Curtin University

COLLABORATION BETWEEN RESEARCH INSTITUTES AND INDUSTRY

Lessons learned from the Murchison Widefield Array and applicability to the Square Kilometre Array

A CASE STUDY by Andy Farrant - January 2013

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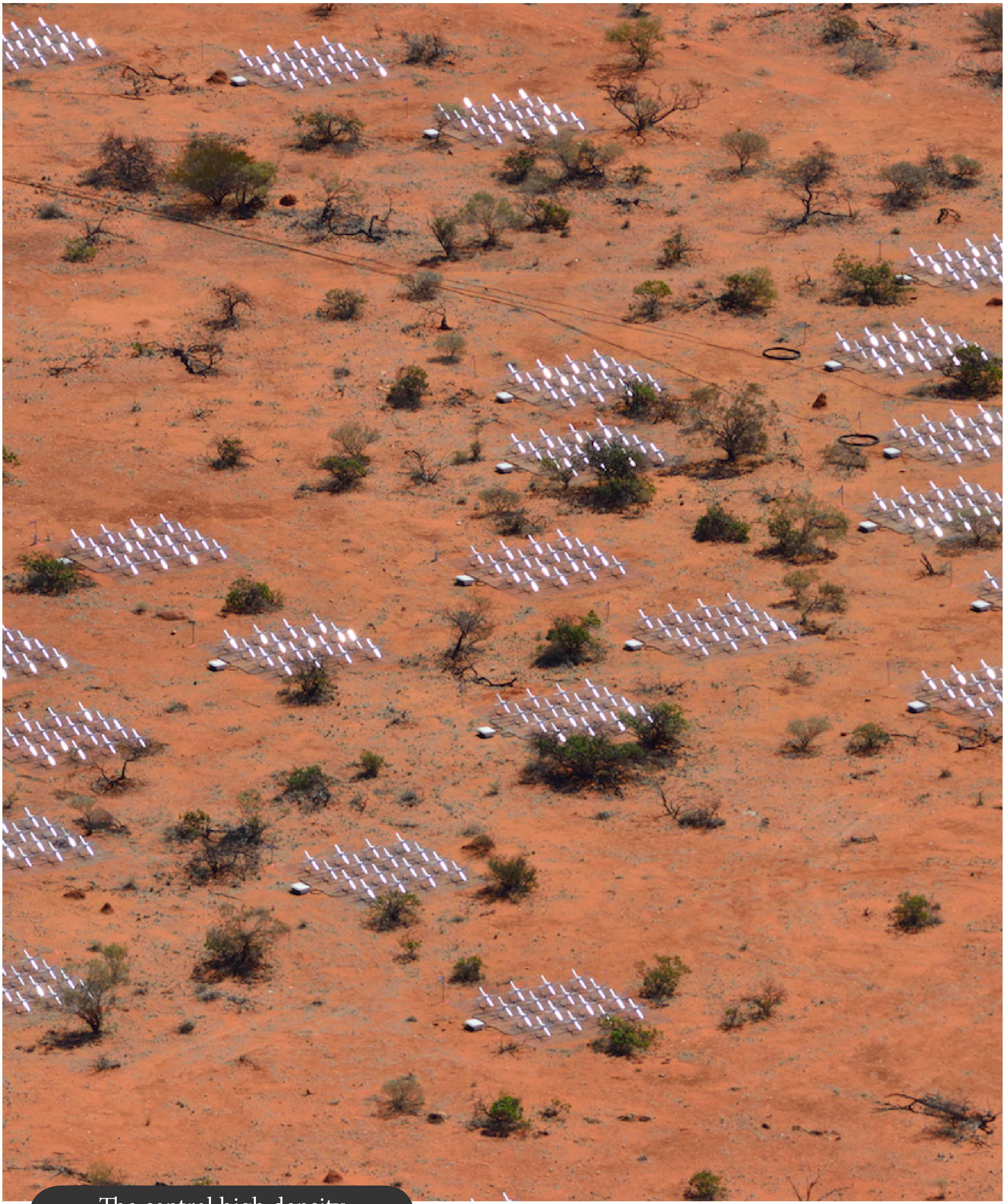

The central high density core of the MWA

EXECUTIVE SUMMARY

One small but significant step towards better understanding the beginnings of the Universe was made when academia and industry came together in Perth, Western Australia; it was a collaborative relationship between an academic research centre and a small specialist company that saw them build a next-generation radio telescope and precursor for the Square Kilometre Array (SKA).

The MWA (or Murchison Widefield Array) is a unique radio telescope with no moving parts. It is driven by high-level computing power and is designed to capture wide-field images of the radio sky. It operates at low radio frequency, giving astronomers the opportunity to 'look back in time' - almost to the beginning of the Universe.

Thirteen research institutions from four countries combined to create the MWA, with a substantial amount of the funding coming from Australian sources. The total value of the project was approximately $50 million; $20 million in cash and $30 million of in-kind contributions over the last seven years from research partners.

In 2008, two years after the first design was completed, the MWA project had stalled. While funding for development had been secured, a combination of lack of appropriately qualified staff, low project focus and the need for additional project configuration led to a worrying period of hiatus. Curtin University's Professor Steven Tingay (and Deputy Director on the International Centre for Radio Astronomy Research when that institute was formed in 2009) was appointed to lead the MWA and he began a search for effective methods to reinvigorate the project.

In an effort to regain momentum, Tingay turned to a small Fremantle-based company, Poseidon Scientific Instruments (PSI), which specialised in radio frequency instrumentation. From tentative beginnings, a collaborative approach emerged which brought the benefits of industry techniques and expertise to this landmark project.

In interviews for this case study, both ICRAR-Curtin and PSI personnel provided examples of how collaboration between the two groups has added great value to the MWA. But a recurring theme and the key finding of this case study - is that it is imperative to bring the researchers and industry personnel together very early in projects such as this.

