Industry and Technology

A report to the National Committee for Astronomy for the Australian Astronomy Decadal Plan 2006-2015
By Working Group 1.3

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1. Executive Summary

The questions tackled by this working group is how should Australian Astronomy be more proactive in engaging Australian Industry, and how we might maximise the wider take-up of technological developments, particularly in the era of the 'next generation' international facilities?

The challenge is that the enthusiasm within Astronomy R&D activities is not reciprocated by Industry due to the very different underlying drivers: Australian astronomy is driven by the development of technologies for the public good (often on 'extended' timescales subject to funding availability, etc) whereas industry (particularly the small/medium enterprise (SME) dominated Australian scene) cannot justify nor fund investment in risky, long lead-time, speculative R&D where the outcome may not be a significant contract or single-ownership IP.

It cannot be claimed that Astronomy generates innovative technologies for the wider market on either a reliable or frequent basis: historically there has been one outstanding example (Radiata) and a couple of viable, but smaller companies and technology spin-outs. So, rather than argue for an Astronomy initiative to support the direct flow-on to new industries we focus on ensuring that Government R&D funds are invested within Australia to the greatest extent possible over the period 2006 -2015. With the investment on-shore, further benefit(s) and spin-offs will be more naturally captured, should the technologies emerge.

1. Background - Industry Linkages

1.1 Astronomy and industry – what drives the relationship?

Forefront astronomical research is often driven by what the technology can do, relying on the development of increasingly more sensitive telescopes and instrumentation. Astronomy isn't alone in this respect, but it is one of a number of scientific endeavours (particle physics, atmospheric sciences, etc) which drive a wide range of technologies, from the development of mm-size integrated circuits to integrated telescope control systems to fast computer algorithms to process gigabytes of data. These sciences and their technologies co-evolve – the specification of scientific goals 'pushes the envelope' of the available technologies, which in turn are underpinned by fundamental science.

Astronomy is an attractive science: it excites the general public and also offers industry a "show casing" opportunity for technologies which otherwise might be underexposed due to secrecy or other sensitivities (e.g. defence). For Australian companies the highly networked astronomical community provides a direct route to potential international customers and also to like-minded companies in specialist fields of engineering.

Australia has several builders of astronomical instrumentation (AAO, CSIRO-ATNF, RSAA-ANU). These groups cover a wide spectrum of technical capabilities – theoretical and applied – which includes optical design, grating and photonics design, electronic and mechanical engineering, systems engineering and integration, telescope control systems, graphics simulation and software. These groups are increasingly dependent on close relationships with universities, observatories, government laboratories, industrial partners, and industrial research networks. These links are essential to the R&D programs for a number of reasons:
Access to new ideas (although often at the expense of committing to non-disclosure agreements)
Access to state-of-the-art lab facilities & expensive software packages
Attracting excellent students
Opening new avenues for research funding (e.g. through DITR and DEST's Innovation Access Program).

Australian astronomical research has a long and illustrious history, backed up by the development of novel and ground-breaking instrumentation at radio, microwave and optical wavelengths: e.g. the Parkes HI multi-beam receiver (CSIRO-ATNF 1997), the two degree field instrument (2dF, AAO 1998) and the near-infrared integral field spectrograph for Gemini (NIFS AUD $4M, RSAA 2004). Not only do these developments generate contracts for similar instruments for other (international) telescopes - e.g. ALFA on the Arecibo telescope (Cornell University) 2004 from the Parkes HI multi-beam and FLAMES/Ozpoz on the VLT from AAO 2dF - but they can spawn new companies as discussed in the PMSEIC report (June 2004) 'Technology Transfer' section 7. An outstanding highlight in this history was the Australian start-up Radiata, whose fundamental capabilities can be traced to R&D at CSIRO Radiophysics (Matthews and Frater[1]).

External income for instrumentation contracts represents the *direct* return on Government funding of Astronomy: e.g. NIFS (AUD $4M), NASA Parkes tracking missions ($2M) and potential future tracking programmes (Lunar, Mars) using the ATCA. Government (ARC & MNRF 2001) funding for Australia's share of Gemini twin-8m telescopes has opened up contracts worth at least this much to RSAA and AAO, with the potential for significantly more in the coming decade.

