand in national and international meetings. ICRAR staff were invited and contributed to national and international committees and details can be seen in the Programmatic sections, D, E, F and also G.

Detailed reason for variance

H.3 CENTRAL OFFICE ACTIVITIES AND OUTPUTS

Summary list of Central Office activities and outputs

Please provide a list of the Central Office activities and outputs for the Term of the 2014-19 FAA.

1. ICRAR Planning
2. ICRAR HR Management:
3. ICRAR Budget Financial Management
4. ICRAR Risk and Compliance
5. IP, Legal and Contractual
6. ICRAR Reporting Requirements
7. ICRAR Management and Operations
8. ICRAR Research Management

Progress against Central Office activities and outputs (in this reporting period)

Summarise the progress towards achieving each Central Office activity and output.

Please also discuss any encountered difficulties/failures and improvements put or to be put in place.

1. **ICRAR Plan and ICRAR Budget**: ICRAR Plan V 3.0 defining ICRAR activities from 2014 to 2019 was finalised by ICRAR Executive and staff and was submitted to the OoS for signatures by the Minister for Science on 6 February 2015. The Plan has been developed in two parts. The main body of the plan along with the Executive Summary has eleven sections including Science, Engineering and the DIA Programs, Central Functions, Governance, Budget and Acronyms. The part 2 of the Plan has details of three ICRAR Programs and 13 projects, ICRAR's plans for OEC, Industry Participation Plan, Intellectual Property Management Plan and Education and Training Plan. The ICRAR Plan and ICRAR Budget for 2014 to 2019 approved by the Hon Premier and Minister for Science on 26 March 2015.

2. **ICRAR Human Resource (HR) Management:** ICRAR attracted some of the highest calibre candidates through ICRAR II recruitment drive**.** ICRAR UWA advertised internationally three external positions namely the Jim Buckee Fellow and 2 positions at Senior Research Fellow to Senior Principal Research Fellow and for these a total of 18 and 56 applications were received respectively. Through merit based selection process candidates were selected. ICRAR UWA also advertised three positions internally to fill the three ongoing positions that were part of UWA's commitment to ICRAR. A total of 13 applications received and three have been appointed. Two positions were head hunted for the Science and DIA program from Europe. ICRAR/Curtin advertised five postdoctoral positions in October 2014 and a strong pool of applicants was received and a short-list of 16 candidates was drawn up and selection process finalised. Offers were made and positions are likely to be occupied fully by September 2015. There were additional research funded positions recruited to ICRAR.

3. ICRAR student strength in this reporting period is 43 and since 1 July 2014 nine students have completed. 26% of currently enrolled ICRAR students are women.

4. **ICRAR Financial Management and External Audit**: Detailed ICRAR Budget developed and approved by ICRAR Board and the Hon Minister for Science on 26 March 2015. The budget included ICRAR's Science, DIA and Engineering Programs and for ICRAR's Central Functions and Governance. Expenditure against the budget was incurred against the budget with internal controls in place and in line with the financial policies and procedures of the JV Universities. KPMG were appointed to audit ICRAR accounts. Special purpose report with auditors report attached to this report.

5. **ICRAR Risk and Compliance**: ICRAR Risk Register is a living document that was regularly updated and reported to the F&A Committee and to the Board and is attached at Appendix C of this report. Compliance with ICRAR agreement clauses was monitored through the F&A Committee. ICRAR complies with the required University policies, procedures and code of conduct and ethics.

6. **Legal, Contractual and IP Management:** ICRAR JV, CA agreements were signed by the JV parties on 9 September 2014. The WA State Government FAA was finalised in consultation with the JV and also the OoS and signed by the CA and the Hon Premier and Science Minister. In the reporting period ICRAR progressed discussions with CSIRO for joint appointment agreements, with LSST Corporation on future joining possibility. Advice on all IP matters related to MoU's with the SKAO and Consortia was provided regularly through the Central Office in coordination with the Legal and ORD offices at the JV universities.

7. **ICRAR Reporting Requirements**: The final Annual Report for ICRAR 2013/14 was submitted to the OoS in September 2014. Included in the report was the audited special purpose financial report and the audit report from KPMG. The ICRAR Annual Report 2013/14 **was** received and approved by the OoS. ICRAR finances reported on a quarterly basis to the Finance and Audit Committee and then to the Board on a quarterly basis. ICRAR Project level budget managed and monitored through bi-monthly management meetings. ICRAR II Annual Report for 2014/15 will be submitted by 30 August 2015. In addition to these ICRAR also complies with the University specific reporting requirements.

8. **ICRAR Management and Operations**: Day to day management and operational activities to support more than 100 staff and students and over 175 visitors were successfully managed by the Central office and through the nodes.

9. **ICRAR Research Management**: Leveraging ICRAR Grant from the State Government is an important activity for ICRAR. To achieve this ICRAR research staff at both nodes apply for nationally and internationally competitive grants. These grants were managed through the Central office and node offices for contractual, financial, HR, compliance and reporting purposes. The list of external grants can be seen in section C.6 and C.7.

10. Special Requirements delivered successfully: Independent ICRAR Review by DAE and review by Visiting Committee.

H.4 CENTRAL OFFICE KPIS AND MILESTONES

Summary list of Central Office KPIs and milestones

1. **On time delivery of State reporting requirements.**
2. **On time delivery of Board reporting requirements.**
3. **On time delivery of Finance and Audit Committee reporting requirements.**
4. **Full compliance with Occupational Health and Safety (OH&S) and equity and diversity requirements.**
5. **Host seven community events to raise awareness of astronomy, engineering, data science and SKA.**
6. **Interact at least with 2,000 school students including in regional areas.**
7. **Host two industry events to update industry on opportunities and requirements for involvement in SKA.**
8. **Establishes collaborative relationships with at least three WA based businesses.**

Progress against Central Office KPIs and milestones (in this reporting period)

Summarise the progress towards achieving each Central Office KPI and milestone.

Please also discuss any encountered difficulties/failures and improvements put or to be put in place.

1. **On time delivery of State reporting requirements:** ICRAR has complied with the milestones as listed in the FAA Schedule 2 for the ICRAR Plan, Budget and quarterly reporting requirements in time.

2. **On time delivery of Board reporting requirements**

   The Board met on a quarterly basis and in the reporting period all requirements for the Board meetings were successfully delivered.

3. **On time delivery of Finance and Audit Committee reporting requirements**

   The F&A Committee met on a quarterly basis and in the reporting period all requirements for the F&A Committee meetings were successfully delivered.

4. **Full compliance with OH&S and equity and diversity requirements**

   ICRAR complies with the JV University OH&S policies. Staff and students are inducted for safety requirements in line with the policies. A verbal report on safety was presented to the Board by the Executive Director. Safety was also monitored through the management meetings for all ICRAR Programs and projects. Both nodes of ICRAR received the Pleiades Bronze Award for commendable efforts in implementing and promoting an equitable workplace.

5. **Host seven community events to raise awareness of astronomy, engineering, data science and SKA**

   See Section G

6. **Interact at least with 2,000 school students including in regional areas**

   See Section G

7. **Host two industry events to update industry on opportunities and requirements for involvement in SKA**

   ICRAR hosted with ASKAIC an event to update industry on SKA on 10 June 2015 at UWA and more than 30 individuals from Government and from over 12 industries participated. Presentation given by Professor Peter Quinn can be seen on https://www.dropbox.com/s/v83nlraile3r0gp/ICRAR%20ASKAIC%2006%3A15.pdf?dl=0S

   In addition an event with industry was hosted by ICRAR's DIA team in March 2015 to specifically update industry on progress with SKA and any further opportunities and can be seen in the DIA Program Section F.

8. **Establishes collaborative relationships with at least three WA based businesses.**

   Central Office closely worked with the DIA team and facilitated the process of engaging with Perth based companies ThinkBottomUp, and also globally operating companies having a presence in WA or Australia. This includes ThoughtWorks, DDN, SGI, Intel, Umwelt and Ajilon/Anditi. Two LoIs were signed in the reporting period. Efforts in progress to develop collaborative relationships with other companies.

Detailed reason for variance if any

Excellent progress has been made towards all KPIs and further efforts will be continued in future years.

H.5 CENTRAL OFFICE OUTCOMES FOR WA

Summary list of Central Office outcomes for WA

Please provide a list of outcomes for WA for the Term of the 2014-19 FAA.

1. **Well managed, internationally recognised world class high performing astronomy organisation based in WA.**
2. **Development of intellectual capital in WA by recruiting highest quality staff and students and national and international visitors.**
3. **Contribution to the research and development activities and collaborations in WA including industry.**
4. **Contribute to supporting knowledge based economy in WA.**

Progress against Central Office outcomes for WA (in this reporting period)

Summarise the progress towards achieving outcomes for WA.

Please also discuss any encountered difficulties/failures and improvements put or to be put in place.

1. Progress against these is highlighted in the sections H2, H3 and H4 above and also in the Programmatic sections

   In addition to the information provided in sections above please refer to the attached DAE report on independent review of ICRAR submitted in August 2015.

H.6 KEY PERSONNEL

Title	Name	Position	Level	% FTE on Program	ICRAR location	Existing/New
1	Dunlevy Angela	Administration Coordinator	6	100%	Curtin	Existing
2	Kok Kathy	Finance Manager	7	100%	UWA	Existing
3	Laird Laura	Administration Assistant	4	100%	Curtin	Existing
4	McDade Yolandie	Executive Assistant	6	80%	UWA	Existing
5	O'Keefe Tracey	Administration Officer	6	100%	UWA	Existing
6	Randell Lisa	Administration Assistance	4	100%	UWA	Existing
7	Sallis Tina	Finance Manager	7	100%	Curtin	Existing
8	Sharma Renu	AD and COO	10	100%	UWA	Existing

H.7 CENTRAL OFFICE COLLABORATIONS (in this reporting period)

Summarise the Central Office collaborations between the Joint Venture Participants and externally with local, national and international researchers, and industry, government and other end-users

Please also discuss any encountered difficulties/failures and improvements put or to be put in place.

The Central Office, through the offices of Executive Director and COO, works collaboratively with the State Government and the JV universities on current research and management activities, reporting requirements and planning for the future long term sustainability of ICRAR. The Central Office, through the office of ED, works with the Federal and State Governments through the ANZSCC, AAL, ASKAIC, the Department of Industry and Science, the Department of Premier and Cabinet and the WA OoS. Collaborations on long-term future roles in the SKA have been progressed with CSIRO. Collaborations on the use of ICRAR's "Big Data" expertise are being progressed with CSIRO, MRIWA, and the industries mentioned in section F and H4.8.

The Central Office pursues ICRAR international collaborations with SKAO, LSST, NARIT, NRAO, CAS, and many other organisations. An active and direct collaborative engagement between ICRAR and the SKAO is essential to ensure ICRAR has the opportunity to influence decision making that will impact on our sustainable future. Collaborations with other major international multiwavelength programs/projects like LSST ensure ICRAR's role as a leader in survey science is maintained. Direct collaborative engagement with other major radio astronomy organisations outside of the SKA project (e.g. NRAO) cement ICRAR's leadership in new technological developments like cloud-based data management and analysis. Finally, evolving and new ICRAR relationships with regional (Asia Pacific) organizations (CAS, NARIT, KASI) help lay the basis for ICRAR as a regional centre for the SKA. Central Office plays a key role in facilitating and implementing collaborative arrangements in R&D. See section D.6, E.6 and F.6

H.8 RISK MANAGEMENT (in this reporting period)

Summarise progress against the Risk Management Plan stated in the ICRAR II Plan.

Please also:

- provide an updated ICRAR II High Level Risk Register as Appendix C; and
- summarise below any changes from the register provided in the ICRAR II Plan (i.e. risk deletion or addition or modification).

Changes have been made to the Risks listed in the ICRAR II Plan Risk Register. ICRAR II Risk Register was updated in May 2015 to include the following changes to the Risk Register as a result of the SKA rebaselining process outcomes.

Existing Risk ID R2 retired after rebaselining outcome. Two new Risks R3 and R5 were added. Existing ID R3 labelled as R4. Existing R4 labelled as R6. Existing R5 labelled as R7. Existing R6 labelled as R8. Exiting R7 labelled as R9. Exiting R8 labelled as R10 and the same trend continues till exiting R19 labelled as R21.

New Risks added and also mitigation strategies added to Risk Register (for details see attached Risk Register. Highlight of changes given below):

New Risk ID R2 added to highlight delays in ASKAP completion /or ASKAP capabilities are reduced and possible impact on ICRAR's Science returns. ASKAP is not completed on a timescale, nor with the capabilities, to allow ICRAR's survey science return before 2019.

New Risk ID R3 added to highlight the risk that SKA delays may result in ICRAR running out of funds to support pre-construction teams. Due to SKA Phase 1 rebaselining, the establishment of procurement policies and the creation of an intergovernmental organization, result in delays to Phase 1 construction start and Phase 2 pre-construction opportunities. The ICRAR II budget foresees funding for pre-construction commitments until mid-2017. There is a potential short fall in staff funding to bridge staff from the pre-construction to construction phase.

New Risk ID R5 added: SKAO procurement policies and resulting national priorities do not allow WA and ICRAR engagement in SKA construction phase opportunities. The definition of the SKAO procurement policies and the resulting national priorities, funding shares and returns may see technology oriented contracts and opportunities, and WA returns in general, be allocated to parties outside of WA.

The Risk Register is a living document and is updated regularly based on any new developments that have a potential or perceived impact on ICRAR.

The Risk Register is attached as Appendix C.

H.9 INTELLECTUAL PROPERTY (in this reporting period)

Summarise progress in intellectual property management and use/licensing/commercialisation, including progress against the Intellectual Property Plan in the ICRAR II Plan.

Please include details of:

(i) all intellectual property (IP) created under ICRAR II;

(ii) all patents (including provisional patents) in Australia and in overseas countries, including new patents filed, pending patents and issued patents; and

(iii) any commercialisation opportunities that have arisen in relation to the ICRAR II and how these opportunities are being pursued.

ICRAR proactively pursued intellectual property (IP) management during this reporting period. This was most evident in the conclusion of the governing agreements after extensive review and consultation, the considered approach to the Intellectual Property Plan for ICRAR II, continued collaborator engagement and a commitment to IP education at ICRAR. Updates on IP management were provided to the ICRAR Finance and Audit Committee during its regular quarterly meetings. Some of the key IP management and related activities that were undertaken in

the reporting period are given below.

- **ICRAR Governing Agreements**
  ICRAR concluded its governing agreements after extensive review and consultation. The JV Agreement and CA Agreement were executed in September 2014 and the FAA was executed in November 2014. The agreements play a key part in directing and instructing IP management matters for ICRAR.

- **ICRAR Collaborations**
  ICRAR continues to actively pursue collaborations with industry and other research organisations. Of particular note are the following engagements pursued in the last quarter of this reporting period:

  - **Letters of Intent** with companies Ajilon and Umwelt/Anditi (including its subsidiary Anditi Pty) to explore collaborative opportunities around projects of common interest that relate to the field of data management, analysis and sharing of large, complex and heterogeneous data sets.
  - Engagement with the LSST Corporation under a **Memorandum of Agreement** (MoA) to enable participation by specified scientists in the scientific exploitation of data and data products produced by the LSST, with participating institutions contributing to the operational costs of the LSST observatory. This engagement is being pursued by UWA. Five UWA-ICRAR personnel have been identified as scientists with interest in accessing the LSST's data and data products. UWA submitted its response to the draft MoA on 30 June 2015 and it is currently being reviewed at by the LSST Corporation at committee level.
  - Pursuit of a **MoU** with the National Astronomical Research Institute of Thailand. It is the intention of the parties to strengthen their relationship in the area of astronomy research and education.

- **SKA pre-construction Activity:** ICRAR continues to participate in the SKA Project through three international consortia for the LFAA, CSP and SDP pre-construction work packages. ICRAR remains an active respondent to SKA contractual matters, particularly related to variations to the SKA MoU, which is applicable to all consortia and brings into force such policies as the SKA IP Policy.

- **SKA Construction Phase:** ICRAR played a very significant role in providing input to the SKA Project policies and legal documents for the pre-construction phase. It is expected that this degree of proactivity and engagement will to continue for the Construction phase. During the reporting period ICRAR has engaged in information sessions and contributed to important dialogue with Simon Berry (SKA Director, Policy Development) as discussions about the Construction phase begin to increase.

- **Progress Against Intellectual Property Plan**
  - *Intellectual Property Plan Development*

    The Intellectual Property Plan for ICRAR II was developed as an extension and refinement of the IP management processes recorded for ICRAR I. It has made use of the structures and processes already established under ICRAR I, but it revisited and expanded on key elements of IP management regarding types of IP, knowledge transfer opportunities and commercialisation principles in recognition of the new parameters set by the governing agreements. The Intellectual Property Plan remains a reference and guidance tool for ICRAR for its IP management matters and no changes (material or otherwise) have been made during this reporting period.

  - *Resources [2.6]*

    ICRAR continues to utilise the forms, tools, checklists, processes and templates developed for ICRAR I to assist IP management for ICRAR II. Where these resources are not wholly satisfactory, ICRAR is committed to assessing situations on a case-by-case basis and also determining where improvements can be made to the resources. ICRAR needs to complete internal requirements regarding confirmation documents from staff and students involved in various research activities to ensure contractual obligations regarding IP and similar matters can be met. ICRAR management will continue to take advice from the ICRAR Finance and Audit Committee and ICRAR Board to further improve its processes.

- *Knowledge Transfer [3.5]*

  ICRAR continues to be committed to transferring outputs to the benefit of the community through various forms of knowledge transfer. ICRAR has been active during this reporting period though Its summer school internship program; through its education and outreach activities to disseminate knowledge through community events involving ICRAR researchers; through ICRAR publications, seminars, conferences and scientific meetings

  ICRAR in the reporting period has continually worked with industry and other research organisation engagement – details in section D, E and F.

- *IP Education [3.8]*

  ICRAR has made available the services of its IP Managers at Curtin and UWA for ongoing development of ICRAR staff and students in IP management. Education on IP has been identified as an important focus for ICRAR and the first session is scheduled for later in 2015. Further opportunities for IP education have been identified through UWA's Research Development and Innovation office with its short-form IP seminars. The aim is to make the sessions accessible and informative so that IP becomes a tangible concept, and have the sessions explain the many forms IP can take (not just patents) and how such IP can be leveraged for the benefit of ICRAR and beyond.

- *Publications process [3.9]*

  The publication process established in 2012, which instructs staff to assess significant IP prior to disclosure, continues to be utilised through the ICRAR MEM meetings and induction process.

- **Reporting IP**

  There are two general categories of IP that ICRAR needs to consider – that being brought to ICRAR and that created under ICRAR. The Intellectual Property Plan provides direction regarding the actions to be taken against each type of IP, the reasons for taking such action and the systems in place to support such action. In the last quarter of this reporting period ICRAR has been particularly active in managing internal queries relating to branding and trade marks for its outreach and education (non-research) activities. However, there is no significant IP to report against its research activities. These reports are regularly sought through the MEM meeting process. These meetings are held bimonthly. Specifically, ICRAR reports the following in respect of IP created under ICRAR and commercial activities in relation to that IP.

  (a) All intellectual property (IP) created under ICRAR II

  None to report for 2014-15 reporting period

  (b) All patents (including provisional patents) in Australia and in overseas countries, including new patents filed, pending patents and issued patents

  None to report for 2014-15 reporting period

  (c) Any commercialisation opportunities that have arisen in relation to the ICRAR II and how these opportunities are being pursued
  None to report for 2014-15 reporting period

H.10 UTILISATION OF ICRAR BRAND (in this reporting period)

Summarise how the ICRAR brand has been utilised to showcase WA's radio astronomy capability locally, nationally and internationally (including publications), as per clauses 4.1(b), 12(d) and 12(e) of the 2014-19 FAA.