In the case of the MWA, industry was a latecomer to the scene. This late inclusion led to a range of challenges, which will be discussed below.

In hindsight, both parties shared the view that early contact, open dialogue, opportunity for discussion, and debate focussed on MWA functional requirements and design reviews should have been essential steps, prior to 2008. These would have ensured that assumptions were tested, work imperatives were identified and research objectives were understood by all. Had this approach been applied to the MWA, money would have been saved and the final telescope commissioned earlier.

Yet despite the obstacles, both parties concur that the MWA would not have been built without significant industry participation in its development. Much hinged on the MWA team overcoming its obstacles with its industry collaborator. If the project had been cancelled, it would have significantly impacted on Australia's radio astronomy research and on the international reputation of Australia's research capability. It could even have resulted in Australia being dropped for consideration as a potential site by the Square Kilometre Array (SKA) international consortium.

It can further be argued that academic and industry collaboration delivers wider economic benefits. A significant proportion of the public funds invested in this research project were directed to business, providing employment and business sustainability through the purchase of specialist knowledge. In addition, the MWA commissioning process has provided work for other contractors to deliver infrastructure and services to the MRO site.

No economic study has been carried out on the MWA, but some value can be inferred from the example of the Centres of Excellence program run in Western Australia, as evaluated by the Department of Commerce [1]. These Centres received State Government investment totalling $80.88 million, funds which in-turn attracted a further $626.94 million from external sources. A total economic impact of $1.75 billion is estimated (or a leverage of 2174%) on the original investment over 17 years. The program trained 973 PhD students with 545 individuals being awarded doctorates.

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[1] Department of Commerce, *Research, Knowledge, Innovation: the Renewable Resources!* 2012.

As in the case of radio astronomy research, investment by the State Government in these centres attracts additional resources from other governments, universities and research institutes and industry. This generates an inflow of highly qualified people, significant employment in the knowledge economy and valuable academic outcomes from the research programs.

The SKA project may provide even bigger opportunities and returns for just Western Australia, or for Australia as a whole and the MWA has been a trailblazing project in this respect. However, the challenges for the SKA will be magnified by the scale of the project, and the lessons learned from the MWA will be doubly applicable for the SKA.

RECOMMENDATIONS:

The following recommendations draw on the experiences of the MWA development. In some instances they draw upon effective options adopted by the project partners. In other instances the recommendations are modelled around lessons learned about what not to do in the process of commissioning the MWA.

These recommendations could equally have application to the SKA – in the development of whole- and sub-systems and networks.

Within this paper the word ‘research’ or ‘research institute’ is used to describe universities, national and international research institutions; those centres that apply rigorous processes to diverse studies for the greater benefit to human kind. The word ‘industry’ is used as shorthand for small-medium-enterprises and big business. These are commercial entities that are driven by very different motivations and objectives when compared to those of research. ‘Collaboration’ is the act of sharing ideas, knowledge, effort and expertise for mutual benefit to gain understanding, technical advantage and financial reward in the quest for discovery.

i. Research’s engagement with industry must start at the project functional review stage to enable industry to understand what core objectives of the project are. This single decision will save considerable money and time. Those industry partners can then go away and find relevant solutions to solve functional problems. It will also begin valuable work-team interaction.

ii. Research needs to attract appropriate development funds to engage industry early. This early investment will save project expense and deliver a more cost effective instrument.

iii. There is an important order of activity which leads to the efficient and effective design of a research tool; 1. functional review phase, 2. design phase, 3. design review phase and 4. operations phase. Each requires differing input from industry and research. The functional review phase (what is the job of this research tool?) requires input from both parties. Design phase (what are the elements and systems needed to fulfil the research tool’s function?) should involve industry only. Design review phase (are there better ways of achieving the function with improved design? – NB: this is not an opportunity to add to the function) should involve both teams, with industry taking the lead. Operations phase (making the tool work and improving its capacity and sensitivity) possible short input from industry with the lead from the research team.

iv. Research must appoint a project manager who is experienced, clear eyed, who is good with people and has demonstrated high-level management and communications skills. This person will be the key driver of the project development.

v. Both industry and research need to provide and resource appropriate project management personnel and ensure that technical staff are not distracted by this function.

vi. Research should be aware that a flexible approach to procurement processes will be required. Introducing small groups of potential contractors to solve function-level problems will allow industry insight to the challenges of the project. This sharing of knowledge will also enable research to review how different potential contractors respond and offer solutions. The effect of this will be the maintenance of goodwill and growth of loyalty from industry partners who are selected to undertake the work.

vii. Industry and research must make time for cross-team interaction. Tasks include: define the project requirements, explain methods of work and the work drivers, identify skills crossover and gaps, build a sense of team and open communication. Get to know your collaborator's work environment and day to day realities.

viii. Research must explain the constraints and challenges of funding sources – their drivers and timelines. This understanding can assist in project flow and contribute greatly to the final outcome.

ix. Research should not attempt to 'deal in' research partners into the design process. While this may appeal at first glance, it adds unnecessary complexity, cost and time delay to the project.

x. SKA project leaders should evaluate the Australian Rapid Prototyping, Development and Evaluation (RPDE) model as a potential structure to support meaningful exchange of design, manufacture and commissioning expertise with industry.

xi. SKA project leaders may also find value in the Fundamentals Input to Capability (FIC) structure used by the Australian Defence Force [2].

xii. The SKA should ensure that there is time allowed to manage and reduce the need for regulatory compliance. Exemptions to Australian Standards and regulations must be identified and secured. Failure to do so will add significant cost and delay to the project.

xiii. Research must build the costs of industry interaction, including travel, into the project budget. The cost of not adopting meaningful engagement will far outweigh the cost of early and regular collaboration.

xiv. Research must remember industry is made up of large and very small entities – don't

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[2] See http://www.defence.gov.au/capability/_pubs/dcdm%20chapter%201.pdf

just look to the large companies to solve all the problems, because many things will be outside their skill-set. It is often small companies with specialist knowledge that are able to be flexible and add value to design and development aspects.