What the Radiata and Gemini experiences illustrate is that we cannot 'sell' the cost of Industry engagement on either rapid or guaranteed payback to Industry and the Government but rather on the delivery of an operational instrument which serves as a proving ground for future spin-off: This issue is discussed by Matthews & Frater[1] (in the context of radio astronomy and radio physics) "R&D aimed at improving scientific instrumentation has the advantage of clear paths to adoption and use because it results in a fully working technology. The main question as regards wider commercial outcomes is the extent to which the demonstrated advances in instrumentation

[1] Creating and Exploiting Intangible Networks: How Radiata was able to improve its odds of success in the risky process of innovating, M Matthews & R Frater, Nov 2003, Case study prepared for the Science and Innovation Mapping Study (DEST: http://www.dest.gov.au/mapping/case_studies.htm).

technology will diffuse into other markets and industries." Radiata was an outstanding successful venture – one built upon a clear vision, a healthy network - mostly informal, of key personnel and skills, but most notably spanning decades of backbone research.

1.2 Industry benefits from engagement with astronomy

Astronomical facilities are based on information processing and telecommunications technologies (ICT) – this extends from the ultra-fast processing chips at the front-end to sophisticated imaging algorithms at the user interface. Astronomy provides a demanding development environment for state-of-the-art devices, systems and algorithms. Moreover, it is a benign, ethically-neutral activity, being an observational-based science which cannot dictate nor affect the object(s) of the experiment.

The advantages of collaborating with astronomy projects from the industry perspective include:

- The opportunity to engage the creativity of the best professionals to achieve imaginative projects in a networked, cooperative project (e.g. transfers skill, open new markets, attract and retain key engineers)
- The ability to finesse leading-edge technologies and techniques for very demanding applications with technologically-sophisticated users.
- The ability to generate and share information with R&D partners in a benign commercial environment,
- To be able to publicise project outcomes freely – unlike e.g. defence systems, and to use this publicity as an attractor for other (non-astronomy) contracts and personnel
- High visibility from being associated with an innovative, international mega-science project which will have high impact for decades
- The potential to engage in very early phase R&D for multi-million dollar-projects, almost all of which are cross-discipline – engineering, systems and computing
- The opportunity to 'smooth' the continued employment of talented engineers and scientists, where system integration companies (e.g. very pertinent to the SKA) are reliant on large-$, but 'lumpy', defence contracts. This line of argument can be seen as a negative (to either or both sides) in that underlying this is a general shortage of skilled workers, the competition for which is increased by large science projects.

Ensuring a continuity of a skilled workforce, both in astronomical community and in industry is key. We recognise that astronomy has similar skills as industries such as defence, communications etc.
Example: With the burgeoning wireless communication industry worldwide it is a challenge to meet the demand for qualified radio-frequency (RF) systems engineers. Radio astronomy is one (of many) traditional training grounds for such individuals, with a proportion of undergraduate and graduate affiliates returned to industry. At present there is a particular need for RF engineers having a background in advanced technologies such as RF CMOS integrated circuits - exactly the same areas which need to be developed as part of the SKA engineering program. Current ATNF/SKA projects, particularly those associated with Macquarie University, place an emphasis on combining the know-how from industry and radio astronomy to produce next-generation, high performance systems suitable for use in both domains.

Brett Biddington (Space Initiatives Manager, Cisco Systems) gives the following reasons why Cisco is engaging with the SKA R&D effort, recognising SKA as a long term investment opportunity with an enormous amount of up-front activity needed before there is any possibility of major sales or revenue (for any company) being generated. For Cisco, "the SKA project represents[2] -

- a program of international significance with which we seek to be closely involved from the beginning - as advocates for the project, and to assist with the architectures and the early recognition of technical problems that they might be addressed and solved.
- as the project matures, an opportunity to participate in the technology demonstration process through provision of ideas and equipment that can allow new concepts to be developed, tested and compared,
- in the mature system, a provider of key networking equipment and services awarded via usual tendering processes."