The ICRAR Brand was prominently used during this reporting period through various ICRAR activities held and conducted locally, nationally and internationally

ICRAR delivered programs, activities and events that have engaged more than 2,700 students, 75 teachers and 7,000 members of the public. Written 23 news articles the ICRAR website and distributed 7 research related media releases. Media releases and the videos we have created to support them have generated more than 600,000 individuals views of the videos online, almost 900 articles in print, online and television and a potential audience in the hundreds of millions.

ICRAR supported and sponsored the SKA Engineering workshop at Fremantle where over 300 people from all over the world attended.

ICRAR brand was further strengthened by 61 ICRAR Seminars and over 175 visitors being exposed to ICRAR brand. Committees.

176 ICRAR publications bearing ICRAR address.

Membership of ICRAR staff on various national and international committees as in section D, E and F.

During the reporting period ICRAR was visited by high level delegations from Europe and China.

In addition to above please see Programmatic reports, D, E and F.

H.11 ACKNOWLEDGEMENT OF STATE GOVERNMENT FUNDING (in this reporting period)

Summarise how due acknowledgement was given to the State Government's funding support for ICRAR II, as per clause 12(d)(ii) of the 2014-19 FAA.

ICRAR acknowledged the funding and support received from the State Government by including the State government logo and also through written and/or verbal acknowledgement as appropriate in its:

1. Media releases (e.g. Statement: ICRAR is a JV between Curtin University and The University of WA with support and funding from the State Government of WA)
2. ICRAR Presentation templates
3. Sponsored events
4. ICRAR Plan
5. ICRAR meetings and activities.
6. ICRAR Publications and ICRAR web
7. ICRAR Posters and Templates

H.12 CENTRAL OFFICE BUDGET (for this reporting period)

H12.1 Expenditure of State Government grant

Expenditure type	Agreed expenditure ($)	Actual expenditure ($)	Variance ($)
Central & Governance			
Salaries	108,774	105,583	3,191
Operating	287,500	157,531	129,969
Capital	0	4,841	(4,841)
Travel	152,500	80,215	72,285
Sub-total	*548,774*	*348,170*	*200,604*
Centre & Node Management			
Salaries	629,398	338,219	291,179
Operating	35,000	56,073	(21,073)
Capital	0	0	0
Travel	0	0	0
Sub-total	*664,398*	*394,292*	*270,106*
TOTAL	**1,213,172**	**742,462**	**470,710**

Expenditure details

Summarise the expenditure of the State Government grant cash contribution.

Expenditure is in line with ICRAR Plan and budget. The salary component of Central has been underfunded and will be reviewed in ICRAR budget revision process. Operating expenditure has been to support some strategic ICRAR requirements. Travel is in line with ICRAR budget for Central and Governance activities. Centre and Node Management salaries are in line with the budget. Greater operating expenditure is a timing issue and will even out over next year due to start of ICRAR II.

Variance in expenditure? Yes ☒ No ☐

Detailed reason for variance in expenditure

Variance is due to the agreed late start of ICRAR I from 1 January 2015 instead of 1 July 2014.

H12.2 Expenditure of UWA Joint Venture cash contribution

Expenditure type	Agreed expenditure ($)	Actual expenditure ($)	Variance ($)
Centre Management			
Salaries	0	0	0
Operating	12,000	40,401	(28,401)
Capital	150,500	0	150,500
Travel	10,000	2,147	7,853
TOTAL	**172,500**	**42,548**	**129,952**

Expenditure details

Summarise the expenditure of the UWA Joint Venture cash contribution.

Expenditure is in line with ICRAR Plan and budget. The operating expenditure is higher than anticipated due to start of ICRAR II activities and will be corrected in next budget. Capital and Operating budget will be reviewed again to balance the expenditure requirements.

Variance in expenditure? Yes ☒ No ☐

Detailed reason for variance in expenditure

Variance is due to the agreed late start of ICRAR I from 1 January 2015 instead of 1 July 2014. The operating expenditure is higher than anticipated due to start of ICRAR II activities and will be corrected in next budget

SECTION I: APPENDICES, ATTACHMENTS & CERTIFICATION

I.1 APPENDICES

Has "Appendix A: Publications" been completed? Yes ☒ No ☐

Has "Appendix B: Staff & Students" been completed? Yes ☒ No ☐

Has Appendix C, the updated High Level Risk Register been completed? Yes ☒ No ☐

Please submit completed appendices with Annual Report.

I.2 ATTACHMENTS

Is additional material attached? Yes ☒ No ☐
(e.g. examples of media releases/articles/interviews)

How many additional pages are attached? 140

I.3 CERTIFICATION

I certify that:

i) this is an accurate progress report for the period covered; and

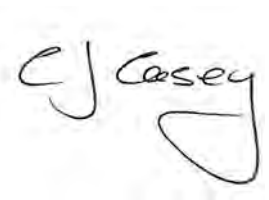
ii) all senior investigators agree that this report is an accurate representation of the progress of the ICRAR II Project within this reporting period.

Title Mrs

Name CHRISTINE CASEY

Position ASSOCIATE DIRECTOR RESEARCH GRANTS

Signature



Date 28/08/2015

APPENDIX A
PUBLICATIONS

APPENDIX A

	ICRAR Refereed Publications	Impact Factor
1	Afonso, J., Casanellas, J., Prandoni, I., Jarvis, M., Lorenzoni, S., Magliocchetti, M., **Seymour, N.**, 2015, ''Identifying the first generation of radio powerful AGN in the Universe with the SKA'', Advancing Astrophysics with the Square Kilometre Array (AASKA14), 71.	N/A
2	Allen, J. T., Croom, S. M., Konstantopoulos, I. S., Bryant, J. J., Sharp, R., Cecil, G. N., Fogarty, L. M. R., Foster, C., Green, A. W., Ho, I.-T., Owers, M. S., Schaefer, A. L., Scott, N., Bauer, A. E., Baldry, I., Barnes, L. A., Bland-Hawthorn, J., Bloom, J. V., Brough, S., Colless, M., Cortese, L., Couch, W. J., Drinkwater, M. J., **Driver, S. P.**, Goodwin, M., Gunawardhana, M. L. P., Hampton, E. J., Hopkins, A. M., Kewley, L. J., Lawrence, J. S., Leon-Saval, S. G., Liske, J., López-Sánchez, Á. R., Lorente, N. P. F., McElroy, R., Medling, A. M., Mould, J., Norberg, P., Parker, Q. A., **Power, C.**, Pracy, M. B., Richards, S. N., **Robotham, A. S. G.**, Sweet, S. M., Taylor, E. N., Thomas, A. D., Tonini, C., Walcher, C. J., 2015, ''The SAMI Galaxy Survey: Early Data Release'', Monthly Notices of the Royal Astronomical Society, 446, 1567.	5.226
3	Alves, M. I. R., Calabretta, M., Davies, R. D., Dickinson, C., **Staveley-Smith, L.**, Davis, R. J., Chen, T., Barr, A., 2015, ''The HIPASS survey of the Galactic plane in radio recombination lines'', Monthly Notices of the Royal Astronomical Society, 450, 2025.	5.226
4	Avila, S., **Murray, S. G.**, Knebe, A., **Power, C., Robotham, A. S. G.**, Garcia-Bellido, J., 2015, ''HALOGEN: a tool for fast generation of mock halo catalogues'', Monthly Notices of the Royal Astronomical Society, 450, 1856.	5.226
5	Baldry, I. K., **Alpaslan, M.**, Bauer, A. E., Bland-Hawthorn, J., Brough, S., Cluver, M. E., Croom, S. M., Davies, L. J. M., **Driver, S. P.**, Gunawardhana, M. L. P., Holwerda, B. W., Hopkins, A. M., Kelvin, L. S., Liske, J., López-Sánchez, Á. R., Loveday, J., Norberg, P., Peacock, J., **Robotham, A. S. G.**, Taylor, E. N., 2014, ''Galaxy And Mass Assembly (GAMA): AUTOZ spectral redshift measurements, confidence and errors'', Monthly Notices of the Royal Astronomical Society, 441, 2440.	5.226
6	Bally, J., Rathborne, J. M., Longmore, S. N., Jackson, J. M., Alves, J. F., Bressert, E., Contreras, Y., Foster, J. B., Garay, G., Ginsburg, A., Johnston, K. G., Kruijssen, J. M. D., Testi, L., **Walsh, A. J.**, 2014, ''Absorption Filaments toward the Massive Clump G0.253+0.016'', The Astrophysical Journal, 795, 28.	6.28
7	Bassett, R., Glazebrook, K., Fisher, D. B., Green, A. W., Wisnioski, E., **Obreschkow, D.**, Cooper, E. M., Abraham, R. G., Damjanov, I., McGregor, P. J., 2014, ''DYNAMO - II. Coupled stellar and ionized-gas kinematics in two low-redshift clumpy discs'', Monthly Notices of the Royal Astronomical Society, 442, 3206.	5.226
8	**Bekki, K.**, 2015, ''Dust-regulated galaxy formation and evolution: a new chemodynamical model with live dust particles'', Monthly Notices of the Royal Astronomical Society, 449, 1625.	5.226
9	**Bekki, K.**, 2015, ''Cosmic Evolution of Dust in Galaxies: Methods and Preliminary Results'', The Astrophysical Journal, 799, 166.	6.28
10	**Bekki, K.**, 2014, ''Formation and evolution of molecular hydrogen in disc galaxies with different masses and Hubble types'', Monthly Notices of the Royal Astronomical Society, 444, 1615.	5.226
11	**Bekki, K.**, Tsujimoto, T., 2014, ''Chemical evolution of galaxies with radiation-driven dust wind'', Monthly Notices of the Royal Astronomical Society, 444, 3879.	5.226
12	**Bhat, N. D. R., Ord, S. M., Tremblay, S. E., Tingay, S. J.**, Deshpande, A. A., van Straten, W., Oronsaye, S., Bernardi, G., Bowman, J. D., Briggs, F., Cappallo, R. J., Corey, B. E., Emrich, D., Goeke, R., Greenhill, L. J., Hazelton, B. J., Hewitt, J. N., Johnston-Hollitt, M., Kaplan, D. L., Kasper, J. C., Kratzenberg, E., Lonsdale, C. J., Lynch, M. J., McWhirter, S. R., Mitchell, D. A., Morales, M. F., Morgan, E., Oberoi, D., Prabu, T., Rogers, A. E. E., Roshi, D. A., Udaya Shankar, N., Srivani, K. S., Subrahmanyan, R., **Waterson, M., Wayth, R. B.**, Webster, R. L., Whitney, A. R., Williams, A., Williams, C. L., 2014, ''The Low-frequency Characteristics of PSR J0437-4715 Observed with the Murchison Wide-field Array'', The Astrophysical Journal, 791, L32.	6.28
13	**Bignall, H. E.**, Croft, S., Hovatta, T., Koay, J. Y., Lazio, J., **Macquart, J. P., Reynolds, C.**, 2015, ''Time domain studies of Active Galactic Nuclei with the Square Kilometre Array'', Advancing Astrophysics with the Square Kilometre Array (AASKA14), 58.	N/A

14	Blair, W. P., Chandar, R., Dopita, M. A., Ghavamian, P., Hammer, D., Kuntz, K. D., Long, K. S., **Soria, R.**, Whitmore, B. C., Winkler, P. F., 2014, ''An Expanded HST/WFC3 Survey of M83: Project Overview and Targeted Supernova Remnant Search'', The Astrophysical Journal, 788, 55.	6.28
15	Blair, W. P., Winkler, P. F., Long, K. S., Whitmore, B. C., Kim, H., **Soria, R.**, Kuntz, K. D., Plucinsky, P. P., Dopita, M. A., Stockdale, C., 2015, ''A Newly Recognized Very Young Supernova Remnant in M83'', The Astrophysical Journal, 800, 118.	6.28
16	Blyth, S., van der Hulst, T. M., Verheijen, M. A. W., Catinella, B., Fraternali, F., Haynes, M. P., Hess, K. M., Koribalski, B., **Lagos, C., Meyer, M., Obreschkow, D., Popping, A., Power, C.**, Verdes-Montenegro, L. L., Zwaan, M., 2015, ''Exploring Neutral Hydrogen and Galaxy Evolution with the SKA'', Advancing Astrophysics with the Square Kilometre Array (AASKA14), 128.	N/A
17	Braiding, C., Burton, M. G., Blackwell, R., Glück, C., Hawkes, J., Kulesa, C., Maxted, N., Rebolledo, D., Rowell, G., Stark, A., Tothill, N., Urquhart, J. S., Voisin, F., **Walsh, A. J.**, de Wilt, P., Wong, G. F., 2015, ''The Mopra Southern Galactic Plane CO Survey - Data Release 1'', Publications of the Astronomical Society of Australia, 32, e020.	2.266
18	Branchesi, M., Woan, G., Astone, P., Bartos, I., Colla, A., Covino, S., Drago, M., Fan, X., Frasca, S., Hanna, C., Haskell, B., Hazboun, J. S., Heng, I. S., Holz, D. E., Johnson-McDaniel, N. K., Jones, I. D., Keer, L., Klimenko, S., Kostas, G., Larson, S. L., Mandel, I., Mapelli, M., Messenger, C., Mazzolo, G., Melatos, A., Mohanty, S., Necula, V., Normandin, M., Obara, L., Opiela, R., Owen, B., Palomba, C., Prodi, G. A., Re, V., Salemi, F., Sidery, T. L., **Sokolowski, M.**, Schwenzer, K., Tiwari, V., Tringali, M. C., Vedovato, G., Vousden, W., Yakushin, I., Zadrożny, A., Ziosi, B. M., 2014, ''C7 multi-messenger astronomy of GW sources'', General Relativity and Gravitation, 46, 1771.	1.77
19	**Bruzzese, S. M., Meurer, G. R., Lagos, C. D. P.,** Elson, E. C., Werk, J. K., Blakeslee, J. P., Ford, H., 2015, ''The initial mass function and star formation law in the outer disc of NGC 2915'', Monthly Notices of the Royal Astronomical Society, 447, 618.	5.226
20	Bryant, J. J., Owers, M. S., **Robotham, A. S. G.,** Croom, S. M., **Driver, S. P.**, Drinkwater, M. J., Lorente, N. P. F., Cortese, L., Scott, N., Colless, M., Schaefer, A., Taylor, E. N., Konstantopoulos, I. S., Allen, J. T., Baldry, I., Barnes, L., Bauer, A. E., Bland-Hawthorn, J., Bloom, J. V., Brooks, A. M., Brough, S., Cecil, G., Couch, W., Croton, D., Davies, R., Ellis, S., Fogarty, L. M. R., Foster, C., Glazebrook, K., Goodwin, M., Green, A., Gunawardhana, M. L., Hampton, E., Ho, I.-T., Hopkins, A. M., Kewley, L., Lawrence, J. S., Leon-Saval, S. G., Leslie, S., McElroy, R., Lewis, G., Liske, J., López-Sánchez, Á. R., Mahajan, S., Medling, A. M., Metcalfe, N., Meyer, M., Mould, J., **Obreschkow, D.**, O'Toole, S., and 8 colleagues, 2015, ''The SAMI Galaxy Survey: instrument specification and target selection'', Monthly Notices of the Royal Astronomical Society, 447, 2857.	5.226
21	Campbell, L. A., Lucey, J. R., Colless, M., Jones, D. H., **Springob, C**. M., Magoulas, C., Proctor, R. N., Mould, J. R., Read, M. A., Brough, S., Jarrett, T., Merson, A. I., Lah, P., **Beutler, F.**, Cluver, M. E., Parker, Q. A., 2014, ''The 6dF Galaxy Survey: Fundamental Plane data'', Monthly Notices of the Royal Astronomical Society, 443, 1231.	5.226
22	Casteels, K. R. V., Conselice, C. J., Bamford, S. P., Salvador-Solé, E., Norberg, P. R., Agius, N. K., Baldry, I., Brough, S., Brown, M. J. I., Drinkwater, M. J., **Driver, S. P**., Graham, A. W., Bland-Hawthorn, J., Hopkins, A. M., Kelvin, L. S., López-Sánchez, A. R., Loveday, J., **Robotham, A. S. G.**, Vázquez-Mata, J. A., 2014, ''Galaxy And Mass Assembly (GAMA): refining the local galaxy merger rate using morphological information'', Monthly Notices of the Royal Astronomical Society, 445, 1157.	5.226
23	Coppin, K. E. K., Geach, J. E., Almaini, O., Arumugam, V., Dunlop, J. S., Hartley, W. G., Ivison, R. J., Simpson, C. J., Smith, D. J. B., Swinbank, A. M., Blain, A. W., Bourne, N., Bremer, M., Conselice, C., Harrison, C. M., Mortlock, A., Chapman, S. C., **Davies, L. J. M**., Farrah, D., Gibb, A., Jenness, T., Karim, A., Knudsen, K. K., Ibar, E., Michałowski, M. J., Peacock, J. A., Rigopoulou, D., Robson, E. I., Scott, D., Stevens, J., van der Werf, P. P., 2015, ''The SCUBA-2 Cosmology Legacy Survey: the submillimetre properties of Lyman-break galaxies at z = 3-5'', Monthly Notices of the Royal Astronomical Society, 446, 1293.	5.226
24	Corbel, S., **Miller-Jones, J. C. A.,** Fender, R., Gallo, E., Maccarone, T., O'Brien, T., Paragi, Z., Rupen, M., Rushton, A., Sabatini, S., Sivakoff, G., Strader, J., Woudt, P. A., 2015, ''Incoherent transient radio emission from stellar-mass compact objects in the SKA era'', Advancing Astrophysics with the Square Kilometre Array (AASKA14), 53.	N/A

25	Cortese, L., Fogarty, L. M. R., Ho, I.-T., **Bekki, K.**, Bland-Hawthorn, J., Colless, M., Couch, W., Croom, S. M., Glazebrook, K., Mould, J., Scott, N., Sharp, R., Tonini, C., Allen, J. T., Bloom, J., Bryant, J. J., Cluver, M., Davies, R. L., Drinkwater, M. J., Goodwin, M., Green, A., Kewley, L. J., Kostantopoulos, I. S., Lawrence, J. S., Mahajan, S., Medling, A. M., Owers, M., Richards, S. N., Sweet, S. M., **Wong, O. I.,** 2014, ''The SAMI Galaxy Survey: Toward a Unified Dynamical Scaling Relation for Galaxies of All Types'', The Astrophysical Journal, 795, L37.	6.28
26	**Coward, D. M., Howell, E. J.**, Wan, L., Macpherson, D., 2015, ''Selection biases in the gamma-ray burst E_{iso} - L_{opt, X} correlation'', Monthly Notices of the Royal Astronomical Society, 449, L6.	5.226
27	Díaz Trigo, M., Migliari, S., **Miller-Jones, J. C. A.**, Guainazzi, M., 2014, ''XMM-Newton observations reveal the disappearance of the wind in 4U 1630-47'', Astronomy and Astrophysics, 571, A76.	4.479
28	Dai, S., Hobbs, G., Manchester, R. N., Kerr, M., Shannon, R. M., van Straten, W., Mata, A., Bailes, M., **Bhat, N. D. R.**, Burke-Spolaor, S., Coles, W. A., Johnston, S., Keith, M. J., Levin, Y., Osłowski, S., Reardon, D., Ravi, V., Sarkissian, J. M., Tiburzi, C., Toomey, L., Wang, H. G., Wang, J.-B., Wen, L., Xu, R. X., Yan, W. M., Zhu, X.-J., 2015, ''A study of multifrequency polarization pulse profiles of millisecond pulsars'', Monthly Notices of the Royal Astronomical Society, 449, 3223.	5.226
29	Dannerbauer, H., Kurk, J. D., De Breuck, C., Wylezalek, D., Santos, J. S., Koyama, Y., **Seymour, N.,** Tanaka, M., Hatch, N., Altieri, B., Coia, D., Galametz, A., Kodama, T., Miley, G., Röttgering, H., Sanchez-Portal, M., Valtchanov, I., Venemans, B., Ziegler, B., 2014, ''An excess of dusty starbursts related to the Spiderweb galaxy'', Astronomy and Astrophysics, 570, A55.	4.479
30	**Davies, L. J. M., Driver, S. P., Robotham, A. S. G.**, Baldry, I. K., Lange, R., Liske, J., **Meyer, M., Popping, A.**, Wilkins, S. M., **Wright, A. H.,** 2015, ''Galaxy And Mass Assembly (GAMA): curation and reanalysis of 16.6k redshifts in the G10/COSMOS region'', Monthly Notices of the Royal Astronomical Society, 447, 1014.	5.226
31	Davis, T. A., Rowlands, K., Allison, J. R., Shabala, S. S., Ting, Y.-S., **Lagos, C. d. P.**, Kaviraj, S., Bourne, N., Dunne, L., Eales, S., Ivison, R. J., Maddox, S., Smith, D. J. B., Smith, M. W. L., Temi, P., 2015, ''Molecular and atomic gas in dust lane early-type galaxies - I. Low star formation efficiencies in minor merger remnants'', Monthly Notices of the Royal Astronomical Society, 449, 3503.	5.226
32	de Bruyn, A. G., **Macquart, J.-P.**, 2015, ''The intra-hour variable quasar J1819+3845: 13-year evolution, jet polarization structure, and interstellar scattering screen properties'', Astronomy and Astrophysics, 574, A125.	4.479
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TOTAL NUMBER:	**177**
AVERAGE IMPACT FACTOR	**5.265**
TOTAL WITH IF>3	**129**
TOTAL WITH MEASURED IF	**145**
PERCENTAGE OF PAPERS WITH IF>3	**89.0%**