INTRODUCTION

The opportunity to build new research tools, explore the big questions on the origins of the Universe and create strong collaborative relationships with industry is a rare and privileged occurrence. Each of these occurred in the development of the uniquely designed Murchison Widefield Array radio telescope.

This document is part case study and part commentary. It examines the challenges, opportunities and outcomes of a dynamic collaboration between industry and research institutions, in the advancement of radio astronomy.

It uses as its case study the design and construction of the Murchison Widefield Array (MWA) [3] receivers for ICRAR-Curtin University.

These low frequency (80-300MHz) receivers are a core component of one of the two radio telescopes commissioned at the Murchison Radio-astronomy Observatory (MRO) in the remote Murchison region of Western Australia. The second telescope is the Australian Square Kilometre Array Pathfinder (ASKAP). Both telescopes are precursor projects for the Square Kilometre Array, a huge international radio astronomy facility that will also have telescopes built at the MRO.

The process of design and manufacture of the MWA receivers has been recognised within the Australian radio astronomy community as a rare and successful collaboration, in this instance between ICRAR-Curtin and PSI.

This document seeks to identify steps applied in the making of the MWA that give direction for potential future collaborations between industry and research organisations. The examples illustrate:

- The successful elements of the relationship
- The opportunities for greater success
- Gaps or errors that were identified during the process.

The paper's purpose is threefold:

- To outline what was learned from the development of this project.
- To provide evidence of how significant value can be leveraged by research institutes in actively seeking out industry expertise and collaboration. It provides detail of the steps needed to gain maximum value from this relationship.
- To explain to industry how best to engage with research teams; identify where challenges lie, cultures don't match and demonstrate the opportunity for new business with this sector.

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[3] For more about the MWA see www.mwatelescope.org and www.facebook.com/murchison.widefield.array

PROJECT DEVELOPMENT

An act of desperation led Curtin University's Professor Steven Tingay (MWA project Director) to contact a small hi-tech company in Fremantle and share his problems. At stake was the integration of sub-components and design of manufacturing processes to build the receivers needed to process data for the experimental MWA radio telescope. A central part of this work was to create a design that met the demands of the unique environment of the Murchison region while providing radio frequency shielding.

This Australian-led project, shared between international and national research partners, was well behind its original schedule. Funding bodies were losing patience and the project was caught in a complex, multi-campus consortium.

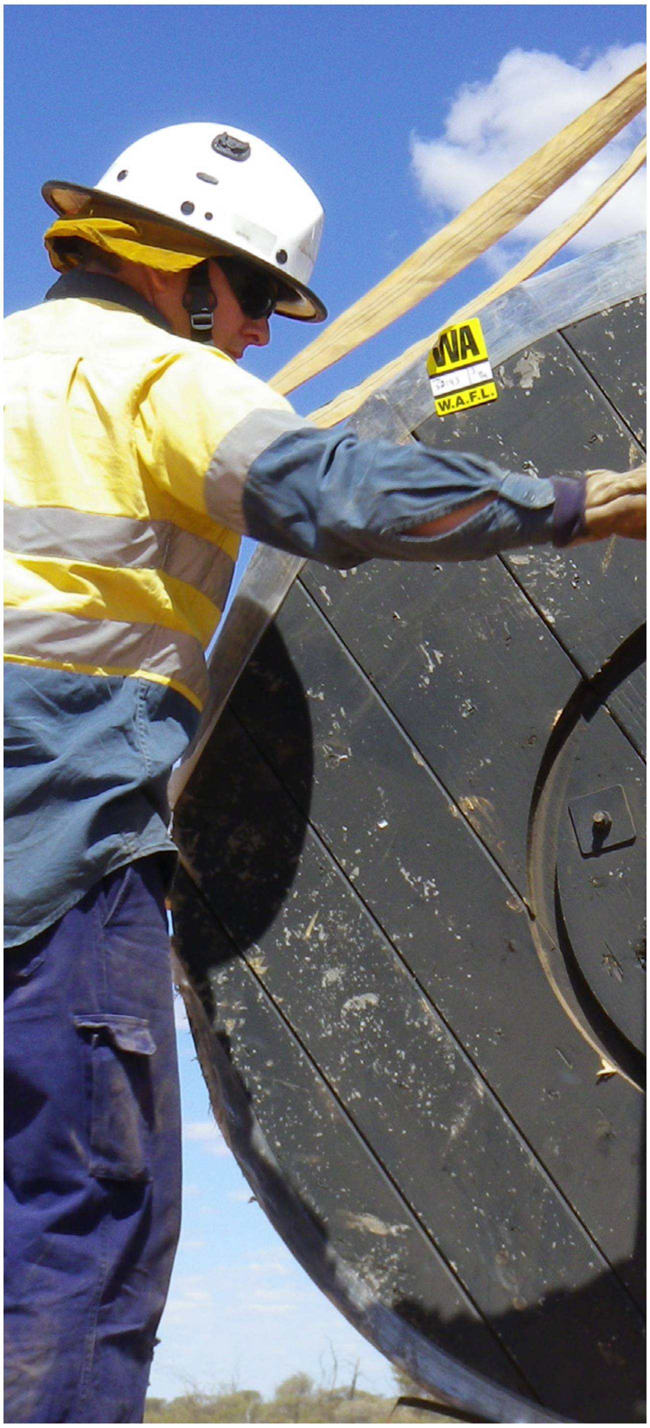
The previous project management team had been dissolved and Tingay had been placed in charge of the new team and given the job of getting the MWA back on track and ready for commissioning.

The MWA had attracted support, in cash and in-kind, from Australian funding bodies, international universities and observatories. As the lead astronomer at ICRAR- Curtin, Steven Tingay knew there was much at stake. He needed to jump-start the project and keep all project partners engaged.