The technologies spawned by astronomy are not always obvious – some examples are discussed elsewhere in this document and many diverse opportunities have been identified within the SKA project, e.g. if the SKA is sited in Australia, it is expected to:

- increase knowledge of remote areas of Australia
- facilitate improvements in community infrastructure in remote areas
- extend Australia's fibre optic network
- provide supplementary communications capacity
- expand communications bandwidth ex Australia
- significantly develop antenna and communications technology
- encourage further development of low cost renewable energy including solar, wind and geothermal power generation and hydrogen storage technologies
- stimulate parallel communications research
- sponsor the development of new low cost antennas, and

The flow-on benefits of these dot points are not identified or quantified here – but are only recorded to show that there are many benefits and potential industry 'links' which extend beyond the telescope structure itself.
For the SKA the infrastructure component alone is expected to be in the order of $400 million, and it too has potential spin-off applications: e.g. Steensenvarmig (Australia) see a particular challenge in developing the type of distributed system that may be required for the SKA. These must have a green 'soft-footprint', low RFI, being energy efficient and able to operate in a remote, standalone mode. "This has interesting potential applications beyond just astronomy. A facility with standalone energy source which is secure and reliable, green, high-tech, smart and restorable may be developed into an economically-viable venture in itself. There are potential markets internationally in health, defence, police, customs, communications, mining, tourism, indigenous communities etc. Specialised, but potentially highly successful business niche" [3]

[2] Brett Biddington's submission to the Electronics Industry Action Agenda Implementation Group meeting, June 2005.

[3] SKA industry benefits submission from Mr Dan MacKenzie, Director, Steensenvarming, January 2005

The astronomy-industry link also strongly benefits the scientific community - e.g. this list from Tony Barry's (Connell Wagner) presentation to the IAU GA Sydney 2003 Industry Day.

- provides consultative networks
- focuses research on industry needs
- provides a greater understanding of current and future demands (market knowledge)
- facilitates additional funding and resources
- provides an impartial and objective contribution to the development of project concepts
- assists in management of the applied science projects
- assists in the commercialisation of research.

1.3 Astronomy-industry case histories

Historical perspective

Radio astronomy emerged from the invention and application of Radar during World War II. Since then Australia has invested in radio astronomy and as a result there are linkages between radio astronomy and industry extending from its earliest days. To some extent these close links between radio astronomy and electronics companies have helped to build and sustain a modest number of competitive Australian companies.

It is well established that 'pure' curiosity-driven research creates new knowledge and opens up new applications – two examples- (i) the development of semiconductors spawning microcomputers, and (ii) the need to share information between particle physicists creating the internet.

We intend to continue to grow Australian astronomy's engagement with industry to maximise technology diffusion – lots of push for innovation and new technologies from data-hungry scientists. The key is to identify groups (industry) able to exploit them both within astronomy (the international, close-network of observatories) and outside of astronomy: An example is the ATCA project. From the outset, the ATCA was always to be built in Australia and have high Australian content. The ATCA was developed from 1982 onwards, as a bicentennial project built and fully operational in 1990. The $ value of the Australian-supplied content is of order 90%[4]. Key developments for the ATCA included the design of the antenna dishes as shaped parabolas with high efficiency through to the microwave part of the spectrum.

Connell Wagner has been involved in supporting CSIRO both in the build, and subsequent development of the ATCA and the upgrade of the Parkes Telescope for the NASA Jupiter mission (Galileo) in 1995. The expertise gained by Connell Wagner (and its forerunners and partner companies) has enabled them to win contracts for:[5]

- the Australian Defence Satellite Communication Station in Geraldton (4 x 26 m diameter antennas)
- the Perth International Telecommunications station (1 new 20 metre and 1 refurbished 27.5 metre antenna)
- communications antennas in Australia, (6 x 18 metre diameter, not designed by CW, project management only) two in Vietnam and one in Cambodia
- numerous other smaller communications antennas

[4] No reliable reference or figure has been sourced for this %

[5] A Barry, NSW Director of Connell Wagner Pty Ltd

The early experience with the ATCA design and development enabled Connell Wagner to grow relationships with Aussat and Overseas Telecommunications Commission (OTC) leading to Satellite Earth Stations around Australia for Aussat and the OTC earth station at Oxford Falls. Subsequently Connell Wagner has developed a strong relationship with Optus of providing a wide range of management, design and consulting services on over 3500 sites for their GSM network and over 1000 sites for other mobile carriers around Australia.
As Tony Barry states "Connell Wagner has always valued its relationship with CSIRO and in a broader sense the science community. This relationship is one through which the co-dependence of engineering and the sciences has flourished. In 1995 Connell Wagner was presented with a copy of the Sir Ian McLennan Achievement for Industry Award made to CSIRO's Dr Bruce Thomas for "contributions to and development of the antennas design industry in Australia' which "recognises the part played by Connell Wagner Pty Ltd in the development"."
The contract value of the ATCA antenna spin-off alone has more than recovered the build cost of the ATCA ($50M) according to the study by the Bureau of Industry Economics[6]. The benefit-to-cost ratio for the antennas built for export has been assessed at 4.6:1. Around 20 earth station antennas for satellite communications have been built based on CSIRO expertise – most in Asia and the Pacific rim.