Additional Engineering Conference Papers

	Engineering Publications	Impact factor
1	Sutinjo, A.T.; Hall, P.J., "Antenna Rotation Error Tolerance for a Low-Frequency Aperture Array Polarimeter," Antennas and Propagation, IEEE Transactions on , vol.62, no.6, pp.3401,3406, June 2014, doi: 10.1109/TAP.2014.2312201	2.181
2	A. Sutinjo and T. Colegate, et. al., “Characterization of Aperture Array Verification System 0.5: Radio Astronomy Interferometry and Full-Wave Simulation,” submitted to IEEE Trans. Antennas Propagat. (in revision)	2.181
2	C. Choeysakul, F. Schlagenhaufer, and P. Hall, “EMC Applications for the Navy: Reverberation Chamber Tests,” Royal Thai Naval Academy Journal of Science and Technology, Issue Number 1, Aug. 2014.	
4	C. Choeysakul, F. Schlagenhaufer, P. Rattanakreep, and P. Hall, “EMC Applications for Military: Reverberation Chamber Tests,” The 20th Asia-Pacific Conference on Communications; APCC, Pattaya, Oct. 1-3, 2014	
5	A. Sutinjo, R. Wayth, S. Padhi, T. Colegate, and P. Hall, “Complex Gain Calibration in `Hybrid’ Low-Frequency Aperture Arrays: an Array Prototype and the Murchison Widefield Array,” 2015 IEEE International Symposium on Antennas and Propagation and North American Radio Science Meeting, 19-24 July 2015, Vancouver, Canada	
6	T. Colegate, A. Sutinjo, P. Hall, S. Padhi, R. Wayth, J. G. bij de Vaate, B. Crosse, D. Emrich, A. Faulkner, N. Hurley-Walker, E. de Lera Acedo, B. Juswardy, N. Razavi-Ghods, S. Tingay, and A. Williams, "Antenna array characterization via radio interferometry observation of astronomical sources," Antenna Measurements & Applications (CAMA), 2014 IEEE Conference on , vol., no., pp.1,4, 16-19 Nov. 2014	
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9	C. Choeysakul, F. Schlagenhaufer, P. Rattanakreep, and P. Hall, “EMC Applications for Military: Reverberation Chamber Tests,” The 20th Asia-Pacific Conference on Communications; APCC, Pattaya, Oct. 1-3, 2014	

APPENDIX B

STAFF AND STUDENTS

VISITORS AND SEMINARS

ICRAR II Research Staff (1July 2014 to 30 June 2015)

No.	Title	First Name	Last Name	Position classification	Classification level	Field (e.g. radio astronomy, data intensive science, technology development)	ICRAR location (Curtin, UWA)	ICRAR Program (e.g Science, Engineering, DIA)	Position ongoing (yes/no)	2014/15 contract completion date (mmm-yy)
1	Professor	Kenji	Bekki	Professor	LVLD 04	Radioastronomy Science Research	UWA	Science	Yes	31/12/2049
2	Dr	Ramesh	Bhatt	Senior Research Fellow	ALC.03	Radio Astronomy - Researcher	Curtin	Science	No	1/06/2016
3	Dr	Hayley	Bignall	Senior Research Officer	G07.04	Radio Astronomy - Researcher	Curtin	Science	No	30/09/2015
4	Mr	Alessio	Checcucci	Research Associate	LVLA 08	Radio Astronomy - Researcher	UWA	Science	No	31/07/2014
5	Dr	Nathan	Clarke	Research Engineer	ALC.06	Radio Astronomy - Engineering	Curtin	Engineering	No	6/04/2015
6	Dr	Tim	Colgate	Research Assistant	ALA.08	Radio Astronomy - Engineering	Curtin	Science	No	28/01/2016
7	Dr	Weiguang	Cui	Research Associate	LVLA 08	Radioastronomy Science Research	UWA	Science	No	14/11/2016
8	Dr	Peter	Curran	Senior Research Fellow	ALC.01	Radio Astronomy - Researcher	Curtin	Science	No	12/03/2019
9	Dr	Luke	Davies	Research Associate	LVLA 08	Radioastronomy Science Research	UWA	Science	No	27/10/2016
10	Dr	Foivos	Diakogiannis	Research Associate	LVLA 08	Radioastronomy Science Research	UWA	Science	No	29/06/2017
11	Dr	Richard	Dodson	Research Fellow	LVLC 03	Radioastronomy DIA Research and Technology Dev	UWA	DIA	No	31/12/2016
12	Professor	Simon	Driver	Senior Principal Research Fellow	LVLE 01	Radioastronomy Science Research	UWA	Science	Yes	31/12/2049
13	Dr	John	Flexman	Research Officer	GJ05.08	Radio Astrononmy - Research	Curtin	Science	No	13/02/2015
14	Dr	Bi-Qing	For	Research Associate (John Stocker Postdoctoral Fellowship)	LVLB 01	Radioastronomy Science Research	UWA	Science	No	31/07/2016
15	Dr	Thomas	Franzen	Postdoctoral Researcher	ALB.02	Radio Astronomy - Researcher	Curtin	Science	No	14/04/2017
16	Professor	Peter	Hall	Director, Engineering	ALE	Radio Astronomy - Engineering	Curtin	Engineering	Yes	31/12/2075
17	Dr	Paul	Hancock	Early Career Research Fellow	ALB.03	Radio Astronomy - Researcher	Curtin	Science	No	29/09/2018
18	Dr	Natasha	Hurley-Walker	Early Career Research Fellow	ALB.01	Radio Astronomy - Researcher	Curtin	Science	No	31/07/2018
19	Dr	Minh	Huynh	Senior Research Fellow	LVLC 05	Radioastronomy Science Research	UWA	Science	No	30/06/2016
20	Professor	Carole	Jackson	WA Fellow	ALE	Radio Astronomy - Researcher	Curtin	Science	Yes	31/12/2075
21	Dr	Budi	Juswardy	Research Engineer	ALB.06	Radio Astronomy - Engineering	Curtin	Science	No	30/06/2017
22	Dr	Prajwal	Kafle	Research Associate	LVLA 08	Radioastronomy Science Research	UWA	Science	No	11/05/2017
23	Dr	Anna	Kapinska	Research Associate	LVLA 08	Radioastronomy Science Research	UWA	Science	No	18/08/2016
24	Dr	Franz	Kirsten	Research Associate	ALA.06	Radio Astronomy - Researcher	Curtin	Science	No	15/09/2017
25	Dr	Slava	Kitaeff	Senior Research Fellow	LVLC 04	Radioastronomy DIA Research and Technology Dev	UWA	DIA	No	30/06/2016
26	Dr	Claudia	Lagos	ARC Early Career Researcher	LVLB 03	Radioastronomy Science Research	UWA	Science	No	3/05/2018
27	Dr	Jean-Pierre	Macquart	Senior Research Fellow	ALC.06	Radio Astronomy - Researcher	Curtin	Science	No	31/03/2017
28	Professor	Gerhardt	Meurer	Senior Principal Research Fellow	LVLE 01	Radioastronomy Science Research	UWA	Science	Yes	31/12/2049
29	Dr	Martin	Meyer	Senior Research Fellow	LVLC 06	Radioastronomy Science Research	UWA	Science	Yes	31/12/2049
30	Dr	James	Miller-Jones	Senior Lecturer	ALC.02	Radio Astronomy - Researcher	Curtin	Science	Yes	31/12/2075
31	Dr	Amanda	Moffett	Research Associate	LVLA 08	Radioastronomy Science Research	UWA	Science	No	27/10/2016
32	Dr	John	Morgan	RASE Research Fellow (May 2010)	ALB.01	Radioastronomy Science Research	Curtin	Science	No	2/11/2017
33	Dr	Richard	Newton	Research Associate	LVLA 08	Radioastronomy Science Research	UWA	Science	No	7/11/2014
34	Dr	Danail	Obreschkow	Senior Research Fellow	LVLC 04	Radioastronomy Science Research	UWA	Science	Yes	31/12/2049
35	Dr	Se-Heon	Oh	Research Fellow	LVLB 04	Radioastronomy Science Research	UWA	Science	No	22/05/2016
36	Dr	Stephen	Ord	Senior Research Fellow	ALC.06	Radio Astronomy - Engineering	Curtin	Science	No	31/12/2017
37	Dr	Shantanu	Padhi	Research Engineer	ALC.06	Radio Astronomy - Engineering	Curtin	Science	No	6/06/2015
38	Dr	Attila	Popping Attila	Research Fellow	LVLB 02	Radioastronomy Science Research	UWA	Science	No	1/03/2018
39	Associate Professor	Chris	Power	Future Fellow	LVLD 02	Radioastronomy Science Research	UWA	Science	No	31/12/2017
40	Professor	Peter	Quinn	Executive Director	LVLE 01	Radioastronomy Science Research	UWA	CEO	Yes	30/06/2019
41	Dr	Cormac	Reynolds	Senior Research Fellow	ALC.05	Radio Astronomy - Researcher	Curtin	Science	No	30/09/2015
42	Dr	Jonghwan	Rhee	Research Associate	LVLA 08	Radioastronomy Science Research	UWA	Science	No	1/06/2017
43	Dr	Maria	Rioja	Research Fellow	LVLB 06	Radioastronomy Science Research	UWA	Science	No	27/01/2015
44	Dr	Aaron	Robotham	Postdoctoral Senior Research Fellow	LVLC 01	Radioastronomy Science Research	UWA	Science	Yes	31/12/2049
45	Dr	Franz	Schlagenhaufer	Research Engineer	ALC.06	Radio Astronomy - Engineering	Curtin	Engineering	No	30/06/2017
46	Dr	Nick	Seymour	Senior Lecturer	ALC.06	Radio Astronomy - Researcher	Curtin	Science	Yes	31/12/2075
47	Dr	Ryan	Shannon	Research Fellow	ALB.05	Radio Astronomy - Researcher	Curtin	Science	No	21/05/2019
48	Dr	Marcin	Sokolowski	CAASTRO Postdoctoral Researcher	ALA.08	Radio Astronomy - Researcher	Curtin	Science	No	14/1/2016
49	Dr	Roberto	Soria	Senior Research Fellow	ALC.05	Radio Astronomy - Researcher	Curtin	Science	No	20/02/2019
50	Dr	Christopher	Springob	Research Assistant Professor	LVLB 06	Radioastronomy Science Research	UWA	Science	No	16/09/2015
51	Professor	Lister	Staveley-Smith	Director, Science	LVLE 01	Radioastronomy Science Research	UWA	Science	Yes	31/12/2049
52	Dr	Adrian	Sutinjo	Senior Research Fellow	ALC.06	Engineering	Curtin	Engineering	Yes	31/12/2049
53	Dr	Dan	Taranu	Research Associate	LVLA 08	Radioastronomy Science Research	UWA	Science	No	28/01/2018
54	Professor	Steven	Tingay	Director, Science	ALE	Radio Astronomy - Researcher	Curtin	Science	Yes	31/12/2049
55	Dr	Steven	Tremblay	Postdoctoral Research Fellow	ALA.08	Radio Astronomy - Researcher	Curtin	Science	No	1/09/2018
56	Dr	Cathryn	Trott	Senior Research Fellow	ALC.01	Radio Astronomy - Researcher	Curtin	Science	Yes	30/03/2019
57	Associate Professor	Kevin	Vinsen	Research Associate Professor	LVLC 06	Radioastronomy DIA Research and Technology Dev	UWA	DIA	No	30/06/2019
58	Dr	Andrew	Walsh	Senior Research Fellow	ALC.04	Radio Astronomy - Researcher	Curtin	Science	No	6/01/2017
59	Dr	Randall	Wayth	Senior Research Fellow	ALC.06	Radio Astronomy - Engineering	Curtin	Science	Yes	31/12/2075
60	Dr	Tobias	Westmeier	Research Assistant Professor	LVLB 06	Radioastronomy Science Research	UWA	Science	No	1/10/2016
61	Professor	Andreas	Wicenec	Research Winthrop Professor	LVLE 01	Radioastronomy DIA Research and Technology Dev	UWA	DIA	Yes	31/12/2049
62	Dr	Andrew	Williams	MWA Monitor and Control Engineer	G09.03	Radio Astronomy - Engineering	Curtin	Engineering	No	30/06/2019
63	Dr	Ivy	Wong	Super Science Fellow	LVLB 03	Radioastronomy Science Research	UWA	Science	No	30/03/2017
64	Associate Professor	Chen	Wu	Research Associate Professor	LVLC 05	Radioastronomy DIA Research and Technology Dev	UWA	DIA	No	20/03/2019
65	Dr	Matthew	Young	Astronomy & Astrophysics Course Coordinator	L06 01	Radioastronomy Science Research	UWA	Science	No	31/12/2015

ICRAR II Research Staff: New Employees (1 July 2014 to 30 June 2015)

No.	Title	First Name	Last Name	ICRAR position classification	ICRAR classification level	Field (e.g. radio astronomy, data intensive science, technology development)	ICRAR location (Curtin, UWA)	ICRAR Program (e.g. Science, Engineering, DIA)	Start date of employment at ICRAR (dd/mm/yy)	Previous position	Previous equivalent classification level	Previous employer	Country
1	Dr	Foivos	Diakogiannis	Research Associate	LVLA 08	Radioastronomy Science Research	UWA	Science	1/07/2014	PhD Candidate	N/A (PhD Candidate)	University of Sydney	Australia
2	Dr	Franz	Kirsten	Research Associate	ALA.06	Radio Astronomy - Researcher	Curtin	Science	1/10/2014	PhD Student	N/A	Max Planck Institute for Radio Astronomy	Germany
3	Dr	Claudia	Lagos	ARC Early Career Researcher	LVLB 03	Radioastronomy Science Research	UWA	Science	1/05/2015	Research Fellow	A8	European Southern Observatory	Germany
4	Dr	Nick	Seymour	Senior Lecturer	ALC.06	Radio Astronomy - Researcher	Curtin	Science	21/07/2014	Senior Office and ARC Future Fellow	LVL C	CSIRO	Australia
5	Dr	Ryan	Shannon	Research Fellow	ALB.05	Radio Astronomy - Researcher	Curtin	Science	1/06/2015	Postdoctoral Fellow	LVL 5 (equiv. to LVLB?)	CSIRO	Australia
6	Dr	Dan	Taranu	Research Associate	LVLA 08	Radioastronomy Science Research	UWA	Science	1/12/2014	Software Engineer	Level 5/6, Step 4	European Southern Observatory	Germany
7	Dr	Richard	Dodson	Senior Research Fellow (SKA RA Data Reduction)	LVLC 03	Radioastronomy DIA Research and Technology Dev	UWA	DIA	1/07/2014	Research Fellow	LVL B 6	ICRAR	Australia
8	Dr	Maria	Rioja	Research Fellow (VLBI Specialist)	LVLB 06	Radioastronomy Science Research	UWA	Science	24/07/2014	Research Fellow	LVL B 6	ICRAR	Australia
9	Dr	Aaron	Robotham	Postdoctoral Senior Research Fellow	LVLC 01	Radioastronomy Science Research	UWA	Science	1/04/2015	Senior Research Fellow	LVLC 01	ICRAR	Australia
10	Dr	Martin	Meyer	Senior Research Fellow	LVLC 06	Radioastronomy Science Research	UWA	Science	1/04/2015	Senior Research Fellow	LVLC 06	ICRAR	Australia
11	Dr	Danail	Obreschkow	Senior Research Fellow	LVLC 04	Radioastronomy Science Research	UWA	Science	1/04/2015	Senior Research Fellow	LVLC 04	ICRAR	Australia

ICRAR II Professional and Technical Staff (1 July 2014 to 30 June 2015)

No.	Title	First Name	Last Name	Position classification	Classification level	Field (e.g. radio astronomy, data intensive science, technology development)	ICRAR location (Curtin, UWA)	ICRAR Program (e.g Science, Engineering, DIA)	Position ongoing (yes/no)	2014/15 contract completion date (mmm-yy)
1	Mr	Alex	Beckley	Web Programmer/ Analyst	L06 03	Radioastronomy DIA Research and Technology Dev	UWA	DIA	No	31/01/2016
2	Mr	Tom	Booler	MWA Project Manager	GJ09.07	Radio Astronomy - Engineering	Curtin	Science	No	30/06/2019
3	Mr	Mark	Boulton	IT Manager	L09 01	Radioastronomy DIA Research and Technology Dev	UWA	DIA	No	30/07/2019
4	Mr	Ian	Cooper	Project Manager	L10G1 03	Radioastronomy DIA Research and Technology Dev	UWA	DIA	No	31/12/2017
5	Mr	Brian	Crosse	MWA Commissioning Engineer	Contract	Radio Astronomy - Engineering	Curtin	Engineering	No	10/01/2016
6	Mr	Markus	Dolensky	Technical Leader	L10G1 02	Radioastronomy DIA Research and Technology Dev	UWA	DIA	No	13/01/2016
7	Mr	David	Emrich	MWA Commissioning Engineer	G08.04	Radio Astronomy - Engineering	Curtin	Engineering	No	30/06/2019
8	Mr	David	Kenney	Senior Technical Officer	G07.4	Radio Astronomy - Technical Engineering	Curtin	Engineering	No	31/03/2017
9	Ms	Liz	Mannering	Web Developer and Outreach Assistant	L05 01	Outreach, Communication & Education	UWA	OEC	No	30/04/2016
10	Mr	Dave	Pallot	Software Engineer and Administrator (DIA)	L09 01	Radioastronomy DIA Research and Technology Dev	UWA	DIA	No	5/08/2018
11	Mr	Jonathan	Tickner	Senior Technical Officer	GJ06.08	Radio Astronomy - Technical Engineering	Curtin	Engineering	No	30/06/2019
12	Mr	Rodrigo	Tobar	Sortware Engineer	L08 01	Radioastronomy DIA Research and Technology Dev	UWA	DIA	No	3/05/2018
13	Dr	Andrew	Williams	MWA Monitor and Control Engineer	G09.03	Radio Astronomy - Engineering	Curtin	Engineering	No	30/06/2019

ICRAR II Management and OEC Staff (1 July 2014 to 30 June 2015)