A combination of targeted action and good luck brought Tingay into contact with Poseidon Scientific Instruments (PSI). The sequence of events which led the two MWA key players together is lost in time, but a crucial recommendation by a member of the Department of Commerce's Industry, Science and Innovation Division led to Tingay contacting PSI's Managing Director Jesse Searls to discuss the MWA.

PSI is a small radio frequency specialist company which designs and manufactures the world's leading defence radar oscillators.

The outcome of their conversations was a three-year collaboration in which PSI successfully configured and manufactured the MWA receivers. The project's development was not uneventful or free of errors, but goodwill and a can-do attitude by both parties meant that the objective was achieved. The MWA was commissioned on the site of the Murchison Radio-astronomy Observatory in November 2012.



PROJECT BACKGROUND

The Murchison Widefield Array is '*a radical new radio telescope which has no moving parts*' [4]. Its scientific purpose is described on the MWA website as follows:

> The three key projects are detection and characterization of red-shifted 21cm neutral hydrogen signals from the Epoch of Reionization, a high sensitivity survey of the dynamic radio sky, and measurements of the Sun and the heliospheric plasma, including constraints on the magnetic field in coronal mass ejections (CMEs). Other science enabled by the MWA includes pulsar studies of various kinds, radio recombination line mapping, and high resolution probes of the local interstellar medium [5].

In essence, the MWA will 'look back in time' to relatively close to the Big Bang epoch to detect radio signals. It will use its large collecting area, enormous field of view and enhanced sensitivity to capture new data.

The MWA is a precursor to radio astronomy's largest infrastructure project, the Square Kilometre Array (SKA) – a project estimated to cost €1.5 billion. The MWA's installation at the MRO site, along with the Australian Square Kilometre Array Pathfinder (ASKAP), are seen as 'proving stages' to demonstrate to the international SKA partners that Australia is capable of designing and building sophisticated radio astronomy installations in remote locations. The international consortium had listed Australia and South Africa as possible sites for the SKA. In early 2012 the consortium decided to allocate segments of the SKA to each site. In Australia's case it has been tasked with the SKA low frequency telescope. This reinforces the importance of the commissioning and research outcomes from the MWA.

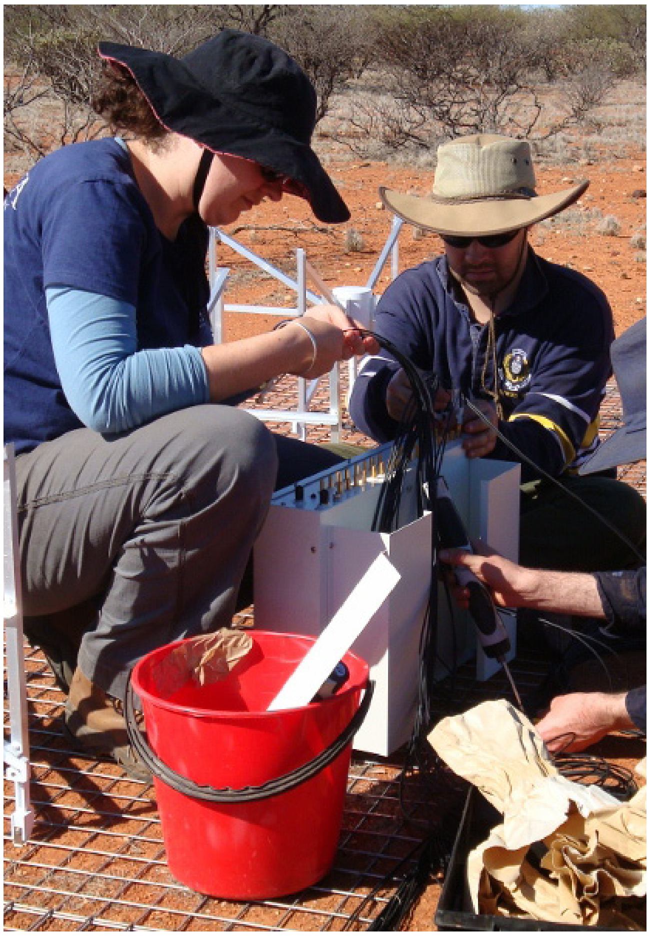
In essence, the MWA project managers set out to build a scientific installation that had no precedent, using parts that were yet to be designed and manufactured by research groups across the world. This could be compared to designing a new motor car with parts variously supplied by Nissan, Ford, India's Tata Motors and General Motors. Clearly, good logistics, clear specification and integration of all of the systems and sub-systems were going to be crucial factors for success. This proved to be the case. This multi-sourcing of sub-systems is not recommended.

While PSI's introduction to the MWA was welcomed by both parties, it came late in the project's development. PSI began a staged work process stepped out over nine contracts.   The stages could be listed as:

1. Technology transfer for project scoping and understanding. Design and build a pre-prototype to a) enclose the receiver electronics to ensure protection from the MRO environment, b) limit radio frequency leakage and c) ensure the units are easily accessible for maintenance and repairs.
2. Improve receiver electronics design, integrate the sub-systems being manufactured by research partners and standardise the use of components for ease of manufacture and maintenance.
3. Coordinate and assemble 16 receiver units using completed sub-assemblies from research partners and dispatch the completed receivers .

One challenge lay in the climate of Western Australia's Midwest desert. Summer temperatures often reach 50°C in a flat desert-like terrain that, conversely, can be subject to flood in a high rain event.

The location couldn't change, since the Murchison is a preferred location for radio astronomers. This is due to the very low level of radio signal interference (the intrusive by-product of modern life) in this remote location. These environmental factors were a principle consideration in the design of the MWA receivers.



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[4] http://mwatelescope.org/

[5] http://mwatelescope.org/science/index.html

Example One:

There were two parts to the infrastructure roll-out on the MRO that serviced the MWA. The design of the MWA infrastructure and its installation on site; each stage used a different contractor.