Another company that directly benefited from early R&D towards the ATCA was Austek Microsystems. Austek manufactured an array of 5000 signal processing chips for the correlator.

Thus the development phase of the ATCA clearly illustrated how Government funding of basic research stimulated industry. However, the benefits are not only from the initial R&D phase of facilities or instrumentation: There are also spin-off benefits to Australian industry during the operational phase of major facilities due to the necessity of maintaining sophisticated facilities and upgrading: An example of this would be the US-based SETI Institute who required a specialised wideband receiver for their project (AUD $2M) contracted from ATNF and Radiophysics (now ICTC). Projects such as this have a high international profile and wide impact, such that the SETI receiver contract generated orders for similar instruments for other international telescopes.

The development of new astronomical instrumentation is an opportunity for industry to engage in leading-edge R&D – which is particularly attractive to companies which rely on creating new markets. Industry may not make significant money from the development of astronomical devices, but the R&D often provides the basis of profitable technologies and future contracts as illustrated by Connell Wagner's experience.

There is also the intellectual challenge as the attraction for bright minds within the engineering profession – e.g. the Association of Consulting Engineers Australia (ACEA) – uses the SKA project as a 21st century challenge for (particularly young) members of their profession.

Present day perspective
As astronomy projects become larger and multi-national from the outset it is encouraging to see such projects identified from the industry side – e.g. the SKA project in "The Victorian electronics industry Cluster"[7]. This study aimed to identify one or two major projects that offer the potential for seeding major new industry development opportunities – to be tested in cluster workshops convened by AEEMA (pg 19) – lead projects being the 'missing ingredient' to focus R&D especially in SMEs. The SKA was noted in this report as a potential project to provide the

[6] DITAC, Aug 1991: Analysis of CSIRO Industrial Research: Earth Station Antennas
[7] DITR/AEEMA report August 2004, Centre for Strategic Economic Studies (Victoria University)

focus for the development and implementation of local electronics capabilities/products and related technologies.

The astronomical community are now engaging at an early stage through a ‘cluster mapping’ project for the SKA within the Electronics industry Action Agenda. Both industry and astronomy partners will use DITR (AusIndustry) programs to foster increased R&D, networking and collaboration between research institutions and industry. These schemes are attractive in that they reduce direct risk for SMEs who cannot otherwise invest in long-leadtime R&D. A key player in such alliances is the support of an Industry peak body to champion the project to all levels of Australian Industry (in the case of the SKA cluster mapping this is AEEMA).

The Antarctic astronomy activities led by UNSW have funded design studies on various aspects of telescope design with Connell Wagner and with Electro Optic Systems. In each case the industry partners has been able to extend their own knowledge base and expertise as a result of the astronomy funding.

UNSW has made extensive use of Australian-made products in the construction of the AASTINO and other experiments deployed to Antarctica. In each laboratory tests of components have been made at very low temperatures and have monitored the performance of systems under Antarctic conditions. Wherever the manufacturer has requested it, the results have been supplied the manufacturer to facilitate future product development.

The best example of this is with the Stirling engines. Unfortunately the manufacturer is a NZ company, not Australian. See http://www.whispergen.com/ We have signed a non-disclosure agreement with this company, and in addition to the low temperature aspects of the research UNSW has

* developed software to facilitate remote control and monitoring
* explored operation of the engines at high altitude
* developed a high-reliability coolant circulation system
* developed an anti-icing exhaust system

Australian manufacturers whose products UNSW has tested under extreme environmental conditions and in many cases modified and improved are:

* Malcolm Wallhead and Associates, Tasmania - "Igloo" fibreglass cabin.
* Battery Energy, Sydney - "Sungel" sealed lead-acid batteries
* AERL, Brisbane - Maximum Power-Point Tracker

Xilinx have provided a set of FPGAs to the SKAMP project (University of Sydney) to push their chips in the correlator design. This has the potential to be a ‘marketing’ tag for other applications.