No.	Title	First Name	Last Name	Position classification	Classification level	Field (e.g. radio astronomy, data intensive science, technology development)	ICRAR location (Curtin, UWA)	ICRAR Program (e.g Science, Engineering, DIA)	Position ongoing (yes/no)	2014/15 contract completion date (mmm-yy)
1	Ms	Lara	Delacour	IP Manager	L0804	Management	UWA	Management	No	Ongoing
2	Mr	Joseph	Diamond	Outreach & Education Assistant	L04.01	Outreach, Communication & Education	UWA	Management	No	20/08/2014
3	Mrs	Angela	Dunleavy	Administration Coordinator	G05.04	Management	Curtin	Management	No	30/06/2019
4	Dr	Wiebke	Ebeling	Lecturer	ALN.02	Radio Astronomy - Researcher	Curtin	OEC	No	31/12/2017
5	Ms	Kirsten	Gottschalk	Outreach, Communication & Education Officer	L07 02	Outreach, Communication & Education	UWA	OEC	No	21/09/2017
6	Ms	Kathy	Kok	Finance Manager	L07 01	Management	UWA	Management	No	29/07/2015
7	Ms	Laura	Laird	Administrative Assistant/Receptionist	G0401	Management	Curtin	Management	No	30/06/2019
8	Ms	Yolandie	McDade	Executive Assistant	L06 04	Management	UWA	Management	No	30/06/2019
9	Mrs	Tracey	O'Keefe	Administrative Officer	L06 02	Management	UWA	Management	No	15/07/2016
10	Mrs	Clare	Peter	Administrative Officer	L06 02	Management	UWA	Management	No	12/08/2017
11	Ms	Lisa	Randell	Administrative Assistant	L04 02	Management	UWA	Management	No	19/07/2019
12	Ms	Tina	Sallis	Operations Coordinator	G06.04	Management	Curtin	Management	Yes	31/12/2075
13	Dr	Renu	Sharma	Associate Director	L10G5 02	Management	UWA	Management	No	14/09/2019
14	Mr	Pete	Wheeler	Outreach & Education Manager	L09 01	Outreach, Communication & Education	UWA	OEC	No	19/07/2019

ICRAR II All Staff (1 July 2014 to 30 June 2015)

No.	Title	First Name	Last Name	Position classification	Classification level	Field (e.g. radio astronomy, data intensive science, technology development)	ICRAR location (Curtin, UWA)	ICRAR Program (e.g Science, Engineering, DIA)	Position ongoing (yes/no)	2014/15 contract completion date (mmm-yy)
1	Mr	Laurens	Bakker	Research Engineer	G09.04	Radio Astronomy - Engineering	Curtin	Engineering	No	2/05/2017
2	Mr	Alex	Beckley	Web Programmer/ Analyst	L06 03	Radioastronomy DIA Research and Technology Dev	UWA	DIA	No	31/01/2016
3	Professor	Kenji	Bekki	Professor	LVLD 04	Radioastronomy Science Research	UWA	Science	Yes	31/12/2049
4	Mr	Ramesh	Bhatt	Senior Research Fellow	ALC.03	Radio Astronomy - Researcher	Curtin	Science	No	1/06/2016
5	Dr	Hayley	Bignall	Senior Research Officer role	G07.04	Radio Astronomy - Researcher	Curtin	Science	No	30/09/2015
6	Mr	Tom	Booler	MWA Project Manager	GJ09.07	Radio Astronomy - Engineering	Curtin	Science	No	30/06/2019
7	Mr	Mark	Boulton	IT Manager	L09 01	Radioastronomy DIA Research and Technology Dev	UWA	DIA	No	30/07/2019
8	Mr	Alessio	Checcucci	Research Associate	LVLA 08	Radio Astronomy -Researcher	UWA	Science	No	31/07/2014
9	Dr	Nathan	Clarke	Research Engineer	ALC.06	Radio Astronomy - Engineering	Curtin	Engineering	No	6/04/2015
10	Dr	Tim	Colgate	Research Assistant	ALA.08	Radio Astronomy - Engineering	Curtin	Science	No	28/01/2016
11	Mr	Ian	Cooper	Project Manager	L10G1 03	Radioastronomy DIA Research and Technology Dev	UWA	DIA	No	31/12/2017
12	Mr	Brian	Crosse	MWA Commissioning Engineer	Contract	Radio Astronomy - Engineering	Curtin	Engineering	No	10/01/2016
13	Dr	Weiguang	Cui	Research Associate	LVLA 08	Radioastronomy Science Research	UWA	Science	No	14/11/2016
14	Dr	Peter	Curran	Senior Research Fellow	ALC.01	Radio Astronomy - Researcher	Curtin	Science	No	12/03/2019
15	Dr	Luke	Davies	Research Associate	LVLA 08	Radioastronomy Science Research	UWA	Science	No	27/10/2016
16	Ms	Lara	Delacour	IP Manager	LVL0804	Management	UWA	Management	No	Ongoing
17	Dr	Foivos	Diakogiannis	Research Associate	LVLA 08	Radioastronomy Science Research	UWA	Science	No	29/06/2017
18	Mr	Joseph	Diamond	Outreach & Education Assistant	L04 01	Outreach, Communication & Education	UWA	Management	No	20/08/2014
19	Dr	Richard	Dodson	Research Fellow	LVLC 03	Radioastronomy DIA Research and Technology Dev	UWA	DIA	No	31/12/2016
20	Mr	Markus	Dolensky	Technical Leader	L10G1 02	Radioastronomy DIA Research and Technology Dev	UWA	DIA	No	13/01/2016
21	Professor	Simon	Driver	Senior Principal Research Fellow	LVLE 01	Radioastronomy Science Research	UWA	Science	Yes	31/12/2049
22	Mrs	Angela	Dunleavy	Administration Coordinator	G05.04	Management	Curtin	Management	No	30/06/2019
23	Dr	Wiebke	Ebeling	Lecturer	ALN.02	Radio Astronomy - Researcher	Curtin	OEC	No	31/12/2017
24	Mr	David	Emrich	MWA Commissioning Engineer	G08.04	Radio Astronomy - Engineering	Curtin	Engineering	No	30/06/2019
25	Dr	John	Flexman	Research Officer	GJ05.08	Radio Astrononmy - Research	Curtin	Science	No	13/02/2015
26	Dr	Bi-Qing	For	Research Associate (John Stocker Postdoctoral Fellowship)	LVLB 01	Radioastronomy Science Research	UWA	Science	No	31/07/2016
27	Dr	Thomas	Franzen	Postdoctoral Researcher	ALB.02	Radio Astronomy - Researcher	Curtin	Science	No	14/04/2017
28	Ms	Kirsten	Gottschalk	Outreach, Communication & Education Officer	L07 02	Outreach, Communication & Education	UWA	OEC	No	21/09/2017
29	Professor	Peter	Hall	Deputy Director, Engineering	ALE	Radio Astronomy - Engineering	Curtin	Engineering	Yes	31/12/2075
30	Dr	Paul	Hancock	Early Career Research Fellow	ALB.03	Radio Astronomy - Researcher	Curtin	Science	No	29/09/2018
31	Dr	Natasha	Hurley-Walker	Early Career Research Fellow	ALB.01	Radio Astronomy - Researcher	Curtin	Science	No	31/07/2018
32	Dr	Minh	Huynh	Senior Research Fellow	LVLC 05	Radioastronomy Science Research	UWA	Science	No	30/06/2016
33	Professor	Carole	Jackson	WA Fellow	ALE	Radio Astronomy - Researcher	Curtin	Science	Yes	31/12/2075
34	Dr	Budi	Juswardy	Research Engineer	ALB.06	Radio Astronomy - Engineering	Curtin	Science	No	30/06/2017
35	Dr	Prajwal	Kafle	Research Associate	LVLA 08	Radioastronomy Science Research	UWA	Science	No	11/05/2017
36	Dr	Anna	Kapinska	Research Associate	LVLA 08	Radioastronomy Science Research	UWA	Science	No	18/08/2016
37	Mr	David	Kenney	Senior Technical Officer	G07.4	Radio Astronomy - Technical Engineering	Curtin	Engineering	No	31/03/2017
38	Dr	Franz	Kirsten	Research Associate	ALA.06	Radio Astronomy - Researcher	Curtin	Science	No	15/09/2017
39	Dr	Slava	Kitaeff	Senior Research Fellow	LVLC 04	Radioastronomy DIA Research and Technology Dev	UWA	DIA	No	30/06/2016
40	Ms	Kathy	Kok	Finance Manager	L07 01	Management	UWA	Management	No	29/07/2015
41	Dr	Claudia	Lagos	ARC Early Career Researcher	LVLB 03	Radioastronomy Science Research	UWA	Science	No	1/05/2018
42	Ms	Laura	Laird	Administrative Assistant/Receptionist	None	Management	Curtin	Management	No	30/06/2019
43	Ms	Liz	Mannering	Web Developer and Outreach Assistant	L05 01	Outreach, Communication & Education	UWA	OEC	No	30/04/2016
44	Dr	Jean-Pierre	Macquart	Senior Research Fellow	ALC.06	Radio Astronomy - Researcher	Curtin	Science	No	31/03/2017
45	Ms	Yolandie	McDade	Executive Assistant	L06 04	Management	UWA	Management	No	30/06/2019
46	Professor	Gerhardt	Meurer	Senior Principal Research Fellow	LVLE 01	Radioastronomy Science Research	UWA	Science	Yes	31/12/2049
47	Dr	Martin	Meyer	Senior Research Fellow	LVLC 06	Radioastronomy Science Research	UWA	Science	Yes	31/12/2049
48	Dr	James	Miller-Jones	Senior Lecturer	ALC.02	Radio Astronomy - Researcher	Curtin	Science	Yes	31/12/2075
49	Dr	Amanda	Moffett	Research Associate	LVLA 08	Radioastronomy Science Research	UWA	Science	No	27/10/2016
50	Dr	John	Morgan	RASE Research Fellow (May 2010)	ALB.01		Curtin	Science	No	2/11/2017
51	Dr	Richard	Newton	Research Associate	LVLA 08	Radioastronomy Science Research	UWA	Science	No	7/11/2014
52	Dr	Danail	Obreschkow	Senior Research Fellow	LVLC 04	Radioastronomy Science Research	UWA	Science	Yes	31/12/2049
53	Dr	Se-Heon	Oh	Research Fellow	LVLB 04	Radioastronomy Science Research	UWA	Science	No	22/05/2016
54	Mrs	Tracey	O'Keefe	Administrative Officer	L06 02	Management	UWA	Management	No	15/07/2016
55	Dr	Stephen	Ord	Senior Research Fellow	ALC.06	Radio Astronomy - Engineering	Curtin	Science	No	31/12/2017
56	Dr	Shantanu	Padhi	Research Engineer	ALC.06	Radio Astronomy - Engineering	Curtin	Science	No	6/06/2015
57	Mr	Dave	Pallot	Software Engineer and Administrator (DIA)	L09 01	Radioastronomy DIA Research and Technology Dev	UWA	DIA	No	5/08/2018
58	Ms	Clare	Peter	Administration Officer	L06 02	Management	UWA	Management	No	12/08/2017

59	Dr	Attila	Popping Attila	Research Fellow	LVLB 02	Radioastronomy Science Research	UWA	Science	No	1/03/2018
60	Associate Professor	Chris	Power	Future Fellow	LVLD 02	Radioastronomy Science Research	UWA	Science	No	31/12/2017
61	Professor	Peter	Quinn	Director	A999A	Radioastronomy Science Research	UWA	CEO	Yes	30/06/2019
62	Ms	Lisa	Randell	Administrative Assistant	L04 02	Management	UWA	Management	No	6/07/2019
63	Dr	Cormac	Reynolds	Senior Research Fellow	ALC.05	Radio Astronomy - Researcher	Curtin	Science	No	30/09/2015
64	Dr	Jonghwan	Rhee	Research Associate	LVLA 08	Radioastronomy Science Research	UWA	Science	No	1/06/2017
65	Dr	Maria	Rioja	Research Fellow	LVLB 06	Radioastronomy Science Research	UWA	Science	No	27/01/2015
66	Dr	Aaron	Robotham	Postdoctoral Senior Research Fellow	LVLC 01	Radioastronomy Science Research	UWA	Science	Yes	31/12/2049
67	Ms	Tina	Sallis	Operations Coordinator	G06.04	Management	Curtin	Management	Yes	31/12/2075
68	Dr	Franz	Schlagenhaufer	Research Engineer	ALC.06	Radio Astronomy - Engineering	Curtin	Engineering	No	30/06/2017
69	Dr	Nick	Seymour	Senior Lecturer	ALC.06	Radio Astronomy - Researcher	Curtin	Science	Yes	31/12/2075
70	Dr	Ryan	Shannon	Research Fellow	ALB.05	Radio Astronomy - Researcher	Curtin	Science	No	21/05/2019
71	Dr	Renu	Sharma	Associate Director	L10G5 02	Management	UWA	Management	No	14/09/2019
72	Dr	Marcin	Sokolowski	CAASTRO Postdoctoral Researcher	ALA.08	Radio Astronomy - Researcher	Curtin	Science	No	14/1/2016
73	Dr	Roberto	Soria	Senior Research Fellow	ALC.05	Radio Astronomy - Researcher	Curtin	Science	No	20/02/2019
74	Dr	Christopher	Springob	Research Assistant Professor	LVLB 06	Radioastronomy Science Research	UWA	Science	No	16/09/2015
75	Professor	Lister	Staveley-Smith	Deputy Director, Science	A999A	Radioastronomy Science Research	UWA	Science	Yes	31/12/2049
76	Dr	Adrian	Sutinjo	Senior Research Fellow	ALC.06	Engineering	Curtin	Engineering	Yes	31/12/2049
77	Dr	Dan	Taranu	Research Associate	LVLA 08	Radioastronomy Science Research	UWA	Science	No	28/01/2018
78	Mr	Jonathan	Tickner	Senior Technical Officer	GJ06.08	Radio Astronomy - Technical Engineering	Curtin	Engineering	No	30/06/2019
79	Professor	Steven	Tingay	Deputy Director, MRO	ALE	Radio Astronomy - Researcher	Curtin	Science	Yes	31/12/2049
80	Mr	Rodrigo	Tobar	Sortware Engineer	L08 01	Radioastronomy DIA Research and Technology Dev	UWA	DIA	No	3/05/2018
81	Dr	Steven	Tremblay	Postdoctoral Research Fellow	ALA.08	Radio Astronomy - Researcher	Curtin	Science	No	1/09/2018
82	Dr	Cathryn	Trott	Senior Research Fellow	ALC.01	Radio Astronomy - Researcher	Curtin	Science	Yes	30/03/2019
83	Associate Professor	Kevin	Vinsen	Research Associate Professor	LVLC 06	Radioastronomy DIA Research and Technology Dev	UWA	DIA	No	30/06/2019
84	Dr	Andrew	Walsh	Senior Research Fellow	ALC.04	Radio Astronomy - Researcher	Curtin	Science	No	6/01/2017
85	Dr	Randall	Wayth	Senior Research Fellow	ALC.06	Radio Astronomy - Engineering	Curtin	Science	Yes	31/12/2075
86	Dr	Tobias	Westmeier	Research Assistant Professor	LVLB 06	Radioastronomy Science Research	UWA	Science	No	1/10/2016
87	Mr	Pete	Wheeler	Outreach & Education Manager	L09 01	Outreach, Communication & Education	UWA	OEC	No	19/07/2019
88	Professor	Andreas	Wicenec	Research Winthrop Professor	LVLE 01	Radioastronomy DIA Research and Technology Dev	UWA	DIA	Yes	31/12/2049
89	Dr	Andrew	Williams	MWA Monitor and Control Engineer	G09.03	Radio Astronomy - Engineering	Curtin	Engineering	No	30/06/2019
90	Dr	Ivy	Wong	Super Science Fellow	LVLB 03	Radioastronomy Science Research	UWA	Science	No	30/03/2017
91	Associate Professor	Chen	Wu	Research Associate Professor	LVLC 05	Radioastronomy DIA Research and Technology Dev	UWA	DIA	No	20/03/2019
92	Dr	Matthew	Young	Astronomy & Astrophysics Course Coordinator	L06 01	Radioastronomy Science Research	UWA	Science	No	31/12/2015

Enrolled ICRAR MSc and PhD students (1 July 2014 to 30 June 2015)