The infrastructure included the provision of power and communications cables to the receivers plus appropriately built roads.

While the technical engagement with industry for the MWA receivers occurred later than optimum, engagement with companies able to complete the infrastructure roll-out began in time to allow for useful information exchange. A significant part of this work and a major expense of the whole project was the installation of cables. These cables deliver power to each receiver unit and carry the digital signals from the receiver to the signal processing facility onsite.

The Australian Standard applicable to the installation of power distribution systems is highly prescriptive in how power cables should be installed in common scenarios. However, the Standard also provides scope for the development of alternative implementations where it can be demonstrated that they comply with the fundamental, electrical safety, principles that underpin the Standard. Remote, restricted access sites such as the MRO provide are excellent candidates to take advantage of the opportunities inherent in the flexibility of such standards.

However, the schedule required to be met by MWA's funding authority did not allow time for the exemption to be sought and approved. MWA's power and communications cabling is now buried – an activity of significant expense. Had time been available the cables may have been installed in above ground and insulated cable housing saving both time and money.

MWA Project Manager Tom Booler observed when asked about the infrastructure roll-out:

> *"Compliance is a major cost driver of projects with large infrastructure components. Too often the strictest interpretation/implementation of standards and regulations is accepted in the belief that it represents the path of least resistance. It is true that an investment of time and money is required to secure relief from standards and regulations, but the substantial cost efficiencies to be had justify the investment.*
>
> *The SKA must explore and leverage the flexibility offered by the myriad standards and regulations that will be applicable to its design and deployment in order to minimise the cost of compliance to the greatest extent possible. Industry has a wealth of experience to offer with respect to managing compliance with local standards and regulations. The challenge for research is to provide industry with the scope (time and resources) to explore the possibilities. The challenge for industry is to add value by thinking outside the box and providing effective and compliant alternatives for consideration by SKA."*

There is a silver lining to this story; the MWA engaged with potential contractors to install the in-site infrastructure early and full briefings regarding the nature of the project, requirements of funding and other elements were outlined. The contractor that won this work demonstrated that it saw part of its role was to add value by providing solutions to issues as they emerged. This contractor was a comparatively small company and locally based in Geraldton.

MWA project staff ensured that this contractor understood many elements of the project including the realities and requirements of its funding provider. With this understanding, and following a request from MWA, the contractor timed the roll-out of infrastructure works to suit the funding requirements. The contractor's willingness to be flexible was a major benefit of the close working relationship that had been developed.

WHEN PROJECTS NEED INDUSTRY INPUT

Interviews held with ICRAR-Curtin and PSI staff for this paper provide clear advice on the benefits to be gained in involving industry in radio astronomy research projects. Comments from individuals from both groups cite the benefits of industry engagement:

- Efficiency of design and construction for unique applications is the strength of industry.
- Industry uses efficient manufacturing techniques which deliver standardised technology and reduced maintenance costs.
- A clear delineation between the project management role and the technical functions is important, so that best advantage is achieved from these specialist disciplines.
- Time-effective delivery of the research tools enables researchers to do what they do best.
- Contemporary knowhow and manufacturing techniques, add significantly to the performance of the research tools, offering opportunities higher-level discoveries and reduced maintenance costs.

In larger scale projects the need for industry engagement is even more vital. Steven Tingay comments:

> *I think the MWA marks a transition point into the domain of large scale project work. At this level, it is simply impossible for a typical academic team to undertake the development and implementation without industry. So, for projects as big or bigger than the MWA, the implication is clear to me. Without industry involvement the project does not get done, or else it gets started with an academic workforce and fails.*
>
> *This second scenario was the path the MWA was taking before I got PSI involved. In these larger scale projects it is clear that the industrial supply chain and manufacturing methods, as well as rigorous project controls, are required. It is better to buy these capabilities from industry, as well as buy their knowledge of latest technology and manufacturing developments, rather than attempt to build it within an academic group.*

NAVIGATING THE COLLABORATION

In 2006, in the US, an MWA systems design was detailed by Dr Colin Lonsdale and Dr Alan Whitney of the MIT Haystack Observatory. However, there was no systems engineering staff to write and enforce the interface control documents (ICDs). Such documents govern how elements of one system might interact with those of other systems or sub-systems for the various electronics that would go into the receiver unit.

The result was that the project, being managed across three continents, was uncoordinated; budgets and timelines were stretched. How could the problem have been avoided?

ICRAR-Curtin and PSI staff interviewed for this paper argue that a full functional review should have taken place with PSI very early in proceedings, had PSI been brought into the project much earlier. A functional review is a process of agreement on what the research tool (in this instance a radio astronomy telescope) is to do. The function review would include information on where it will operate, with relevant climatic and geographic information and, if required, a list of the functions of sub components – like reticulation of the power source on site.

The starting point for the functional review could have been:

> We need a radio telescope to be able to work in the remote Murchison area:
>
> - To operate at 80-300 MHz
> - Specified ‘X’ sensitivity
> - Use as little power as possible – where possible renewable power
> - Use the Lonsdale/Whitney design
> - With full understanding the limitations of the project scope
> - To limit the amount of remote infrastructure to save on installation and maintenance costs
> - To ensure high level integration of sub-systems

A functional review for MWA would have also begun to examine the trade-offs required between different elements. This is an essential part of this process.

“If we’d been able to achieve this for MWA, I think the telescope would be very different,” notes Project Manager, Tom Booler.

Example Two:

PSI had designed the box with many considerations in mind, including such pragmatic and simple issues as the width of the loading door at the back of its Fremantle office. However, this door was wider than the entry door to the area that became the MWA laboratory.

The result was that every time a receiver needed to be taken into the ICRAR-Curtin lab for testing, the whole digital crate and air conditioner had to be disassembled and then re-assembled within the lab. The box had to be turned on its side and squeezed through the door. This proved to be a time-consuming and unrewarding task for ICRAR-Curtin staff which could have been easily avoided.