On the international scale, astronomical tools and techniques are regularly transferred to medicine, industry, defence and environmental science. For example, the Low-Intensity X-ray Imaging Scope (Lixiscope) has its origins in X-ray astronomy and is now one of NASA’s largest sources of royalties.
Astronomical data imaging techniques have been adopted for reconstructing 3-D images from CT scans, MRI (magnetic resonance imaging) and position emission tomography, for medicine, material science and other applications. Specific software developed for astronomy (e.g. IRAF and AIPS, developed by NRAO) have been applied to cardiac angiograms, monitoring neutron

activity in the brain, studying car crash scenarios and testing aircraft hardware. The FORTH computer language, developed by NRAO, was commercialised and subsequently used to control systems in the space shuttle, Argo submersible vehicle, quality control of Kodak film production and extensively for hand-held computers systems.

1.4 Astronomy PhDs and links with industry

Astronomical instrumentation provides graduate scientists and engineers with the facilities on which to develop and stretch their talents: there is an outstanding precedent, for two decades the Fleurs radio telescope of the University of Sydney provided the focus for PhD research for both scientists and engineers, many of whom went on to work on chip design and wireless networks. The Fleurs synthesis telescope provides a 'real-world' radio astronomy challenge – one that can only be created by a complete, operational radio telescope. David Skellern and John O'Sullivan, two of the key individuals behind the formation of Radiata both completed their PhDs using the Fleurs radio telescope and spent many years working on radio astronomy instrumentation.

PhD students develop a wide range of technical and personal skills that make them highly employable:

- Data analysis – the ability to analyse vast quantities of complex data
- IT – astronomy demands powerful, modern computers and software
- Innovation and entrepreneurship – a PhD in astronomy requires that the students explore the potential of their (often narrowly-focused) research to the wider field, as well as being able to work on novel problems requiring highly developed mathematical and reasoning skills.
- Time management – the ability to complete a challenging research project to a tight timescale.
- Teamwork – working with other scientists and engineers, often internationally
- Communication and presentation skills – being able to convey the key results succinctly and 'sell' a research project proposal or scientific argument for further funding are an astronomer's 'business case'.

Whilst many astronomy PhDs are employed in astronomy and related scientific fields, there is an increasing number who choose a career in business, the finance industry and IT. The skills required for investment banking and astronomy are (perhaps) surprisingly similar – computing models of complex data, searching for patterns and trends etc.

Astronomical development work provides a challenging environment to stretch the most able students. University based facilities – e.g. SKAMP, NTD, 2.3-m, Skymapper, AAT etc, provide hands-on training grounds for students – these students are science and technology-literate – well-grounded in digital electronics and radio astronomy (receiver technologies, antennas, communications etc).

About 30% of all Australian astronomy PhDs move overseas or into industry or commerce: as noted already, some astronomy PhDs move into management consulting, finance (e.g. derivatives trading) all of which are niches often suited to the skills learnt within PhD.
The records of past PhD graduates from RSAA (ANU) show that of 78 graduands over the last 10 years, 50 have pursued an astronomy career (64%) with 41 of these being abroad (52%) although as the RSAA attracts international students this may be somewhat inflated. 11 of the graduands are in the IT industry (14%) and 17 are 'other' – either unknown, or other profession where no one option dominates.

The spread in RSAA PhD career paths are also seen in the UK PPARC survey result (DTZ, 2003) although the fraction of PPARC PhDs in the private sector is 48% (doubled compared to an earlier survey in 1995), 35% in universities and 12% in government and other public sector organisations. What the PPARC survey reveals PhDs are highly employable with only 2% being unemployed at the time of either survey.

The population of PhD graduands who move into industry create a real positive – they create networks of skilled, experienced people and are a key to future innovation. It is the wide-scale, multi-discipline integration of technologies, involving collaboration and sharing of ideas which underpins many successful ventures. Astronomical instrumentation requires stringent technical specs – requiring innovation, reassessment of current knowledge and an on-going requirement to adapt technologies to achieve the required outcome. Ultimately the entire economy is lead by innovators and creators – people who can create and/or combine knowledge into new products, services and outcomes. These are skills which are transferable from astronomy and astronomical engineering.