No.	Title	First Name	Last Name	MSc/PhD	Project title	Field (e.g. radio astronomy, data intensive science, technology development)	ICRAR location (Curtin, UWA)	ICRAR Program (e.g. Science, Engineering, DIA)	Enrolment date (mmm-yy)
1	Mr	Kamran	Ali	PhD	Large-scale Structure of Universe	Radioastronomy Science Research	UWA	Science	27/01/2015
2	Mr	Stephen	Andrews	PhD	Measuring and Modelling the Extragalactic Background Light using the GAMA survey	Radioastronomy Science Research	UWA	Science	25/02/2014
3	Ms	Fiona	Audcent-Ross	PhD	Star Formation demographics in HI selected galaxies	Radioastronomy Science Research	UWA	Science	6/03/2013
4	Mr	Arora	Balwinder Singh	PhD	Ionosphere Faraday Rotation, it's Estimation and Mitigation for Radio Astronomy Applications	Radioastronomy Science Research	CURTIN	Science	2/10/2012
5	Ms	Sarah Marie	Bruzzese	PhD	Initial mass function of NGC 2915	Radioastronomy Science Research	UWA	Science	5/03/2012
6	Mr	James	Buchan	PhD	Power System Design for Square Kilometre Array (SKA) Radio-Telescope Considering Electromagnetic Compatibility (EMC) and Reliability	Radioastronomy Science Research	CURTIN	Engineering	30/03/2015
7	Mr	Andrew	Butler	PhD	Measuring AGN Feedback: Black Hole Kinetic Luminosity Outputs in the HERG and LERG Paradigm	Radioastronomy Science Research	UWA	Science	6/01/2015
8	Ms	Kirsty	Butler	Masters	Angular Momentum of Dwarf Galaxies	Radioastronomy Science Research	UWA	Science	23/02/2015
9	Mr	Choeysakul	Chittawan	PhD	Characterisation of a Reverberation Chamber Model for Electromagnetic Emission Measurements	Radioastronomy Engineering Research	CURTIN	Engineering	1/07/2011
10	Ms	Krystal	Cook	Masters	Radio Recombination Lines Using the MWA	Radioastronomy Science Research	UWA	Science	24/02/2014
11	Mr	Geoff	Duniam	Masters	Big Data Architecture in Radio Astronomy: The SkyNet and SKA	Radioastronomy DIA Research and Technology Dev	UWA	Science	20/03/2014
12	Mr	Robert	Finnegan	Masters	Galactic morphological provenance, evolution	Radioastronomy Science Research	UWA	Science	25/02/2013
13	Ms	Hatsune	Furui	Masters	Extended Ultraviolet Disks in HI selected galaxies	Radioastronomy Science Research	UWA	Science	16/03/2014
14	Mr	Benjamin	Henderson	Masters	Search for high-z dropouts in the GAMA mutli-wavelength database	Radioastronomy Science Research	UWA	Science	16/03/2014
15	Mr	David	Herne	PhD	High Fidelity Mapping And Calibration Of Earth's Ionosphere To Low - Frequency Radio Signals	Radioastronomy Science Research	CURTIN	Science	28/02/2006
16	Ms	Laura Janine	Hoppmann	PhD	Deep Studies of the Universe in 21cm	Radioastronomy Science Research	UWA	Science	10/01/2011
17	Ms	Katharine	Kelley	PhD	A Radio Astronomy search for Axionic Dark Matter	Radioastronomy Science Research	UWA	Science	1/06/2014
18	Ms	Rebecca	Lange	PhD	Understanding the physical growth of galaxies and their components over the past 5 billion years.	Radioastronomy Science Research	UWA	Science	11/06/2012
19	Mr	Chris	Lord	Masters	VLF telescope for studying ionospheric phenomena	Radioastronomy Science Research	CURTIN	Science	1/01/2009
20	Mr	Damien	Macpherson	PhD	Optimal strategies for detecting the first stars: the biggest explosions in the Universe	Radioastronomy Science Research	UWA	Science	27/02/2012
21	Ms	Lesley	Maddox	Masters	Spin of Galaxies	Radioastronomy Science Research	UWA	Science	1/03/2015
22	Mr	Jurek Tadek	Malarecki	PhD	Data Organisation and Data Interrogation in the SKA	Radioastronomy DIA Research and Technology Dev	UWA	DIA	30/03/2015
23	Mr	Jurek Marin	Malarecki	PhD	The Warm-Hot Intergalactic Medium	Radioastronomy Science Research	UWA	Science	28/01/2011
24	Mr	Scott Adrian	Meyer	PhD	Investigating the Tully-Fisher relation and galaxy kinematics through neutral Hydrogen spectral line stacking techniques	Radioastronomy Science Research	UWA	Science	20/02/2012
25	Mr	Mehran	Mossammaparast	Masters	Radiometric Receiver for Measuring Red-Shifted 21cm Hydrogen Monopole During EoR	Radioastronomy Science Research/Engineering	CURTIN	Science	00/05/11
26	Mr	Steven	Murray	PhD	Tools and Statistics for Dark Matter Haloes	Radioastronomy Science Research	UWA	Science	4/04/2012
27	Mr	Rakesh	Nath	PhD	Estimating the neutral hydrogen signal from the Epoch of Reionisation using low-frequency radio interferometers	Radioastronomy Science Research	CURTIN	Science	22/10/2014
28	Mr	Samuel	Oronsaye	PhD	Survey for Pulsars with the Murchison Widefield Array	Radioastronomy Science Research	CURTIN	Science	2/08/2012
29	Ms	Divya	Palaniswamy	PhD	The High Resolution Dynamic Radio Sky	Radioastronomy Science Research	CURTIN	Science	30/06/2011
30	Mr	HaiHua	Qiao	PhD	Accurate OH maser positions from SPLASH	Radioastronomy Science Research	CURTIN	Science	27/10/2014
31	Mr	Hayden	Rampadarath	PhD	Applications of Wide-Field VLBI	Radioastronomy Science Research	CURTIN	Science	20/08/2010
32	Mr	Alfonso	Rossi Perez	Masters	Detection, Identification and Correlation of Solar Flare Bursts via the use of BIGHORNS Antenna Systems.	Radioastronomy Science Research	CURTIN	Science	9/02/2015
33	Mr	Thomas	Russell	PhD	The connection between inflow and outflow around accreting stellar mass black holes	Radioastronomy Science Research	CURTIN	Science	2/04/2012
34	Mr	Paul	Scott-Taylor	PhD	Advanced Computing of Simulated Galaxies in the SKA Era.	Radioastronomy Science Research	UWA	Science	13/05/2013
35	Ms	(Morag) Iona	Scrimgeour	PhD	Measuring Cosmology with Motion in the Universe	Radioastronomy Science Research	UWA	Science	19/04/2010
36	Mr	Hongquan	Su	PhD	Mapping the Galaxy in 3D using observations of HII region absorption with the MWA	Radioastronomy Science Research	CURTIN	Science	1/09/2014
37	Mr	Chenoa	Tremblay	Masters	Study of Complex Molecules at Low Frequency	Radioastronomy Science Research	CURTIN	Science	12/04/2015
38	Mr	Vlad	Tudor	PhD	Quiescent accreting black holes in globular clusters	Radioastronomy Science Research	CURTIN	Science	22/01/2015
39	Mr	Ryan	Urquhart	PhD	Understanding the evolution of a super-Eddington outburst	Radioastronomy Science Research	CURTIN	Science	22/02/2015
40	Mr	Kevin	Vinsen	PhD	A Method For Automated Classification Of Galaxies Using Multi-wavelength Data And Machine Learning Algorithms	Radioastronomy DIA Research and Technology Dev	UWA	DIA	15/02/2011
41	Mr	Ruonan (Jason)	Wang	PhD	A data optimised I/O middle ware and API for applications to access heterogenous storage hierarchies in HPC and cloud environments	Radioastronomy DIA Research and Technology Dev	UWA	DIA	21/11/2012
42	Mr	Stefan Lennart	Westerlund	PhD	A Parallel Source Finder For Searching Radio Astronomy Images using High Performance Computing	Radioastronomy Science Research	UWA	Science	22/03/2010
43	Mr	Alexander	Williamson	Masters	How Common are Large Streams of HI	Radioastronomy Science Research	UWA	Science	3/03/2015
44	Mr	Angus	Wright	PhD	Using Multi-band Photometry and HI Stacking to Constrain the Universal Baryonic Mass Function	Radioastronomy Science Research	UWA	Science	11/03/2013
45	Mr	Cameron	Yozin-Smith	PhD	Tracing the chemodynamical evolution of our dwarf galaxy neighbours, with CUDA-accelerated numerical methods	Radioastronomy Science Research	UWA	Science	26/03/2012
46	Ms	Giovanna	Zanardo	PhD	Radio evolution of supernova SN1987A	Radioastronomy Science Research	UWA	Science	8/02/2010

ICRAR MSc and PhD Graduates (1 July 2014 to 30 June 2015)

No.	Title	First Name	Last Name	MSc/PhD	Project title	Field (e.g. radio astronomy, data intensive science, technology development)	ICRAR location (Curtin, UWA)	ICRAR Program (e.g. Science, Engineering, DIA)	Graduation date (mmm-yy)	Current position[1] (e.g. post doctoral fellow)	Organisation & Country[1]
1	Ms	Divya	Palaniswamy	PhD	The High Resolution Dynamic Radio Sky	Radioastronomy Science Research	CURTIN	Science	1/07/2014	Software Engineer	India
2	Ms	Laura Janine	Hoppmann	PhD	Deep Studies of the Universe in 21cm	Radioastronomy Science Research	UWA	Science	9/10/2014	Analyst	Max Planck Digital Library, Germany
3	Mr	Mehran	Mossammaparast	Masters	Radiometric Receiver for Measuring Red-Shifted 21cm Hydrogen Monopole During EoR	Radioastronomy Science Research	CURTIN	Science	00/05/15	Senior RF Engineer	Standard Communications, Sydney
4	Mr	Hayden	Rampadarath	PhD	Applications of Wide-Field VLBI	Radioastronomy Science Research	CURTIN	Science	1/07/2014	Postdoctoral Fellow	University of Manchester, UK
5	Mr	Chris	Lord	Masters	VLF telescope for studying ionospheric phenomena	Radioastronomy Science Research	CURTIN	Science	1/07/2014	Director/Owner	Lord Electronics, Australia
6	Mr	Stefan Lennart	Westerlund	PhD	A Parallel Source Finder For Searching Radio Astronomy Images using High Performance Computing	Radioastronomy Science Research	UWA	Science	22/02/2015		Australia
7	Ms	Giovanna	Zanardo	PhD	Radio evolution of supernova SN1987A	Radioastronomy Science Research	UWA	Science	31/03/2015	Engineer	Main Roads Australia
8	Mr	Robert	Finnegan	Masters	Galactic morphological provenance, evolution	Radioastronomy Science Research	UWA	Science	12/12/2014		Australia
9	Ms	(Morag) Iona	Scrimgeour	PhD	Measuring Cosmology with Motion in the Universe	Radioastronomy Science Research	UWA	Science	25/07/2014	Data Scientist	Square, San Fransisco, USA

ICRAR Seminars (1 July 2014 to 30 June 2015)

No.	First Name	Last Name	Company	Topic	ICRAR Location	Status
1	Kevin	Schawinski	ETH Zurich	The evolutionary pathways in the quenching of early- and late-type galaxies	ICRAR-Fairway	International
2	Jim	Jackson	Boston University	The Millimetre Astronomy Legacy Team 90 GHz Survey (MALT90)	ICRAR-Brodie	International
3	Di	Li	National Astronomical Observatories of China	The Promise of a Giant Radio Telescope	ICRAR-Fairway	International
4	Swapan	Saha	Formerly with Indian Institute of Astrophysics	Genesis of Optical Interferometry	ICRAR-Fairway	International
5	Nissim	Kanekar	National Centre for Radio Astrophysics	Do the Fundamental Constants change with Time ?	ICRAR-Brodie	International
6	Sebastian	Haan	CSIRO Astronomy and Space Science	Measuring IGM properties and extragalactic velocities in 3D	ICRAR-Fairway	National
7	Nissim	Kanekar	National Centre for Radio Astrophysics	The nature of high-redshift damped Ly-alpha systems	ICRAR-Fairway	International
8	Elaine	Sadler	University of Sydney/CAASTRO	Powerful radio galaxies and the search for HI in the distant universe	ICRAR-Brodie	National
9	Brynmor	Haskell	University of Melbourne	Investigating neutron star interior dynamics and pulsar glitches	ICRAR-Brodie	National
10	Boudewijn	Roukema	Nicolaus Copernicus University, Torun Centre for Astronomy	Newtonian dark energy vs Einsteinian structure formation	ICRAR-Fairway	International
11	Michele	Peron	European Southern Observatory	Engineering at ESO	ICRAR-Fairway	International
12	Alan	Duffy	Swinburne University	First Galaxies and DRAGONS	ICRAR-Fairway	National
13	Jonathan	Davies	Cardiff University	Cosmic Dust in Galaxies	ICRAR-Fairway	International
14	Jonghwan	Rhee	ICRAR, UWA	Probing neutral hydrogen gas evolution using HI spectral stacking and HI intensity mapping technique	ICRAR-Fairway	ICRAR
15	George	Heald	Astron	Galaxy Surveys in the SKA Era	ICRAR-Fairway	International
16	Rick	Perley	NRAO	The Jansky Very Large Array - Present and Future Capabilities	ICRAR-Brodie	International
17	Jordan	Collier	UWS	Infrared-Faint Radio Sources: a new population of high-redshift radio galaxies	ICRAR-Brodie	National
18	Amy	Kimball	CSIRO	Probing the early Universe with sub-millimetre observations of extreme quasars	ICRAR-Fairway	National
19	Amy	Kimball	CSIRO	The Radio Luminosity Function of Optically Selected QSOs: Star Formation and AGNs	ICRAR-Brodie	National
20	Nick	Seymour	ICRAR-CURTIN	Rapid Galaxy Growth at the Crossroads of the Universe	ICRAR-Fairway	ICRAR
21	Kunal	Mooley	Caltech	Slow Transient Surveys with the VLA	ICRAR-Brodie	International
22	David	Parkinson	University of Queensland	Lessons from BICEP2	ICRAR-Fairway	National
23	Dave	Mcconnell	CASS	BETA: the ASKAP prototype	ICRAR-Brodie	National
24	Dave	Mcconnell	CASS	BETA: the ASKAP prototype	ICRAR-Fairway	National
25	Huib	Intema	National Radio Astronomy Observatory	SPAM - Scripted data reduction for high-resolution, low-frequency radio-interferometric observations	ICRAR-Fairway	International
26	Lee	Spitler	Macquarie University	The ZFOURGE survey: the evolution of galaxies since z=4	ICRAR-Fairway	National
27	Stuart	Ryder	Australian Astronomical Observatory	Radio Supernovae Young and Old	ICRAR-Brodie	National
28	Brad	Tucker	ANU	Results from ESSENCE and the Kepler Extra-Galactic Survey (KEGS)	ICRAR-Brodie	National
29	Soheil	Koushan	UWA	The Theory of Mie Scattering	ICRAR-Fairway	National
30	Wasim	Raja	Raman Research Institute	Polarized Emission from Cassiopeia A at low frequencies: Could we be witnessing a PWN in the making?	ICRAR-Fairway	International
31	David	Coward		The Zadko Telescope: a fully robotic telescope for transient source and multi-messenger astronomy	ICRAR-Brodie	National
32	Jeff	Hodgson	MPIfR, Bonn	3 mm global VLBI monitoring of Gamma-ray blazars	ICRAR-Brodie	International
33	Danail	Obreschkow	ICRAR/UWA	Evolution of Structure: In memoriam Steve Rawlings, 1961-2012	ICRAR-Fairway	ICRAR
34	Aaron	Dutton	Max Planck Institute for Astronomy	A non-universal stellar Initial Mass Function in galactic spheroids	ICRAR-Fairway	International
35	David	Coward	UWA	The Zadko Telescope: a fully robotic telescope for transient source and multi-messenger astronomy	ICRAR-Fairway	National
36	Angel	Lopez-Sanchez	Australian Astronomical Observatory	Dwarf Star-forming galaxies and the assembly of spiral galaxies	ICRAR-Fairway	National
37	Laura	Wolz	University of Melbourne	Intensity Mapping: Foreground Subtraction and Power Spectrum Analysis	ICRAR-Fairway	National
38	Elisabete	Da Cunha	Swinburne University	The Physical Properties of Sub-millimeter Galaxies observed with ALMA	ICRAR-Fairway	National
39	Yu-Qing	Lou	Tsinghua University	Hypermassive Black Holes in the Universe	ICRAR-Fairway	International
40	Chiaki	Kobayashi	University of Hertfordshire	Cosmological simulations with AGN feedback	ICRAR-Fairway	International
41	Stuart	Ryder	AAO	The changing landscape of Australian 8 metre telescope access	ICRAR-Fairway	National
42	Andy	Bunker	Oxford University	Finding Distant Galaxies and Determining the Star Formation History of the Universe	ICRAR-Brodie	International
43	Stuart	Anderson	University of Adelaide	Field geometry and the dynamics of radio wave polarisation transformation in the ionosphere	ICRAR-Brodie	National
44	Rainer	Beck	Max Planck Institute for Astronomy	Magnetic fields in galaxies and prospects with the SKA	ICRAR-Fairway	International
45	Dave	Russell	NYU Abu Dhabi	Polarimetric Evidence for Jet Synchrotron Emission from Radio to Gamma-ray in X-ray Binaries	ICRAR-Brodie	International
46	Lyndsay	Old	University of Nottingham	How well can we measure the masses of galaxy clusters using galaxies as tracers?	ICRAR-Fairway	International
47	Rob	Hollow	CASS	PULSE@Parkes, Engaging Students through Hands-On Radio Astronomy	ICRAR-Brodie	National
48	Patricia	Carroll	University of Washington	A Survey of Foreground Galaxies in the MWA Epoch of Reionization Field	ICRAR-Fairway	International
49	Dan	Taranu	ICRAR	Forming Elliptical Galaxies via Mergers in Galaxy Groups	ICRAR-Fairway	ICRAR
50	Patricia	Carroll	University of Washington	A Survey of Foreground Galaxies in the MWA Epoch of Reionization Field	ICRAR-Brodie	International
51	Barry	Green	UWA	ITER - the fusion reactor development project	ICRAR-Fairway	National
52	Cleo	Loi	University of Sydney	The Murchison Widefield Array and the ionosphere dilemma	ICRAR-Brodie	National
53	Richard	Wolstenhulme	University of Cambridge	Three-point phase correlations: A new measure of non-linear large-scale structure	ICRAR-Fairway	International
54	Paul	Hurley	IBM	The ASTRON/IBM DOME project and striving to make radio telescope data less astronomic	ICRAR-Brodie	International
55	Andrew	Walsh	ICRAR-CURTIN	Structure and Dynamics at the Centre of the Milky Way	ICRAR-Fairway	ICRAR
56	John	Norgard	NASA/JSC	Space Exploration: EMI/EMC Problems/Solutions NASA – Past/Present/Future Missions “Orion” Mars/Moon Spacecraft	ICRAR-Brodie	International
57	Aina	Musaeva	University of Sydney	Searching for Intermediate-mass Black Holes in Dwarf Galaxies	ICRAR-Brodie	National
58	Julia	Scharwachter		Probing supermassive black holes in the Perseus Cluster via molecular gas: NGC 1275 and NGC 1277	ICRAR-Fairway	International
59	Duncan	Farrah	Virginia Tech University	The dusty side of galaxy assembly as unveiled by Herschel	ICRAR-Fairway	International
60	Ewen	Barr	Swinburne University	Pulsar Timing instrumentation for SKA1-Mid and SKA1-Low	ICRAR-Brodie	National
61	Adela	Kawk	Astronomical Institute, The Czech Academy of Sciences	Properties and origin of magnetic fields in white dwarfs	ICRAR-Brodie	International

ICRAR Visitors (1 July 2014 to 30 June 2015)

No.		Name	Surname	From	To	Home Institution/OrganiSouth Africation	Country	ICRAR Location	Status
1		James	Jackson	10/07/2014	14/07/2014	Boston University	USA	Curtin	International
2		Di	Li	12/07/2014	14/07/2014	National Astronomical Observatories of China	China	UWA	International
3		Swapan	Saha	16/07/2014	17/07/2014	Indian Institute of Astrophysics, Bangalore, India	India	UWA	International
4		Nissim	Kanekar	27/07/2014	10/08/2014	National Centre for Radio Astrophysics		Curtin	International
5		Sebastian	Haan	30/07/2014	1/08/2014	CSIRO Astronomy and Space Science	Australia	UWA	National
6		Madhura	Killedar	31/07/2014	1/08/2014	Uni Observatory Munich/Ludwig-Maximilians University	Munich	UWA	International
7		Nissim	Kanekar	7/08/2014	7/08/2014	National Centre for Radio Astrophysics	Australia	UWA	National
8		Lisa	Harvey-Smith	7/08/2014	7/08/2014	CSIRO	Australia	UWA	National
9		Yasuo	Fukui	14/08/2014	16/08/2014			UWA	International
10		Elaine	Sadler	20/08/2014	20/08/2014	University of Sydney	Australia	Curtin	National
11		Andrew	Butler	1/09/2014	31/12/2014	Liverpool JMU	Australia	UWA	National
12		Kate	Gunn	15/09/2014	18/09/2014	CAASTRO COO	Australia	UWA	National
13		Brian	Gaensler	15/09/2014	18/09/2014	CAASTRO Advisory committee	Australia	UWA	National
14		Jacinta	Delhaize	15/09/2014	26/09/2014	University of Zagreb	Croatia	UWA	International
15		Antonia	Rowlinson	18/09/2014	18/09/2014	CSIRO Astronomy and Space Science	Australia	UWA	National
16		Jonathan	Davies	20/09/2014	3/10/2014	Cardiff University	United Kingdom	UWA	International
17		Michele	Peron	20/09/2014	28/09/2014	European Southern Observatory, Garching	France	UWA	International
18		Hazel	Martindale	22/09/2014	19/12/2014	University of Sussex	United Kingdom	UWA	International
19		Hayden	Rampadarath	22/09/2014	26/09/2014	University of Southhampton	Trinidad	Curtin	International
20		Boudewijn	Roukema	23/09/2014	26/09/2014	Nicolaus Copernicus University	Poland	UWA	International
21		Brynmor	Haskell	23/09/2014	26/09/2014	University of Melbourne	Australia	Curtin	National
22		Rahim	Lakhoo	25/09/2014	26/09/2014	University of Oxford	United Kingdom	UWA	International
23		William	Garnier	1/10/2014	2/10/2014	SKAO	United Kingdom	UWA	International
24		Mathieu	Isidro	1/10/2014	2/10/2014	SKAO	United Kingdom	UWA	International
25		Jerry	Skinner	1/10/2014	2/10/2014	Department of Industry	Australia	UWA	National
26		Ben	Scandrett	1/10/2014	2/10/2014	Department of Industry	Australia	UWA	National
27		Tommy	Makhode	1/10/2014	2/10/2014	South Africa DST	South Africa	UWA	International
28		Eleonora	Ferroni	1/10/2014	2/10/2014	INAF	Italy	UWA	International
29		Eric	Chisholm	1/10/2014	2/10/2014	NRC Herzberg, Institute of Astrophysics	Canada	UWA	International
30		Bojan	Nikolic	3/10/2014	3/10/2014	University of Cambridge	United Kingdom	UWA	International
31		Ferdl	Graser	3/10/2014	3/10/2014	SKA-South Africa	South Africa	UWA	International
32		Francois	Malan	3/10/2014	3/10/2014	SKA-South Africa	South Africa	UWA	International
33		George	Beckett	3/10/2014	3/10/2014	ivec	Australia	UWA	National
34		Robert	Simmonds	3/10/2014	3/10/2014	University of Calgary	Canada	UWA	International
35		Chris	Harris	3/10/2014	3/10/2014	ivec	Australia	UWA	National
36		Nicolas	Erdody	3/10/2014	3/10/2014	New Zealand Aliance	New Zealand	UWA	International
37		Daniel	Daniel	3/10/2014	3/10/2014	ivec	Australia	UWA	National
38		Staf	Salvini	3/10/2014	3/10/2014	Oxford e-Research Centre	United Kingdom	UWA	International
39		Ronald	Nijboer	3/10/2014	3/10/2014	ASTRON	Netherlands	UWA	International
40		Tony	Willis	3/10/2014	3/10/2014	NCR-CNRC	Canada	UWA	International
41		Chris	Broekema	3/10/2014	3/10/2014	ASTRON	Netherlands	UWA	International
42		Rahim	Lakhoo	3/10/2014	3/10/2014	Oxford e-Research Centre	United Kingdom	UWA	International
43		Anna	Scaife	3/10/2014	3/10/2014	University of Southampton	United Kingdom	UWA	International
44		Chris	Skipper	3/10/2014	3/10/2014	University of Southampton	United Kingdom	UWA	International
45		Hayden	Rempadareth	3/10/2014	3/10/2014	University of Southampton	United Kingdom	UWA	International
46		Daniel	Mitchell	3/10/2014	3/10/2014	CSIRO	Australia	UWA	National
47		Kristian	Zarb Adami	3/10/2014	3/10/2014	University of Oxford	United Kingdom	UWA	International
48		Maxim	Voronkov	3/10/2014	3/10/2014	CSIRO	Australia	UWA	National