A functional review would have required full participation from staff of the research partners and PSI. And there was another shared belief – that time should have been allocated to talk through the research objectives, establish communications protocols, document management and a host of other crucial processes in order to design, build and commission in a highly efficient manner.

Such a course would have led to tighter coordination and a shared understanding of research and commercial imperatives between the teams. It would have resulted in improved communications and a stronger sense of shared effort. It would also have ensured that PSI understood the 'funding two-step'; process that research centres need to complete to keep their funding partners informed and funds flowing.

Furthermore, the research and industry collaborators could have agreed to review the list of components and simplify a number of systems designs, thus aiding efficient manufacture and maintenance needs.

They could have checked all sub-systems being designed and manufactured by the research partners to ensure design integration. It would have also provided an opportunity to rehearse delivery of the first receiver to the ICRAR-Curtin laboratory.

This last omission provides a useful illustration of how small details can have a major impact. In this case, the metal box that housed all the MWA receiver systems had the wrong dimensions.

The overwhelming message is clear and endorsed by both groups. Preliminary planning and close discussion is of paramount importance in collaborations between two such different organisations. Each party needs to understand the environment that the other works in, and the impediments and aids to efficient development and effective program delivery.

Advice from the two groups could be set out as follows:

- Ensure that each party has a good understanding of the skills, attributes, technical knowledge and work style of the other party, within their own team and identify any adjustments that may need to be made for the project.
- Create a one-team approach though discussions, preliminary design workshops, social gatherings, presentations of findings by other installations and establish the common areas of interest shared by the two groups.
- Enable work style and work needs to be discussed and reflected upon. This means that industry needs to understand the drivers of research personnel and vice versa. In this way a whole-of-project list of motivations can be established, understood and monitored to ensure that problematic issues are minimised.
- Challenge project assumptions made by each team. This will help minimise miscommunications along the way. While the 'getting to know you' time may seem costly for both parties initially, the payoff will be in savings from efficient and effective function, design and operations (see recommendation 3). In addition, industry is likely to be cooperative if the core costs of these initial interactions are paid at an agreed rate and any direct materials costs are also covered. This approach will encourage industry to be more generous with staff time and a solutions-focus during the project.
- Both parties would benefit from an interchange of staff where one staff member from the research institute is placed within industry and where feasible, vice versa. These personnel need to be on the shop floor early in the collaboration, working closely with key staff; they must have technical knowledge, authority to commit resources, be good communicators and be management-smart to help negotiate some issues between the two parties. The number of days per week of a secondment should be reviewed regularly to ensure that both parties are benefiting and that the project aims are being supported.

Each of the above steps requires funds to sustain it. These funds would:

- Create a jointly reviewed functional requirement which leads to a design that meets performance targets and can be efficiently manufactured.
- Enable clarity of objectives to be reached and sustained.
- Ensure a sense of common purpose by both parties.

Understanding and applying the right principles of project management also can be a game changer. MWA Project Manager Tom Booler commented, when asked about staffing ratios:

> *The appropriate ratio of project management (to technical staff) is highly dependent on the scope of work. The key is to acknowledge the basic tenet that dedicated management is required. The benefits are innumerable, but the principle benefit is that it frees technical personnel from the quagmire of management and bureaucracy so*

> *that they can concentrate on actually doing some work to progress the project. The irony—lost on many—is that often it is the very management processes (overhead, as distinct from personnel) introduced under the guise of best practice distract and slow projects to the point of stagnation and failure! You can't have a best practice project management apparatus without investing in an appropriate level of dedicated resources to support it—if project management just adds to the already full plates of the delivery resources then it hinders more than helps. This (approach) is at the root of many people's scepticism with respect to project management.*

PSI's greatest frustration was that there was no final high-level specification for the project and a number of sub-systems had to be re-designed as documentation for manufacture was being completed. Industry is used to working on a fully designed project, yet research uses the design process to evolve a final research tool. This major culture difference requires careful bridging between industry and research partners.

One ICRAR-Curtin staff member described the project as *'like designing a plane while you're flying'*.

THINGS THE PROJECT PARTNERS WISHED THEY HAD DONE OR SHOULD HAVE DONE

Events happened in the course of the project that, with the benefit of hindsight, could have been done differently.

MWA Project Engineer (a US-based NASA Satellite specialist), Dr Bob Goeke has some sobering advice for industry. He says: *"If you see 'getting into science' merely as a business strategy, don't get involved."* Yet where industry has persisted with innovative research projects, they have - over the longer term - reaped the financial benefits of developing ground-breaking technology that could be applied in other markets.

There are many examples of research and industry collaborating. Bob Goeke observes: "*almost any NASA satellite job falls in this category... at the bid phase, the science group pairs with some industrial partner(s), the largest of whom will provide the spacecraft (which delivers the satellite into orbit)*."

The research and industry collaborations were central to the funding and commissioning of the Dutch-built LOFAR radio telescope [6]. These relationships successfully linked the development of LOFAR with the industry of the region in which the telescope is sited.

Goeke notes: "*The top level of the company needs to have a commitment to the science, enough to add resources to the effort when things go badly without worrying too much about how out-of-scope those resources are.*"

Tingay notes that PSI displayed this willingness and extended significant good-will to the project team. In return Tingay was very mindful of not trading excessively on this good-will. This environment triggered the use of a series of structured contracts for the work, rather than one major document. This had the effect of giving PSI maximum opportunity for cost-recovery when project scope change occurred – which it did. This flexible approach to the procurement process was most effective as it meant that PSI could continue to do work as required, rather than just doing work that was scheduled in a contract. This approach enabled efficient use of time in the project's development.

Tingay believes that a flexible approach, plus constant and open communications allowed difficulties to be overcome.