There is often concern expressed on the "export" of PhDs as a negative, but it creates network of international links spanning both R&D institutions and industry. These persons are our "on-side friends" being high-level and influential ambassadors for Australian astronomy. There are many examples, e.g. Richard Schilizzi – currently the International SKA Project Director and graduate of Sydney University.

Quote from MNRF 2001 review team (A Beasley, G Illingworth, P Shaver, June 2005): "The committee notes that the SKAMP sub-program has another extremely important deliverable to the MNRF and society in general – producing scientifically and technically-literate students who are well-grounded in digital electronics and radio astronomy. The hands-on training provided by this kind of development program is vital to ensuring Australia's continued major role in these fields."

Here are a few examples of CSIRO radio physics (astronomy) engineers who have gone on to other areas and have moved between astronomy and industry: Harry Fagg (previous Parkes engineer) now leads a mm-wave receiver group at the University of Arizona in Tucson. John Glowacki (previous Parkes engineer) now has a position with the Bureau of Meteorology in Darwin. Marcus Price (PhD ANU 1966, ATNF engineer) and Graeme Gaye (ATNF) now works at Univ New Mexico. Craig Carter (ATNF engineer) now works for Alcatel. Terry Percival (ATNF signal proc system, PhD from Sydney Univ Fleurs RT) is now CENTiE Director, CSIRO. Robert Ticehurst (ATNF/Radio physics engineer) went to oto work with OTC Australia, working on MMIC-based microwave systems for satellite communications. Craig Carter (MEngSc Sydney Univ, CSIRO Radiophysics engineer (ATCA)) went on to be manager R&D at Alcatel-TCC. Peter Martin (JBO, ATCA) now runs microwave company, RF Shop, in QLD: Peter's previous employment experience includes Ferranti Electronics , University of Manchester (UK), CSIRO (Radiophysics), Mitec (Australia) and Filtronic (UK and Australia).

1.5 Australian astronomy track record

Current expertise 1: Gemini & other 8-m class telescope instrumentation

RSAA is developing 2 major instruments for the Gemini 8-m telescope consortium – the Near-infrared Integral Field Spectrograph (NIFS) and the Gemini South Adaptive Optics Imager (GSAOI). These are front-line instruments where RSAA has received significant contracts from the International Gemini consortium. The particular novel/new areas are:

- innovative optical design in the IFUs
- manufacture of the complex image slicers
- large cryogenic vacuum vessels with cryogenic mechanisms
- implementation of large IR detector arrays

AAO have developed novel technologies for optical/IR instrumentation and hold a number of patents. The AAO's instrument science group is exploring new technologies on a number of fronts, including photonic devices, smart focal planes, ELT design and inertial drive compensation to counter-act wind shake of telescope structures. The world-leading expertise of this group are aptly demonstrated by the novel "Echidna" fibre-positioning system, based on piezoelectric drive systems and the suppression of OH lines by fibres. AAO is positioned to be a major player in large telescope (8-m and future ELT) instrumentation, given the next-generation ("Aspen") instruments are each likely to have budgets of ~USD 60M (e.g. WFMOS). AAO's instrument science group has links with industrial partners in 8 countries and collaborates with 6 universities in technology development, at the cutting-edge of which are the development of ultra-narrow band "VPH" filters (volume phase holographic) and the development of centimetre-scale 'cyrogenic' autonomous robots which would be central to new instrumentation.

Current expertise 2: Multi-beam wide band receivers and processing systems

CABB – 2 GHz broadband correlator trains DFB designers (a skill which is in demand).
Wide band, multi-beam receiver development for the tough demands of radio astronomy within CSIRO (ICT & ATNF) has lead to further contracts (e.g. ALFA – Arecibo – Cornel University).
CSIRO MMIC design skills (a result of significant funding – MNRF 1997, MNRF 2001 and CSIRO Executive Special Project funding) are highly relevant to industry (e.g. Optus, ESA, etc).
Currently there are end-user restrictions with ITAR (Dept of State, USA) regulations, but through ATNF's good relations with TRW/NGST we are in a position to help Australian companies (and international partners) design and produce MMICS for demanding astro/comms applications (e.g. 20-30 GHz LNAs).