49		Ben	Humphreys	3/10/2014	3/10/2014	CSIRO	Australia	UWA	National
50		Rosie	Bolton	3/10/2014	3/10/2014	University of Cambridge	United Kingdom	UWA	International
51		Mark	Weiringa	3/10/2014	3/10/2014	CSIRO	Australia	UWA	National
52		Shaohua	Wu	3/10/2014	3/10/2014	Inspur	China	UWA	International
53		Lourdes	Verdes-Montenegro	3/10/2014	3/10/2014	IAA	Spain	UWA	International
54		Julian	Garrido	3/10/2014	3/10/2014	IAA	Spain	UWA	International
55		John	Bancroft	3/10/2014	3/10/2014	STFC	United Kingdom	UWA	International
56		Ben	Stappers	3/10/2014	3/10/2014	University of Manchester	United Kingdom	UWA	International
57		Tim	Cornwell	3/10/2014	3/10/2014	SKAO	United Kingdom	UWA	International
58		George	Heald	3/10/2014	1/11/2014	ASTRON	USA	Curtin	International
59		Ben	Stappers	3/10/2014	3/10/2014	University of Manchester, UK	British	Curtin	International
60		Michael	Rupen	3/10/2014	3/10/2014	Dominion Radio Astrophysical Observatory (DRAO)	USA	Curtin	International
61		Jasper	Horrell	6/10/2014	7/10/2014	SKA-South Africa	South Africa	UWA	International
62		Simon	Ratcliffe	6/10/2014	7/10/2014	SKA-South Africa	South Africa	UWA	International
63		Ivan	Baldry	9/10/2014	18/10/2014	Liverpool JMU	Australia	UWA	National
64		George	Heald	13/10/2014	13/10/2014	ASTRON	USA	UWA	International
65		Anis	Inayat-Hussain	20/10/2014	26/11/2014	UWA	Australia	UWA	National
66		Rick	Perley	24/10/2014	1/11/2014	National Radio Astronomy Observatory	USA	Curtin	International
67		Simona	Bekeraite	25/10/2014	29/11/2014	AIP (Leibniz-Institut for Astrophysics, Potsdam)	Lithuanian	UWA	International
68		Joe	Callingham	27/10/2014	2/11/2014	SIfA	Australia	Curtin	National
69		Jordan	Collier	27/10/2014	1/11/2014	University of Western Sydney	Australia	Curtin	National
70		Chiara	Tonini	29/10/2014	31/10/2014	Swinburne University	Australia	UWA	National
71		Shane	O'Sullivan	31/10/2014	7/11/2014	University of Sydney	Australia	UWA	National
72		Amy	Kimball	4/11/2014	6/11/2014	CSIRO	Australia	UWA	National
73		David	Thilker	7/11/2014	11/11/2014	Johns Hopkins University	USA	UWA	International
74		Benjamin	Stone	10/11/2014	12/11/2014	Willeton Senior High School	Australia	UWA	National
75		Monique	Hollick	10/11/2014	12/11/2014	UWA	Australia	UWA	National
76		Kunal	Mooley	10/11/2014	13/11/2014	Caltech	USA	Curtin	International
77		David	Parkinson	12/11/2014	14/11/2014	University of Queensland	Australia	UWA	National
78		David	Mcconnell	13/11/2014	14/11/2014	CASS		Curtin	National
79		Huib	Intema	16/11/2014	18/11/2014	National Radio Astronomy Observatory	Netherlands	UWA	International
80		Sam	Foster	17/11/2014	16/02/2015	Murdoch University	Australia	UWA	National
81		Volker	Springel	17/11/2014	19/11/2014	Heidelberg Institute for Theoretical Studies	Germany	UWA	International
82		John	Kormendy	20/11/2014	22/11/2014	University of Texas, Austin	USA	UWA	International
83		Morag	Scrimgeour	24/11/2014	10/12/2014			UWA	International
84		Lee	Spitler	26/11/2014	28/11/2014	Macquarie University	Australia	UWA	National
85		Dinko	Milakovic	28/11/2014	28/11/2014	University of Zagreb	Croatian	UWA	International
86		Warrick	Couch	28/11/2014	28/11/2014	Australian Astronomical Observatory	Australia	UWA	National
87		Stuart	Ryder	2/12/2014	4/12/2014	Australian Astronomical Observatory	Australia	Curtin	National
88		Brad	Tucker	3/12/2014	5/12/2014	ANU/UC Berkeley	USA	Curtin	International
89		Wasim	Raja	6/12/2014	13/12/2014	Cotton College State University	India	UWA	International
90		Amirhossein	Arabshahi	15/12/2014	23/02/2015	UWA	Australia	UWA	National
91		Noel	Hinton	18/12/2014	23/02/2015	UWA	Australia	UWA	National
92		Alexander	Williamson	23/12/2014	1/03/2015	UWA	Australia	UWA	National
93		Joseph	Dunne	6/01/2015	31/07/2015	UWA	Australia	UWA	National
94		Leon	Drygala	6/01/2015	31/07/2015	UWA	Australia	UWA	National
95		Cole	Bannister	20/01/2015	22/01/2015	Willeton Senior High School	Australia	UWA	National
96		Cole	Bannister	21/01/2015	23/01/2015	Willeton Senior High School	Australia	Curtin	National
97		Aparup	Banerjee	2/02/2015	2/02/2016	University of Southern Queensland	Australia	UWA	National
98		Tom	Campbell	2/02/2015	20/03/2015	United Kingdom Student	United Kingdom	UWA	International
99		Aaron	Dutton	4/02/2015	7/02/2015	Max-Planck Institute for Astronomy	Germany	UWA	International
100		Kate	Gunn	10/02/2015	10/02/2015	CAASTRO HQ	Australia	UWA	National
101		Angel	Lopez-Sanchez	11/02/2015	18/02/2015	Australian Astronomical Observatory	Australia	UWA	National

102		Luca	Cortese	12/02/2015	20/02/2015	Swinburne University	Australia	UWA	National
103		Barbara	Catinella	12/02/2015	20/02/2015	Swinburne University	Australia	UWA	National
104		Virginia	Kilborn	16/02/2015	19/02/2015	Swinburne University	Australia	UWA	National
105		Aina	Musaeva	16/02/2015	20/02/2015	The University of Sydney	Australia	Curtin	National
106		Gabor	Orosz	16/02/2015	28/03/2015	Kagoshima University	Japan	Curtin	International
107		Warrick	Couch	18/02/2015	18/02/2015	AAO	Australia	UWA	National
108		Gabor	Orosz	19/02/2015	28/03/2015	Kagoshima University	Japan	UWA	International
109		Santiago Javier	Avila Perez	20/02/2015	11/05/2015	Universidad Autonoma de Madrid	Spain	UWA	International
110		Richard	Tuffs	21/02/2015	4/03/2015	Max-Planck Institut fuer Kernphysik	Germany	UWA	International
111		Michelle	Cluver	21/02/2015	28/02/2015	University of Western Cape	South Africa	UWA	International
112		Loretta	Dunne	22/02/2015	27/02/2015	Universitys of Canterbury and Edinburgh	United Kingdom	UWA	International
113		Elisabete	Da Cunha	22/02/2015	28/02/2015	Swinburne University	Australia	UWA	National
114		Craig	Burnett	22/02/2015	28/02/2015	University of Melbourne	Australia	UWA	National
115		Laura	Wolz	22/02/2015	26/02/2015	University of Melbourne	Australia	UWA	National
116		Lingyu	Wang	22/02/2015	28/02/2015	Durham University	United Kingdom	UWA	International
117		Yu-Qing	Lou	23/02/2015	8/03/2015	Tsinghua University	China	UWA	International
118		Edward	Taylor	23/02/2015	27/02/2015	University of Melbourne	Australia	UWA	National
119		Dongwei	Fan	28/02/2015	30/04/2015	National Astronomical Observatory, Chinese Academy of Sciences, Beijing	China	UWA	International
120		Takuji	Tsujimoto	7/03/2015	17/03/2015	National Astonomical Observatory Japan	Japan	UWA	International
121		Lyndsay	Old	7/03/2015	6/04/2015	University of Nottingham	United Kingdom	UWA	International
122		Robert	Thacker	7/03/2015	19/03/2015	St Mary's University	Canada	UWA	International
123		Chiaki	Kobayashi	10/03/2015	17/03/2015	University of Hertfordshire	United Kingdom	UWA	International
124		Andrew	Bunker	10/03/2015	17/03/2015	University of Oxford	United Kingdom	Curtin	International
125		Hiroshi	Imai	12/03/2015	24/03/2015	Kagoshima University	Japan	UWA	International
126		Alexander	Knebe	15/03/2015	28/03/2015	Universidad Autonoma de Madrid	Spain	UWA	International
127		Stuart	Anderson	15/03/2015	21/03/2015	University of Adelaide	Australia	UWA	National
128		Stuart	Anderson	15/03/2015	21/03/2015	University of Adelaide	Australia	Curtin	National
129		Patricia	Carroll	16/03/2015	30/04/2015	University of Washington	USA	Curtin	International
130		Daniel	Cunnama	17/03/2015	29/03/2015	UWC	South Africa	UWA	International
131		Rainer	Beck	19/03/2015	23/03/2015	MPIfR Bonn	Germany	UWA	International
132		Pieter	Benthem	19/03/2015	2/04/2015	ASTRON	Netherlands	Curtin	International
133		Stuart	Muldrew	20/03/2015	29/03/2015	University of Leicester	United Kingdom	UWA	International
134		Madhura	Killedar	21/03/2015	28/03/2015	Ludwig Maxmilians University	Germany	UWA	International
135		Federico	Sembolini	22/03/2015	27/03/2015	Unversidad Autonoma de Madrid	Spain	UWA	International
136		Matt	Owers	22/03/2015	27/03/2015	Macquarie University	Australia	UWA	National
137		Claire	Cashmore	22/03/2015	1/04/2015	University of Leicester	United Kingdom	UWA	International
138		Gustavo	Yepes	23/03/2015	26/03/2015	Unversidad Autonoma de Madrid	Spain	UWA	International
139		Pascal	Elahi	23/03/2015	27/03/2015	University of Sydney	Australia	UWA	National
140		Sah	Brough	23/03/2015	26/03/2015	AAO	Australia	UWA	National
141		Pierluigi	Cerulo	23/03/2015	27/03/2015	Swinburne University	Australia	UWA	National
142		Dylan	Cusack-Paquelet	23/03/2015	30/09/2015	UWA	Australia	UWA	National
143		David	Russell	23/03/2015	26/03/2015	New York University Abu Dhabi	United Arab Emirates	Curtin	International
144		Richard	Wolstenhulme	27/03/2015	28/04/2015	University of Cambridge	United Kingdom	UWA	International
145		Robert	Hollow	27/03/2015	27/03/2015	CASS	Australia	Curtin	National
146		Khaled	Said	28/03/2015	28/04/2015	University of Cape Town	South Africa	UWA	International
147		Kingsley	Gale-Sides	31/03/2015	3/04/2016	Keele University	United Kingdom	UWA	International
148		James	Taylor	7/04/2015	20/04/2015	University of Waterloo	Canada	UWA	International
149		Patricia	Carroll	9/04/2015	9/04/2015	University of Washington	USA	UWA	International
150		Jason	Vanaadt	9/04/2015	10/04/2015	SKA South Africa	South Africa	UWA	International
151		Dennis	Jensen	10/04/2015	10/04/2015	Federal Member for Tangney	Australia	UWA	National
152		Mark	Wilkinson	12/04/2015	24/04/2015	University of Leicester	United Kingdom	UWA	International
153		Cleo	Loi	14/04/2015	25/04/2015	Sydney Institute for Astronomy	Australia	Curtin	National
154		Jeremy	Coles	21/04/2015	23/04/2015	University of Cambridge	United Kingdom	UWA	International

155		Denham	Dunstall	22/04/2015	22/04/2015	Scitech	Australia	UWA	National
156		Joseph	Callingham	23/04/2015	23/05/2015	University of Sydney	Australia	Curtin	National
157		Paul	Hurley	29/04/2015	1/05/2015	IBM Research - Zurich	Switzerland	Curtin	International
158		Kim	Monks	1/05/2015	30/04/2016	Systemic	Australia	UWA	National
159		Martin	Zwaan	2/05/2015	8/05/2015	European Southern Observatory, Garching	Germany	UWA	International
160		Wolfram	Freudling	4/05/2015	8/05/2015	European Southern Observatory, Garching	Germany	UWA	International
161		Virginia	Kilborn	4/05/2015	6/05/2015	Swinburne University	Australia	UWA	National
162		Aina	Musaeva	5/05/2015	5/06/2015	The University of Sydney	Australia	Curtin	National
163		John	Norgard	15/05/2015	16/05/2015	NASA/JSC	USA	Curtin	International
164		Christopher	Jordan	25/05/2015	31/07/2015	University of Tasmania	Australia	Curtin	National
165		Anne	Pellerin	28/05/2015	12/06/2015	State University of New York	USA	UWA	International
166		Julia	Scharwaecher	8/06/2015	8/06/2015	Observatorie de Paris	France	UWA	International
167		Laura	Shishkovsky	9/06/2015	19/08/2015	Michigan State University	USA	Curtin	International
168		Duncan	Farrah	11/06/2015	11/06/2015	Virginia Tech University	USA	UWA	International
169		Simon	Berry	11/06/2015	11/06/2015	SKA OrganiSouth Africation	United Kingdom	UWA	International
170		Gary	Davis	12/06/2015	12/06/2015	SKA	Australia	Curtin	National
171		Kate	Gunn	16/06/2015	16/06/2015	CAASTRO	Australia	UWA	National
172		Ewan	Barr,	16/06/2015	18/06/2015	Swinburne University	Australia	Curtin	National
173		Hazel	Martindale	25/06/2015	1/12/2015	University of Sussex	United Kingdom	UWA	International
174		Edoardo	Tescari	29/06/2015	1/07/2015	University of Melbourne	Australia	UWA	National
175		Antonia	Rowlinson	29/06/2015	30/06/2015	CSIRO	Australia	Curtin	National
176		Adela	Kawka	30/06/2015	30/06/2015	Astronomical Institute, The Czech Academy of Sciences	Czech Republic	Curtin	International
177		Vanessa	Moss	30/06/2015	2/07/2015	CAASTRO/University of Sydney	Australia	Curtin	National

APPENDIX C
HIGH LEVEL RISK REGISTER

International Centre for Radio Astronomy Research High Level Risk Register							High Level Updated	Risk Register 20.05.2015
ID	**Category**	**Specific Risk**	**Causal Factors**	**Control**	**Likelihood**	**Consequence**	**Residual Risk**	**Comments/ Responsibility**
		SKA Specific Risks						
R1	Strategic National	The RFI excellence of MRO is compromised	Failure of State and/or Federal Government to protect the Radio Quiet Zone, or by an unforeseen intervention of a third party, the radio frequency interference of the MRO is compromised.	Ensuring significant ICRAR involvement in WA government planning processes; Maintain strong ICRAR links to the State Minister for Science and the Premier; Broad ICRAR participation in the ANZSCC; MRO and regional support mechanisms, including EMC certification processes	Possible	Major	High	WA Government, ACMA, Industry, CSIRO, Mining interests
R2	Strategic National	ASKAP completion is delayed and/or capabilities are reduced	ASKAP is not completed on a timescale, nor with the capabilities, to allow ICRAR's survey science return before 2019.	Work closely with CSIRO on ASKAP planning and ensuring CSIRO and National funding priorities identify ASKAP needs.	Possible	Major	High	CSIRO, ANZSCC
R3	Strategic International	SKA delays result in ICRAR running out of funds to support pre-construction teams	SKA Phase 1 rebaselining, the establishment of procurement policies and the creation of an intergovernmental organization, result in delays to Phase 1 construction start and Phase 2 pre-construction opportunities. The ICRAR II budget foresees funding for pre-construction commitments until mid 2017. There is a potential short fall in staff funding to bridge staff from the pre-construction to construction phase.	ICRAR leadership in international SKA program. Coordination with ANZSCC on Australian and WA support for the pre-construction to construction transition Strong ICRAR - SKAO links	Likely	Major	Extreme	SKAO, CSIRO, ANZSCC
R4	Strategic International	SKA1 baseline design does not contain data intensive research support, archival systems or high level data product support	The current baseline design of the SKA 1 does not include a data archive nor science operations systems for advanced data products (e.g. surveys), data quality control, data curation and data distribution. Similarly the 65 MEuro operations budget (22 MEuro per site) does not contain all science operations costs. These areas are of significant interest to ICRAR and their absence would limit the availability of SKA project funds to contribute to the longer term sustainability of ICRAR. Furthermore, UK funding will seek to pull data focus initiative and opportunities to UK.	Contribute to the development of a realistic operations model for SKA 1 which includes archives and a Regional Centre Concept ICRAR leadership in international SKA programs plus coordination with ANZSCC on Australian priorities for SKA science funding and infrastructure as part of construction and operations Strong ICRAR - SKAO links - develop strong SKA-data science case	Likely	Major	Extreme	SKAO, ANZSCC
R5	Strategic International	SKAO procurement policies and resulting national priorities do not allow WA and ICRAR engagement in SKA construction phase opportunities	The definition of the SKAO procurement policies and the resulting national priorities, funding shares and returns may see technology oriented contracts and opportunities, and WA returns in general, be allocated to parties outside of WA.	Strong ICRAR roles in consortia and with industry ICRAR coordination with ANZSCC and OoS on WA and National priorities and capabilities Strong ICRAR - SKAO links on unique ICRAR capabilities	Possible	Major	High	SKAO, OoS, ANZSCC
R6	Strategic International	SKA 1 does not receive construction funding	SKAO does not convince governments to provide SKA Phase 1 construction funding due to a lack of confidence of the parties, underperformance of SKAO, a failure to reach preconstruction objectives and/or external global financial factors	ICRAR promotion of SKA internationally within ANZSCC program; ICRAR leadership in international SKA programs; Strong ICRAR - SKAO links	Possible	Major	High	SKAO, SKA Board, ANZSCC
R7	Strategic International	SKA Hosting Agreement and SKAO Presence in Australia compromises ICRAR leadership opportunities	The form of onshore presence chosen by SKAO, and supported Federally, does not allow ICRAR a clean and direct relationship with SKAO nor the opportunities to lead in important project areas. The definition and funding of a SKA Regional Centre is central to ICRAR's sustainable future.	ICRAR to work closely with SKAO, CSIRO and ANZSCC to ensure ICRAR capabilities are recognized ; ICRAR leadership in international SKA programs; Strong ICRAR - SKAO links	Unlikely	Major	Moderate	SKAO, ANZSCC, CSIRO
R8	Strategic International	SKA funding from contributing parties is routed through national agendas and priorities e.g. DOME project	Participating countries place their national priorities over and above the global science project and routed resources that benefit national agendas while contributing to the SKA project. This has been accentuated by the UK contributions to construction and their stated priorities.	SKA Board to define clear guidelines on cash and in-kind contributions and contribution mechanisms	Possible	Major	High	SKA Board, SKAO
		ICRAR Specific Risks						
R9	Management	Non-delivery of commitments	ICRAR Fails to deliver on commitments due to dependence on and delays in external projects e.g. ASKAP and Pawsey	ICRAR to develop mechanisms to monitor the progress of external projects e.g. ASKAP and Pawsey and advice ICRAR Board and STAC of potential impacts	Possible	Major	High	Director
R10	Strategic	ICRAR is unable to commit to long-term construction and operational roles due to its governance or nature as a JV	ICRAR is unable to secure a long-term connection to the construction and operational on-shore aspects of the SKA project due to the lack of long-term support or legal capacity	Engage in discussions within ANZSCC, CSIRO/ICRAR Boards, JV partners and WA government on long-term role of ICRAR and the nature of any on-shore SKA HQ in Perth	Possible	Major	High	ICRAR Board and Director
R11	IP	ICRAR fails to safeguard IP and looses opportunities of commercialisation	Due to inadequate IP management practices and culture of IP awareness in ICRAR staff, students and management, ICRAR can potentially loose IP and IP commercialisation opportunities	ICRAR has developed an IP management Plan and has an IP Manager on board to educate and train ICRAR staff and students in IP Management. ICRAR Finance and Audit Committee maintains a regular monitoring of IP matters and the Board is updated on IP matters in all Board meetings.	Unlikely	Major	Moderate	Director
R12	Strategic	The Joint Venture fails to maintain cohesion	The Joint Venture parties fail to work together; ICRAR fails to maintain an integrated, single organisation	Ensure sound working relationships through the JVA, SFA and CAA; Ensure science and technology priorities determine investment; Remove barriers of free movement of staff, provide collaborative incentives and ensure uniformity of image, promotion and attribution (ICRAR communications plan).	Unlikely	Major	Moderate	ICRAR Board and Director
R13	Strategic	Failure in competition and failure to emerge as an international brand	ICRAR fails to meet and match the marketing efforts of competitors. Though lack of proper planning and exposure, ICRAR fails to emerge as an international brand	Appropriate investment in outreach and international/national scientific engagement/ collaboration.	Unlikely	Major	Moderate	Director