Key elements that elevate the chances of success for each party could be summarised as follows:

- Make time to complete a full functional review (as suggested above) and layer that with a second-tier functional review involving relevant companies at sub-system level if necessary.
- Focus on the interface between the sub-systems (how they join up) prepare Interface Control Documents involving members of the functional review groups.
- Ensure funding resources, structures and processes are fully understood by all parties
- Embark on some early, honest and robust discussions about the project, its objectives, the size of the challenge.
- Identify communications protocols and appoint and maintain roles to relevant group members.
- Recognise the need to proceed at short notice in an uncertain framework and plan to maximise the certainties.

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[6] www.lofar.org

ECONOMIC INDICATORS

The estimated total value of the MWA is $50 million. As noted, $20 million cash has been augmented with $30 million in-kind contributions from research partners. This value includes: the establishment of the MRO by CSIRO, State and Federal Departments; access to NBN infrastructure between MRO and Perth, and then access to the supercomputing capacity at the Pawsey Centre in Perth.

There were no economic measures applied to the MWA project. However, similar collaborations between research institutes and industry can be found in the West Australian Centres of Excellence program.

These collaborations have been benchmarked in a paper '*Research, Knowledge, Innovation: the Renewable Resources!'* [7] This document states:

> *The aim of a Centres of Excellence (initiative) is to develop centres of international significance in specific areas of scientific and technical research and expertise relevant to Western Australia's unique circumstances. The program attracts leading international scientists and researchers to collaborate and participate in research projects that increase productivity, sustainability, training and up-skill of the Western Australian labour force whilst leveraging the impact with significant funding contributions from other government and research organisations and directly from industry.*

There are similarities between this and Western Australia's investment in radio astronomy: public funding interacting with research centres and industry attracting leading scientists and researchers.

The Department of Commerce report notes:

> *Seventeen years of State Government funding into the Centres of Excellence program of $80.88 million and additional leverage funding of $626.94 million has a potential economic impact on Western Australia of $1,758.44 million, a multiple of 2,174%*

The publication also observes that *'in some cases the benefits of research and development programs may not be realized for many years to come*'.

The Office of West Australian Chief Scientist, Professor Lyn Beasley, provided clear measures of economic benefit from her review of the Premiers' Fellows [8] – a program that awards research funds to high-achieving individuals undertaking leading edge research.

The report identified that $8.5 million of State funds was allocated to support the work of nine Premiers' Fellows. The first was appointed in 2003. These funds had leveraged over $80 million of additional funding and support to the state. A ratio of almost 10:1.

The Department of Commerce notes that the Centres for Excellence program trained '*over 973 PhD students with at least 545 students being awarded doctorates*'. Market valuations by some investors have estimated the value of each PhD at $1million, offering a substantial benefit to the State.

Radio astronomy has already delivered great rewards to Australia. The now ubiquitous wireless facility, used by millions of computer users the world over, was invented as part of a radio astronomy development program In Australia. It has earned CSIRO hundreds of millions of dollars in (hard-won) patent rights.

For PSI, the opportunity to take on work in a new sector was a welcome one. The initial contact with the project took place some months before the grim realities of the Global Financial Crisis became evident. The radio astronomy work became an important mainstay of income for this small company as its other work for international defence contractors reduced. There were times when the MWA work sustained the company and kept talented engineers and physicists creatively employed, engaging their training and experience to solve problems and find solutions.

Radio astronomy is truly 'the gift that keeps on giving.'

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[7] Department of Commerce, Industry, Science and Innovation Division, 2012.

[8] Western Australian Premier's Fellows, Dr Penny Atkins, Office of the WA Chief Scientist, 2011.

FUTURE ENGAGEMENT

This case study describes the development of a radio astronomy project where industry became a white knight to a project in distress.

For other research leaders planning large projects, open and full engagement with industry is imperative from the beginning – the longer the delay in engagement, the less effective is the value of the collaboration and the project. The price that is paid is additional cost of the project.

Industry is compelled to keep abreast of the latest techniques and contemporary components to stay ahead of its competition. Researchers can get caught up in 'reinventing the wheel' while trying to hand-make solutions with often limited knowledge. There was a day when bespoke solutions were appropriate, but with big budget projects this option is expensive, time-consuming and inefficient.

Planning for some elements of the Square Kilometre Array is underway. An Australian Square Kilometre Array Industry Consortium (ASKAIC [9]) is currently considering ways of usefully engaging with industry.

As design and project management on SKA systems begins, an industry engagement model created by the Australian Defence Force may offer a useful avenue for meaningful engagement with industry. It is a globally recognised program called Rapid Prototype, Development and Evaluation Program (RPDE [10]).

RPDE uses workshops and forums to solve particular problems for Defence. The consortium describes itself thus:

> *We are a unique collaboration between Defence, industry and academia, bringing together the best and brightest from across the defence industry spectrum. When these forces are joined in neutral, non-competitive environment, knowing that intellectual property and commercial interests are protected, the results are formidable.*

If the SKA program office established – along similar lines - an engagement structure in Australia and South Africa, the opportunity for high level engagement, extended scientific outcomes, new technology and intellectual property would no doubt emerge.

The RPDE model warrants close scrutiny as a fitting way of engaging industry across the two radio astronomy sites.

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[9] http://askaic.com/about-askai/

[10] http://www.rpde.org.au/

APPENDIX ONE

RECOGNITION OF DIFFERENCES AND APPLYING SOLUTIONS

Industry and research are two different entities with a number of similar features. The two lists below provide navigation points for consideration by each group.