Current expertise 3: 'tuning' antenna performance

CSIRO radio astronomers have helped bodies such as Telstra and the Department of Defence fine-tune the performance of dozens of their communications dishes, both in Australia and overseas. For the relatively low precision needed for commercial operations this is a traditional tape-and-theodolite operations. For precision applications such as radio astronomy, CSIRO engineers have used radio interferometric holographic techniques to fine-tune the radio astronomy antennas at the VLA, VLBA, Bonn, Urumqi and ATNF and a few specialised antennas of the Department of Defence. Holography is particularly suitable for the very large antennas (eg, Bonn and 100m)and the precision is signal-to-noise driven and can achieve ~1/100 lambda accuracy.

Current expertise 4: wideband linefeed development

University of Sydney is currently undertaking a joint project on line feed development with Argus Technologies. The work is funded through a Linkage Project grant with the specific goal (now fulfilled0 of developing a multi-purpose line feed that would benefit the company. Argus is a medium-size enterprise ($25 million turnover) and the MD is a past USyd PhD. Bevan Jones was in Christiansen's Elec Eng group but his thesis was in radio astronomy.

2. Astronomy and Industry – the challenge

Astronomy recognises the important benefits of early engagement with industry, particularly in this era of billion-euro international facilities – the 'extremely large telescopes' such as the optical-20m and the radio SKA - Astronomy must draw on expertise across a wide range of industry sectors - electronic engineers, ICT, networking, consulting/managing engineers, civil engineers and financiers - to name a few). Projects have benefited enormously from strong industrial engagement – e.g. the VLT programme at ESO fostered strong industrial partnership from the early concept stage, via an EU initiative including many industry briefing workshops and networking (contact at ESO is Robert Fischer for more information).

The challenge is that the enthusiasm and engagement from Astronomy is rarely reciprocated by Industry due to their differing underlying drivers: Astronomy is driven by research and the development of technologies for the public good whereas industry cannot justify investment in risky, long lead-time, speculative R&D where the outcome may not be a significant contract or single-ownership IP. However, early R&D is often the key to developing key capabilities – to gain best benefit Australian industry must be in the ELT projects at their early stages, and not just at the final build/bid stage.

Contributing to the problem internationally, and particularly true in Australia, is that whilst Australian astronomers recognise the need for well-run interaction, there is little resourcing of this activity: often it is left to a keen project leader to be the 'key account manager' for one or more industrial partners which are managed alongside the project delivery. Experience tells us that managing Industry collaborations can be high maintenance, to ensure the project goals are achieved.

The challenge of this decadal plan is to agree an action plan by which both partners (Australian Astronomy and Industry) can engage in a way that both partners can 'afford', and also eventually reap the additional flow-on benefits.

3. Why does the Australian Astronomy community need to engage?

To derive a set of recommendations for the decadal review process (i.e. answer the "How" question), we began by summarising our response to the question "Why do we engage?"

- Engaging Australian industry gives the Australian Astronomy community a strong history/sales point for future grants to the Government – increasingly we have to show we have a flow-on benefit (multiplier effect, not just contract passing).
- Government *policy* is encapsulated in the National Research Priorities (BAA2).
- On big projects we require a wide scope of talent, capacity and skills that is beyond that within the Australian Astronomy community.
- Prior engagement on big project R&D fosters Australian Industry and places them in a strong competitive position for the 'build' contracts – this is an efficient use of the tax-payers investment dollar.
- To ensure the existence of healthy collaboration between CSIRO, Universities and other partners and Australian industry – either from fostering existing capabilities or nurturing new ones.
- To create an environment that is attractive to its staff and students as it shows relevance to key engineering problems rather than 'just' astronomy (flow of talent to/from Industry).
- To ensure Australian industry is well placed to bid for eventual ELT, SKA and other contracts.
- To allow Australian industry to exploit the IP developed within astronomy R&D in the wider marketplace.

The aspirations of Australian Astronomy for the decade 2006-2015 are such that we have to improve our industrial partnerships.

4. How does the Australian Astronomy community engage?

This WG recommends that we re-energise the Australian Astronomy Industry Network (AAIN) for the Australian Astronomy community to capture the capabilities of Australian companies. The AAIN would be used as a first-line resource for networking, consulting and early R&D collaborative information (finding out 'who' can do 'what' 'now').