R14	Safety and Health	Inability to provide safe, healthy, supportive and equitable working environment in workplace and field trips	Due to lack of duty of care/proper planning, ICRAR Management fails to provide a safe and healthy working environment of staff. Students, visitors and contractors. Failure to plan for safety on field trips of rural and remote areas of MRO. ICRAR fails to perform its duties as a POTENTIAL Person Conducting Business or Undertaking (PCBU) under the new harmonised safety laws.	ICRAR to ensure that the Safety and Health policies of both the universities are followed by all ICRAR staff, students, visitors and contractors. Ensure all supervisors are made aware of their responsibility towards following the safety and health policies and regulations. Ensure proper implementation of safety and health practices at both the nodes of ICRAR. Include SAFETY as an agenda item in all meetings to enhance safety consultation and communication. Design and develop the required safety measures for site visits to MRO and for site work at MRO.	Unlikely	Major	Moderate	Director
R15	Financial	Inability to maintain cash flow and control over budget & expenditure	Due to poor monitoring of budgets, ICRAR Management fails to ensure provision of adequate cash flow and control over budget to enable ICRAR to meet its commitments for five years of its current duration.	ICRAR Management, Finance and Audit Committee and the ICRAR Board to regularly monitor the cash flow and the quarterly budget reports to ensure that ICRAR is always maintained in a financially viable state.	Rare	Major	Moderate	Finance and Audit Committee and Director
R16	Information	Data Protection	ICRAR, due to inadequate IT infrastructure, systems and support is unable to unable to protect its scientific and administrative data	Ensuring through the IT Departments of the two universities availability of adequate infrastructure and support to process and protect ICRAR data with adequate testing of backup protocols.	Rare	Major	Moderate	Director
R17	Compliance	ICRAR fails to comply with and fulfil the requirements of the State Funding, Joint Venture and or Centre Agent Agreements	Due to poor planning, processing and monitoring of compliance requirements, ICRAR Management fails to meet the obligations under the State Funding, Joint Venture and or Centre Agent Agreements and is in breach of the agreements.	ICRAR Management, Finance and Audit Committee and the ICRAR Board to regularly monitor and maintain an oversight of the ICRAR compliance requirements. ICRAR Management is developing a compliance register to ensure that all requirements are met. The compliance registered will be monitored by the Finance and Audit Committee.	Rare	Major	Moderate	Director
R18	Academic - Research	ICRAR fails to provide the research ambiance and the environment to support world class research and innovation	Due to lack of academic leadership, vision and mentoring, ICRAR is unable to provide the required research environment conducive for innovative research.	All Research staff & students to have the opportunity of professional development, mentoring and encouragement to develop their research potential and research expertise. ICRAR will achieve this through a structured program for each researcher developed by the supervisor through induction, PDR process and regular meetings. ICRAR Director, senior staff & research supervisors to provide the academic leadership to all early career staff.	Rare	Moderate	Minor	Director
R19	Academic - Education and Training	ICRAR fails to recognise emerging skills needs for SKA and related mega science projects and fails to create the trained manpower for future.	Due to lack of academic leadership, vision and creation of appropriate training programs, ICRAR is unable to take emerging opportunity to create and provide the skilled manpower required for the SKA project and the supercomputing and data needs associated with SKA despite being a JV of two leading universities.	ICRAR Board, Director, Management and ICRAR academic teams to make strategic efforts for ICRAR to create meaningful education and training programs to develop the skilled workforce required for new emerging opportunities that relate to ICRAR's core activities while adding a new dimension.	Unlikely	Major	Moderate	Director
R 20	Growth	ICRAR fails to see new emerging opportunities on the horizon for growth and expansion and also fails to create its niche in a growing need and demand area e.g. Big Data	Due to resource constraint, lack of flexibility and over commitment of existing resources, ICRAR is unable to undertake new opportunities that can enable ICRAR to build on its existing capability, create new direction and expansion. A good example is the rapidly emerging field of Big Data. ICRAR can be a world leader in Big Data to provide expertise to deal with the Big Data not only coming from the SKA but from any other generic source. Including opportunities to create targeted educations and training programs to meet the skills needs of these emerging areas.	ICRAR Board, ICRAR Director, Management and ICRAR academic teams to make strategic efforts for ICRAR to be part of the Big Data effort and other new emerging opportunities that relate to ICRAR's core activities while adding a new dimension.	Unlikely	Major	Moderate	Director
R 21	Sustainability	ICRAR fails to secure a long term self sustainable future for itself beyond 2019	Due to lack of forward planning and funding opportunities, ICRAR may fail to emerge as a long term sustainable R&D organisation that is closely linked to the SKA and other major international radio astronomy projects.	ICRAR Board and Management with relevant stakeholders, to undertake adequate forward planning to map the log term future and sustainability options for ICRAR in the initial phase of ICRAR II. ICRAR to map all potential future roles it can take as an organisation and the funding opportunities available to ICRAR beyond 2019. These tasks are now be addressed within the ICRAR Strategy Committee.	Possible	Major	High	ICRAR Board and Director

APPENDIX D

ICRAR REVIEW REPORT BY

DELOITTE ACCESS ECONOMICS

CONFIDENTIAL REMOVED

APPENDIX E

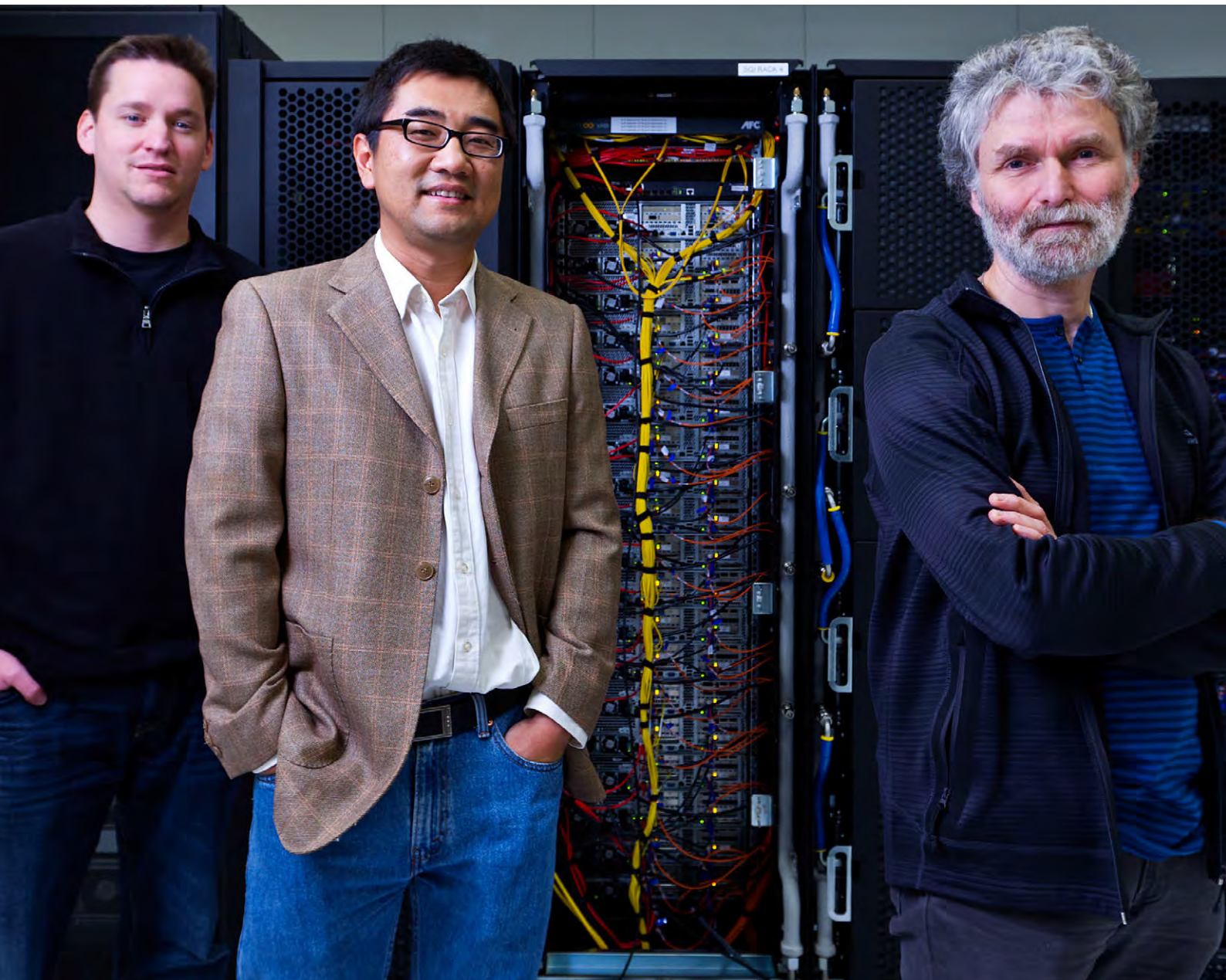
DIA BIG DATA BROCHURE

ICRAR

International Centre for Radio Astronomy Research

DATA INTENSIVE ASTRONOMY

Imagining leading edge solutions for unimaginable volumes of data.



Data Intensive Astronomy –a new industry partner

In this brochure we introduce the capabilities, partners and current projects of our Data Intensive Astronomy team.

Exploring the entire Universe through space and time, from now to the very first stars and galaxies that existed more than 10 billion years ago, is an unparalleled feat of human scientific endeavour.

The volume of data generated by new and planned observatories is currently doubling every six to 12 months—faster than the rate of increase in performance of computer chips (Moore's Law).

Such a challenge is costly and creating the biggest astronomical research facilities in the world is beyond the funding capabilities of individual universities, research organisations and even nations.

For this reason, collaborative alliances of organisations and nations are being formed to fund, build and manage the data of the next generation of telescopes.

This expansion and globalisation of research raises a number of major technical and organisational challenges that need to be tackled and solved by researchers, funding bodies, industries and governments.

In all cases, the challenges of managing, exploring and sharing the huge volumes of digital information flowing from these new global facilities is focusing and leading the international discussion.

We are seeking opportunities to work collaboratively with industry partners who are facing similar challenges as they explore the natural resources of our planet.

Cover L→R Dave Pallot, Dr Chen Wu and Professor Andreas Wicenec from ICRAR's Data Intensive Astronomy Team

Introducing our Data Intensive Astronomy & Science teams

DATA TEAM
PROFESSOR ANDREAS WICENEC

Professor Andreas Wicenec completed a PhD in Physics and Astronomy at the University of Tübingen in Germany.

Having worked for some of the world's premier astronomical research facilities, Andreas has a wealth of experience in the design, implementation and operation of large volume, global data flow and management systems.

For the European Space Agency's Hipparcos satellite Andreas developed data management systems as well as photometric and astrometric data reduction techniques. He then went on to implement the back-end archive system for the European Southern Observatory's Very Large Telescope.

In Chile, for the Atacama Large Millimeter Array, Andreas designed the radio telescope's archive sub system, and for the Murchison Widefield Array located in outback Western Australia, he designed and implemented the archive and data distribution system.

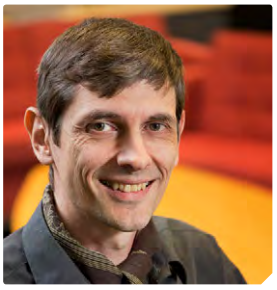
Now, Andreas is leading ICRAR's Data Intensive Astronomy program to research, design and implement data flows and high performance computing systems for current and future observatories and large-scale astronomical surveys.

DATA TEAM
MARKUS DOLENSKY

Markus Dolensky is a computer scientist and the Technical Leader for ICRAR's Data Intensive Astronomy Group.

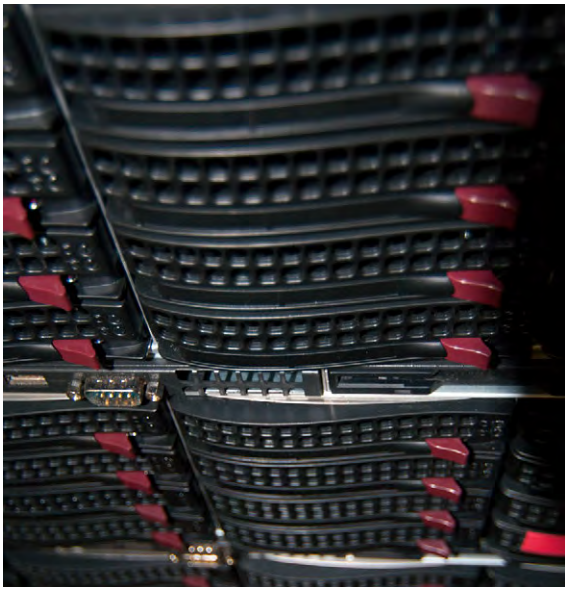
Originally from Austria, Markus has held positions in industry and in several of the world's premier astronomy research institutions, working on projects involving ground and space based missions.

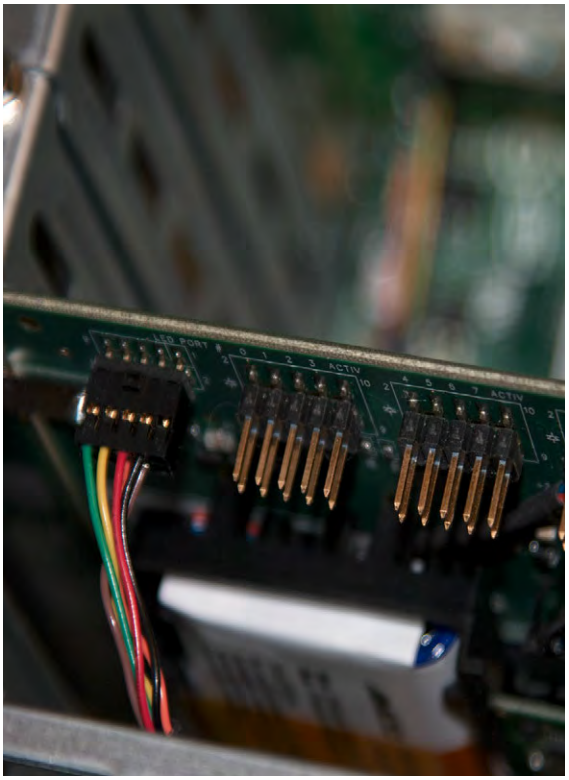
Top Prof. Andreas Wicenec
Below Markus Dolensky



The SKA & ICRAR

The Square Kilometre Array (SKA) will be the biggest and most capable radio telescope ever built. It will expand our understanding of the Universe and drive technological development worldwide.





The International Centre for Radio Astronomy Research (ICRAR) is a joint venture between Curtin University and The University of Western Australia with additional funding from the State Government of WA.

ICRAR was designed to be a multi-skilled institute of astronomers, engineers and data specialists that could support the build up of the SKA in Australia through design, construction and ultimately operations.

In 2014, Deloitte Access Economics identified ICRAR as being one of the top five centres of its kind in the world.

ICRAR's Data Intensive Astronomy (DIA) team, located at the Centre's UWA node, is comprised of researchers from astronomy and industry who have led the development of data and operations systems for billion-Euro astronomical infrastructures in Europe and South America.

In Australia, our ability to lead science projects on pathfinder facilities like the Australian SKA Pathfinder (ASKAP) and the Murchison Widefield Array (MWA), and to design and deploy end-to-end prototype SKA systems into the field, has placed the Centre at the forefront of the international SKA project on several key developments.

The SKA will come online in the next decade and when it does, it will produce a relentless stream of science data products that are exascale in terms of their storage and processing requirements.

ICRAR's DIA team are now leading the international effort to address the challenges surrounding the flow of data within the SKA observatory.

After graduating from the Vienna University of Technology, Markus took a position with GePARD as a software engineer, playing an important role in the development and integration of the Meteosat-6 Anomaly Correction Software deployed at ESOC and the EUMETSAT ground segment that saved the mission.

Then, as a scientific systems analyst for the European Space Agency, Markus went on to design and develop a novel on-demand data processing framework for the Hubble Space Telescope, before pioneering the Virtual Observatory as technical lead and project manager at the ESO.

Markus recently moved to Australia to take on one of the biggest challenges in data intensive computing - designing the data layer for the exascale Science Data Processor of the Square Kilometre Array.

DATA TEAM
MARK BOULTON

Over the past 25 years Mark has held positions in several large multinational companies, working on systems for national and international defence and other large government projects.

Prior to joining ICRAR in 2011, Mark helped design and integrate the front-end systems for Auckland Transport's smart card public transport ticketing system, as well as the ground support systems for the Australian Multirole Helicopter, and was the lead designer for an Intelligent Transportation System network for Queensland Motorways.

Mark is now the Senior Systems Engineer for ICRAR's Data Intensive Astronomy team. He is responsible for the management and support of ICRAR's Petabyte storage servers and is helping to design the data layer for the Square Kilometre Array.

Right Mark Boulton

The Data Deluge

The widening gap between the end user's capabilities to download and process data and the size of the source data sets is driving a major paradigm shift in the way large research data should be processed and accessed.

EACH YEAR, THE SKA WILL PRODUCE 100 TIMES MORE DATA THAN THE WORLD'S INTERNET TRAFFIC IN 2010.

Large data sets and computational resources of the future are likely to be concentrated at data centres located around the world with end users transparently interacting with them.

Data will no longer be migrated from one place to another but rather accessed, processed and explored remotely across a distributed network.