Industry needs to:

- Spend time getting a thorough understanding of the project, the budget, the many variables, and the fact that often the outcome is yet to be grasped. Industry needs to understand that people from research are not used to the time constraints that industry must operate within.
- Accept that research institutions are not good at deadlines. Introduce structures with their project leader that include fair deadlines and agree that both parties will deliver.
- Make sure it has one point of contact for the project, a senior person with authority to make decisions, allocate resources and apply the technical knowledge to complete the work.
- Very early in the process, establish a communications protocol between the two groups. Limit engineer- to- engineer contact (except informal contact) and seek opportunities for both task-focussed and social interaction.
- Check the researchers' assumptions on the project scope, performance, concept and the nature of your role. Once this is done, check them again and keep challenging them. It's the assumptions gone awry that will get you every time.
- Take the lead in using your organisational strengths - team building, goal setting, open communications and accountability measures - so that they become part of the project's DNA.
- Make sure that all company staff know about the project you're working on. Engage them in their commitment to its development and outcomes. In the instance of radio astronomy, invite a research project leader who can speak well to present talks and updates at company lunchtime or after work sessions.
- Be patient. Sometimes researchers appear to be walking in circles but that may constitute an important part of project development. However, be wary of too much reflection or obfuscation as this may indicate that your research partner is confused and doesn't know what s/he doesn't know.
- Understand and accept that research institutions are generally very poor at maintaining a full set of design and versioned documentation. There are rarely sufficient staff resources to do this well. Anticipate that you will be asked to deliver a full set of documents every time a small change is made.
- Be ready to identify where some new techniques, skills and know-how can add to your company's commercial armoury, and seek ways of commercialising this.
- Limit any ego or personality getting in the way of the project development.
- Know and understand the broader research institution strategy. There may be new work opportunities in them, so be ready to take part in other work segments.
- Be solutions-focussed not problem-centric. If there is a problem, bring it into the limelight accompanied by a well-considered solution.
- Be prepared to celebrate your successes and own your mistakes – there will be both.

Research Institutions need to:

- Use basic project principles and appoint a project leader who has the technical skills, management expertise and organisational authority to commit resources. The person needs to be someone with proven leadership skills that go well beyond project management.
- A research budget needs industry input BEFORE the design process begins. Project leaders should ensure that you have the resources to hire industry to spend time with you to undertake a functional review, source options, identify tradeoffs, scope the work, plan the details and develop the design. Then use this process to establish a real cost of the research hardware. This will mean that budgeting and funding will be better managed, will reduce contingency funding embarrassments and strengthen commitment from industry.
- Don't expect industry (especially SMEs) to be prepared to pay to do business. They are professional companies with highly trained people who need to be paid for the work they complete. The promise of 'reaping future rewards' is hollow. If the work is interesting, is structured in a real and deliverable manner, has the potential to develop new skills and knowhow that can be transferred into other work, then industry goodwill, commitment and engagement will follow.
- Review the project from beginning to end to ensure that logical and robust systems engineering processes are in place. Look for logical break points in work development and use them to segment the job. Be very wary of components or sub-systems being developed independently by the research consortium partners. These rarely integrate into other work seamlessly.
- Be sure your project can secure sufficient funds to employ professional project management. This person will set down the project requirements, establish project start up, identify the high-level work packages, set out project steps, apply logic to development phases, structure the production phase, create a detailed and achievable timeline and a realistic commissioning process.
- Standard procurement procedures are generally not recommended in a collaboration seeking a research outcome. Several companies may begin the project development process and one may become the obvious partner choice as time goes on. Both the researcher and company will have invested intellectual property, skills, knowledge, knowhow and effort. If the company is the right company, the procurement process needs to be simple and flexible. It is advisable to have a non-standard process approved by your governing institution before embarking on a protracted relationship with business – particularly an SME.
- Know how much money is available and develop a realistic timeline for deliverables. Companies worth working with are smart. Before they begin committing their own resources to a project they will want to know how much you can spend on the project and whether that sum is realistic. Timing also affects the cost – the shorter the time available, the more expensive it will be.
- Be sure that all the delivery processes have been thought/walked through, from the dock door of the manufacturing company, into your building, research laboratory and to the field.
- Set deadlines for work packages. Make sure that your whole team and the industry partner knows that you intend to achieve them. Do this by reverse engineering work segments to establish achievable deadlines.
- Carefully manage stakeholder expectations. Funding bodies need to know and understand what you mean by crucial words like 'finished'. This is particularly relevant when an organisation that is unrelated to the project has the final say over delivering crucial infrastructure facilities – as was the MWA experience.
- Accept that introducing industry to the equation will add to the project discipline – be ready to harness your own team to this.
- Be ready to limit any ego or personality getting in the way of the project development.
- Be prepared to own your successes and your mistakes – there will be both.
- Don't allow your engineers to continue technical 'finessing' of the project once the final design review is completed – accept that the project will never be perfect. Be happy to produce good working farm utes rather than chasing a Ferrari.
- Manage your budget well, plan for contingencies and then double the allocation you've made.

APPENDIX TWO

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- Swinburne University of Technology
- University of Sydney
- University of Tasmania
- University of Western Australia
- Victoria University of Wellington

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APPENDIX THREE

CLOSING COMMENTS

In researching this paper, I have drawn many busy and talented individuals away from their day jobs to provide insights and observations on the development of the MWA. I am very grateful for their generosity in giving me time and valuable perspectives on the project. These people include:

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- David Emrich – MWA Commissioning Engineer
- Tom Booler – MWA Project Manager
- Bob Goeke – MWA Project Engineer
- Brian Crosse – MWA Commissioning Engineer
- Jesse Searls – Managing Director, Poseidon Scientific Instruments
- Dr Ian Moore – Technical Director, Poseidon Scientific Instruments
- Derek Carroll – Production Engineer, Poseidon Scientific Instruments


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Author's note:

In July 2012 Poseidon Scientific Instruments Pty Ltd was bought by Raytheon Australia Pty Ltd, the wholly owned subsidiary of Raytheon USA, a multinational defence contractor.

About the Author:

Andy Farrant is a consultant specialising in organisational governance and strategic communications. For almost three years, he was General Manager and Company Secretary of Poseidon Scientific Instruments (PSI) and in this role he project-managed much of the development of the MWA receivers for PSI. He has no technical background, but is experienced in change management, team leadership and communications. He learned many things while project managing the MWA receiver development by PSI for ICRAR Curtin.

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