To manage this environment and coordinate these interactions, new software tools and techniques are needed and the Next Generation Archive System, or NGAS as it's commonly called, is one such solution being developed, evolved and used for this purpose.

Originally created under the leadership of Professor Andreas Wicenec, while he was working with the European Southern Observatory, NGAS is being used by many of the world's major astronomical observatories.

Today, ICRAR's version of NGAS has been optimised and finetuned to deal with far higher data rates and volumes than initially possible. It has also been adapted to run in both supercomputing and cloud based environments, and to support the integrated usage of cloud resources for scientific analysis.

The NGAS infrastructure is currently used to control many Petabytes of data stored in hundreds of millions of individual files, distributed and mirrored across four continents, while providing transparent access for end users.

These innovations are not limited to astronomy and have the potential to overcome similar challenges faced by industry now, and in the future.

DATA TEAM
IAN COOPER

Before joining ICRAR, Ian Cooper worked in the satellite communications industry for more than 20 years.

As a Product Manager he led a team of engineers responsible for the certification of Land, Maritime & Aeronautical mobile satellite communications products, which provided both commercial communications and distress and safety systems.

In 2010 Ian started the SwiftBroadBand Satellite (SB-SAT) program, jointly funded by DARPA and the European Space Agency. This system used geostationary satellites to provide an 'always-on' data relay capability for Low Earth Orbit satellite payloads, with applications including weather, imaging and high speed connectivity.

Ian is now ICRAR's Deputy Project Manager for the SKA Science Data Processor.

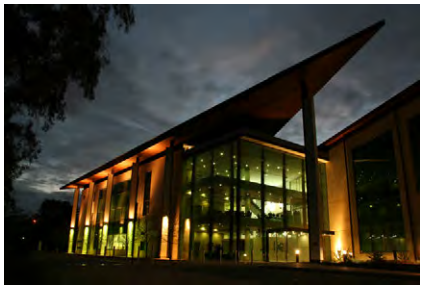
DATA TEAM
DR RICHARD DODSON

Dr Richard Dodson has held research positions at several Australian universities and worked for a number of overseas institutes including the Japan Aerospace Exploration Agency, the National Observatory in Spain and the Korea Astronomy and Space Science Institute.

He is currently investigating ways to export the computing effort required to complete the science analysis of SKA-scale datasets. This is important, as it is probably the only effective way to handle the computing requirements.

Richard is the Project Scientist for ICRAR's Data Intensive Astronomy team and with expertise encompassing both astrophysics and computer science, he is well suited to acting as an interface between big science and big data.

Top Ian Cooper
Below Dr Richard Dodson



Current Projects

SKA SCIENCE DATA PROCESSOR

The Square Kilometre Array Science Data Processor (SDP) work package is responsible for the data reduction, long term archiving and dissemination of the vast data streams delivered by the SKA front-end signal processing systems.

Essentially we are connecting an enormous sensor network directly to a configurable and flexible HPC system and streaming data through a Wide Area Network (WAN) from hundreds of kilometres away into memory and high performance non-volatile storage.

Researchers and industry partners from 14 countries are involved in this significant project for the SKA and our team at ICRAR is responsible for the 'Data Layer'. This is the part of the SDP system which will handle all aspects of data management, from receiving the data streams through to distributing them to thousands of individual compute nodes, triggering the processing steps, collecting the intermediate and final results and then providing access to those results for the global astronomical community.

At its core, the architecture for the Data Layer is a fairly generic design and is applicable to a whole range of data intensive and data driven applications.

SURVEY SCIENCE SUPPORT

ICRAR'S DIA team directly supports the various survey science activities being conducted by our scientists. This research uses data gathered from telescopes imaging the distant Universe across a broad spectrum of wavelengths. This in turn implies a large variety of different algorithms and data formats and results in challenges for the optimal deployment and usage of the available IT infrastructure. The team provides expertise to solve and optimise algorithms and the tasking of available computing resources.

SYSTEM SUPPORT

To support the work of our science teams we operate a data and computing lab. The equipment in this lab includes standard compute servers, a small GPU cluster with Infiniband interconnect and an ample amount of storage.

Through our collaborations with high performance computing providers and vendors we often have access to new and exciting technologies that we trial and evaluate.

DATA TEAM
DAVE PALLOT

Over the past 16 years Dave Pallot has held various engineering positions in the telecommunications and resource sectors with experience in IT administration, software and systems engineering.

Prior to joining ICRAR in 2010, Dave designed process control solutions for BHP Billiton, as well as designing and commissioning protocol stacks for voice and data solutions, and was a telecommunications officer for the Department of Defence.

Dave is now an ICRAR Engineer working on various projects including the data archive for the Murchison Widefield Array and the Square Kilometre Array's Science Data Processor.

DATA TEAM
KEVIN VINSEN

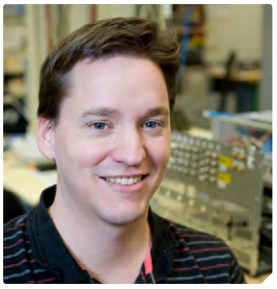
Before coming to ICRAR, Kevin Vinsen was a chief software engineer for Thales, one of Australia's leading defence contractors.

Kevin's research interests now relate to the big data issues facing the SKA. These include high speed data ingest, software engineering for large distributed software teams, data life cycle and optimising high performance computing code.

Currently, he is developing new techniques for the automated classification of galaxies using multi-wavelength data and advancing Spectral Energy Distribution calculations.

Kevin is also providing data support for large galaxy surveys such as GAMA and CHILES and is the project scientist for theSkyNet, a citizen science initiative that links thousands of computers around the world to simulate a powerful supercomputer.

Top Dave Pallot
Below Kevin Vinsen



Top An artists impression of what the SKA's low frequency antennas will look like.

Middle ICRAR headquarters at The University of Western Australia.

Bottom A simulated image of a dwarf galaxy forming several billion years ago. **Credit** Dr Alan Duffy (ICRAR), Paul Bourke (iVEC@UWA), Dr Robert Crain (Leiden Observatory).

DataDirect™ NETWORKS

"Our collaborative work with ICRAR has included the development of a software platform in virtual space within a storage controller to enable a reduction of latency for filtering and processing large data sets.

We feel strongly that the development of any product must directly address specific needs and cannot be done strictly in a laboratory environment. Our collaboration with ICRAR ensures that our product will address the needs of an organisation that is tasked with efficiently reducing, managing and distributing large data sets to a worldwide user community."

Dave Fellinger, Chief Scientist - DDN

ThoughtWorks®

"ThoughtWorks has been proud to work with ICRAR bringing agile software development methods to their data intensive applications. The breadth of work undertaken by ICRAR has given us the ability to adapt our tools and processes to address a wide range of data intensive applications.

We are using these adaptations already, as data intensive applications are becoming more mainstream in the business world, and not just in the scientific computing realm."

Rebecca Parsons, Chief Technology Officer - ThoughtWorks

SYSTEMIC

"Our work with ICRAR has involved many aspects of Big Data and Data Sciences systems engineering, especially in the area of managing the preparation and distribution of the massive quantities of data generated by the SKA.

The enormous data sets involved have given our organisation insights and experience beyond what is typical in our industry. This gives us a head start and a significant competitive advantage as data volumes increase across other industry sectors and Big Data and Data Science in general become more pervasive."

Greg Salotti, Chief Executive Officer - Systemic

DATA TEAM
DR CHEN WU

Dr Chen Wu grew up in China and worked as a software engineer and a researcher at the Chinese Academy of Sciences before moving to Perth to undertake a PhD in data retrieval and storage and then postdoctoral research in pattern recognition.

Currently, Chen is developing a coherent approach towards cost/performance optimal data management in accordance with the data life cycle requirements of various radio astronomy science cases.

Chen is leading the Data Lifecycle Management and Persistent Storage work package for the SKA's Science Data Processor international consortium.

SCIENCE TEAM
PROFESSOR PETER QUINN

Professor Quinn received his BSc (Hons) in Mathematics and Physics from the University of Wollongong in 1978 where he received the University Medal in Physics. He conducted graduate studies in astronomy and astrophysics at the Australian National University and received his PhD in 1982.

During postdoctoral appointments in Theoretical Astrophysics at the California Institute of Technology (1982-1985) and the NASA Space Telescope Science Institute (1985-1989) Peter pursued his research interests in galaxy formation and dynamics, cosmology and dark matter. His work on computational astrophysics was awarded a NASA High Performance Computing and Communications Grand Challenge Award.

In 1995, Peter accepted a position as Division Head of the newly formed Data Management and Operations Division at the

Top Dr Chen Wu
Below Professor Peter Quinn

CASE STUDY: THE NATIONAL RADIO ASTRONOMY ORGANISATION

The Next Generation Archive System (NGAS) was adopted by the National Radio Astronomy Observatory (NRAO) as a strategic partnership with the international Atacama Large Millimeter/submillimeter Array radio telescope while Professor Andreas Wicenec was the lead architect for the telescope's data archive sub-system at the European Southern Observatory (ESO).

NRAO also deployed NGAS with great success to support the observational data archive for the Karl G. Jansky Very Large Array and the Very Long Baseline Array, and is now in the process of implementing at the Green Bank Telescope.

NGAS has provided over three petabytes of aggregate archive storage at NRAO, implemented with diverse site storage for increased availability, enabling NRAO to fulfil its ongoing commitment to preserve all standard observations in perpetuity — even as the data rates from its instruments have increased exponentially.

This unique architecture has the advantage of embedding the processing for archive data management within the storage subsystems, allowing for near-infinite scalability with commodity component storage hardware. This in turn has allowed for an exceptional price/performance value proposition to be realised at a time of ever increasing budget pressure. The insight and support of Professor Wicenec and his team at ICRAR continue to be of substantial benefit to the NRAO and the broader astronomical community.

Left Top The Atacama Large Millimeter/submillimeter Array (ALMA) in northern Chile. **Credit** ESO/NAOJ/NRAO.

Right Bottom The ALMA telescope. **Credit** P. Carillo - ALMA (ESO/NAOJ/NRAO).

The Green Bank Telescope operated by the NRAO in West Virginia, USA. **Credit** ESO/NAOJ/NRAO.

European Southern Observatory headquarters in Munich. While at ESO, Peter led the efforts to design, implement and operate the science data flow system for the 1 billion Euro Very Large Telescope–the world's largest optical and infrared observatory. This work was awarded a Computerworld 21st Century Achievement Award for Science.

During his time at ESO, Peter co-founded the International Virtual Observatory Alliance, directed the FP-5 Astrophysical Virtual Observatory project and coordinated the formation of the EURO-VO as a program to realise VO-enabled science for Europe.

In 2005, Peter was awarded a Western Australian Premier's Fellowship and took up the position of Professor of Astronomy and Astrophysics at The University of Western Australia. In 2008, Peter was appointed inaugural director of the new International Centre for Radio Astronomy Research.

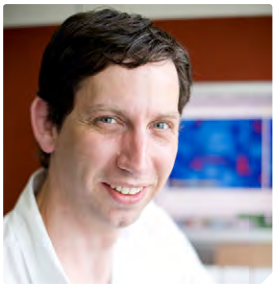
Since then Peter has been named the WA Scientist of the Year and made a Fellow of the Australian Academy of Technological Sciences and Engineering.

SCIENCE TEAM
DR MARTIN MEYER

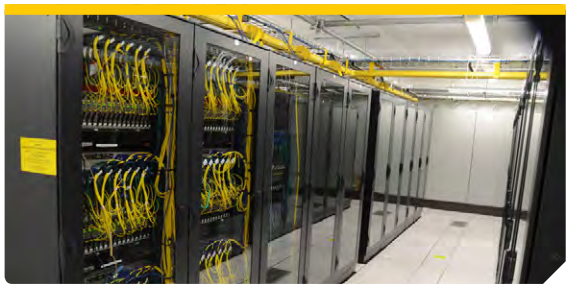
Dr Martin Meyer is Senior Research Fellow at The University of Western Australia node of ICRAR. He completed his PhD thesis "Neutral Hydrogen in the Local Universe" at the University of Melbourne using data from the Parkes radio telescope, before moving to Space Telescope Science Institute in the United States, where he worked on data from the Spitzer and Hubble space observatories.

Martin is an expert in large surveys of neutral hydrogen and since returning to Australia has focused his research efforts on the development of new deep surveys to understand the evolution of neutral gas across cosmic time. He is the Principal

Right Dr Martin Meyer



CASE STUDY: CSIRO



The CSIRO ASKAP Science Data Archive (CASDA) is one of three systems that make up the core computing component for CSIRO's newest radio telescope. This telescope, the Australian Square Kilometre Array Pathfinder (ASKAP), is located at the Murchison Radio-astronomy Observatory (MRO) in Western Australia.

CASDA is the primary point for storing, managing and sharing fully calibrated and science-ready data products. It will also provide the ASKAP Survey Science teams with access to processed data products for analysis.

ASKAP data will arrive at the Pawsey Supercomputing Centre in Perth at a rate of approximately 2.5 GB/s, equivalent to 75 Petabytes per year. ASKAP data processing must therefore be carried out in quasi-real time using automated pipelines to produce data products and associated metadata that are stored and made available through the science archive. The total volume of archive data is expected to reach 5 PB per year.

As part of its multi-tiered system, CASDA makes use of ICRAR's Next Generation Archive System (NGAS) to meet data storage and retrieval needs. The CASDA team has been working closely with Professor Andreas Wicenec and his team to extend NGAS's integration with the hierarchical storage layer and to support the large files produced by the ASKAP pipelines.

Top Super Computer racks in the control building of the Murchison Radio-astronomy Observatory (MRO). **Credit** CSIRO.

An aerial voew of the core of the Australian SKA Pathfinder radio telescope at the MRO in outback Western Australia. **Credit** CSIRO.

Investigator of the DINGO HI survey on the ASKAP radio telescope, a project that surveys the gas content of galaxies over the past 4 billion years, and is a team member of corresponding deep HI surveys on MeerKAT and the Very Large Array.

SCIENCE TEAM
DR ATTILA POPPING

Dr Attila Popping has been with ICRAR at The University of Western Australia since the end of 2010. He completed his PhD thesis in Astronomy at the University of Groningen in the Netherlands, spending a large fraction of his time at CSIRO Astronomy and Space Sciences (CASS) in Sydney.

His research is focused on the distribution of neutral hydrogen (HI) emission in the Universe and he has experience with many major radio observing facilities.

Currently Attila is actively involved in several ongoing and future HI surveys that will all process large data volumes. The most significant is the CHILES survey on the Jansky Very Large Array (JVLA), for which he has developed the imaging pipeline.

Attila is a member of the ASKAP early science and commissioning team and a member of the SKA HI Science Working Group.

SCIENCE TEAM
DR NATASHA HURLEY-WALKER

Dr Natasha Hurley-Walker joined the Curtin University node of ICRAR in 2011, having completed a PhD in Radio Astronomy at the Cavendish Laboratory at the University of Cambridge.

During her PhD studies, Natasha helped to commission the Arcminute Microkelvin Imager, a 15-GHZ radio interferometer, and to carry out surveys for extragalactic radio sources, including clusters of galaxies.

Natasha's expertise in commissioning led to

Top Dr Attila Popping
Below Dr Natasha Hurley-Walker

CASE STUDY:
THE INTERNATIONAL VIRTUAL OBSERVATORY ALLIANCE

The Virtual Observatory framework developed by the International Virtual Observatory Alliance (IVOA) is providing efficient access to astronomical data and services for the world's astronomers. After more than a decade of development this international community-based initiative is transforming the way modern astronomical research is being done.

The Director of ICRAR, Professor Peter Quinn, played a major role in the inception of the Virtual Observatory by leading the first European based project, one of the three inaugural initiatives for the alliance. Peter has been instrumental in defining the IVOA, its role, membership and organisation.

The head of ICRAR's Data Intensive Astronomy team, Professor Andreas Wicenec, was a member of the early Virtual Observatory team at the European Southern Observatory and later re-joined the alliance as the Australian representative having moved to Western Australia and ICRAR.

Collaboration with large astronomical projects is essential for the Virtual Observatory – new projects bring new kinds of data that in turn require new tools and techniques, and ensure the Virtual Observatory initiative remains relevant and sustainable. SKA is of course a prominent element in the landscape and ICRAR obviously has a major role to play in the VO-SKA collaboration.

her performing a critical role in getting the Murchison Widefield Array (MWA) on-line, carrying out the first wide-area radio survey with the telescope and establishing the supercomputing pipelines to process its large volumes of data.

Natasha is the MWA Galactic and Extragalactic Group project scientist and a member of the SKA continuum science working group.

SCIENCE TEAM
DR TOBIAS WESTMEIER

Dr Tobias Westmeier is a Research Fellow at The University of Western Australia node of ICRAR.

Tobias studied physics and astronomy at the University of Bonn in Germany where he completed his doctoral thesis on a study of the high-velocity clouds around the Andromeda Galaxy in 2007. He then moved to Sydney to join CSIRO Astronomy and Space Science as a Bolton Fellow before assuming his current position at ICRAR.

Tobias is the initiator and leader of the SOFIA project, a new source finding pipeline designed to automatically detect and parameterise galaxies in spectroscopic radio surveys. SOFIA is a collaborative effort by radio astronomers from around the world using several novel algorithms to reliably detect signals from very faint galaxies hidden in large data volumes.

Tobias' research interests include the study of neutral hydrogen gas in the Milky Way and beyond, with the aim of understanding its role in the structure and evolution of galaxies. He is involved in several large survey science projects to be carried out with the Australian SKA Pathfinder (ASKAP) and has worked as the ASKAP project scientist in the past.

Right Dr Tobias Westmeier

Far Left An artists impression of a dust torus around a super-massive black hole. **Credit** ESA/NASA, the AVO project and Paolo Padovani.

Right Page The Pawsey Supercomputing Centre in Perth, Western Australia.

CASE STUDY: CHILES

The COSMOS HI Large Extragalactic Survey, or CHILES, is an international collaboration involving astronomers in six continents and ICRAR's Data Intensive Astronomy team.

Using the Very Large Array radio astronomy observatory in New Mexico, this survey will study the same region of sky for 1000 hours spread over several years. By imaging galaxies up to a third the age of the Universe and 4.6 billion light years from Earth, CHILES hopes to provide the most sensitive observations ever made of neutral hydrogen and help researchers better understand how galaxies evolve.

Radio astronomy is becoming extremely data intensive and CHILES is one of the first examples of this new kind of project. The data rate, a Terabyte for every 10 hours of observing, is larger than anything before it.

Reducing and processing such data volumes requires a new approach with large and dedicated computing facilities. This makes the CHILES project not only exciting for astronomers but also an interesting challenge for computer scientists.

Although the project is in its early stages with 200 hours of data in hand so far, ICRAR'S DIA team are playing a crucial role in developing and executing an imaging 'pipeline' for this important work.

CASE STUDY: VICTORIA UNIVERSITY

Victoria University of Wellington (VUW) in New Zealand is one of the partner institutions in the Murchison Widefield Array (MWA) radio telescope and is home to one of the three international MWA NGAS nodes – end points to the data chain that see images and raw data collected from the telescope pushed seamlessly to remote locations from the Pawsey Supercomputer Centre in Perth.

The NGAS node was established in 2012 during MWA commissioning and has been functioning smoothly pushing large volumes of data across Australia and the Tasman to New Zealand.

The provision of the NGAS node in collaboration with ICRAR staff has played a tremendous role in improving the research productivity of the astrophysics researchers in NZ.

Professor Melanie Johnston-Hollitt, Director of Astrophysics at VUW and Chair of the MWA Executive Board says "Working with Andreas and his team to set up this data system has been incredibly easy and efficient and has allowed us to work directly on the 'big data' produced by the MWA. It has been a real pleasure to develop the partnership with ICRAR on the technical side of the big data equations and then to take those data and discover new and exciting things about the Universe."

ICRAR

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APPENDIX F

KPMG AUDIT REPORT
&
AUDITED SPECIAL PURPOSE FINANCIAL REPORT

CONFIDENTIAL REMOVED

END OF ANNUAL REPORT