As reported in the Astronomy Australia report to PMSEIC (June 2004) one of the outcomes from IAU 2003 GA Industry Day sponsored by ANU, CSIRO, DITR and Connell Wagner was the initial formation of the Australian Astronomy Industry Network (AAIN) with the objectives of

- Producing a quarterly newsletter for information, updates and general communication
- Establishing and maintaining a website with interactive communications including the announcement of opportunities
- Producing and maintaining a database of advanced technology capability (to allow participants to locate appropriate skills.)

An initial website was set up in August/September 2003 but the AAIN has lain dormant since. The IAU Industry Day was an excellent start but with a fatal weakness that we haven't had the time, money and effort to maintain this initiative.

One should question why there has been little feedback from industry regarding the lack of action of the AAIN: whilst there has been some continuing discussions with a few companies, the vast majority haven't had an contact since July 2003 - this tells us that astronomy is a small market which is 'interesting' but otherwise may be no different from any other.

It is vital that the Australian Astronomy community presents a single consistent and easy-to-contact interface to industry, showing the commonality between the various initiatives as well as divergent facets of our technologies, at least for the initial phase of any contact. There will be programmes where the primary driver is wavelength – i.e. radio/mm vrs optical/IR – but we should be careful not to partition our efforts too early as technologies converge.

In acting as 'team Australia Astronomy' we remove the requirement for each institution to replicate the basic network and also leaves open a 'wide' communication channel. The AAIN will support the view that all University, national and international facilities are vital to the overall development of fundamental astronomical science: University facilities are both the initial training grounds and test-beds of proof of concept activities, whereas national facilities have an more strategic focus, providing the prototyping and implementation platforms for new instruments.

AAIN can be viewed as a form of 'outreach': potentially costly but at least with some promise of healthy returns. We must become better at presenting the R&D within Australian Astronomy as an intellectual store with an inventory that is open for Australian Industry to exploit.

The database will be two-way, and we hope that this will encourage further sponsorship from industry and/or peak bodies. The AAIN coordinator will be the primary contact point to forward information to the entire network regularly on world-wide opportunities. This contact must be regular, and keep register of 'successes' which is important for future Government funding applications.

The AAIN activities could be fulfilled on a contract basis at about 0.5 FTE with the role defined as the AAIN Coordinator. It would require an individual who is astronomy and industry-literate, who should probably report to AABoM or some similar body, depending on funding arrangements. Ideally, this position would be funded by part of the next NCRIS grant to the whole Australian Astronomy community. Liaise with AEEMA and AIIA. This individual would be best placed to advise astronomical institutions and departments on the scale of likely industry interest for future R&D and the best way to communicate. Thus the incumbent must be a good communicator and able to liaise with IEAust and industry bodies to plan briefings, workshops etc.

Outcomes:

- single resource for initial contacts and opportunity information
- reduction in time spent by nascent projects in identifying potential collaborators and contractors
- easy-to-find entry point for Australian Astronomy
- clearly defined contacts
- maintains 'corporate memory' – removes some of the reliance on key individuals or goodwill for its continuance
- provides history trace of activities and allows the community to plan future events (workshops, etc) of relevance to industry on a shared basis – avoids clashes, makes best use of time (both Industry and Astronomers).

We recognise that within the Universities there are many initiatives (ANU Innovation, etc) which we certainly don't want to duplicate. The best way forward is for us to provide the answers to the one question these Innovation departments pose – 'find a company you can work with' – an operating AAIN is the key to identifying both the players and opportunities.

We might consider also including a job vacancy section on the AAIN – we know that engineers in astronomy migrate to/from Industry and furthermore might use the AAIN as a way to foster more PhD/apprentice sponsorships/exchanges in the future.

5 Contributors

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Appendix 1: A snapshot of Australian companies either stemming from, or using technologies developed within Astronomy

Austek Microsystems – founded 1984 semiconductor startup, Austek Microsystems. Following a first-round financing of $US 6.7 million in 1984, the company developed the world's first single-chip cache controller and other complex logic chips used by PC manufacturers in the U.S, Asia, and Europe, as well as the first asynchronous logic VLSI chip. Austek Microsystems Pty. Ltd. was a company founded to commercialize a break-through design technology developed by CSIRO through their VLSI Programme. Developments also included a floating-point arithmetic processor chip for an American computer company, samples of signal processing chips for Japan and the world's first single-chip cache controller operating at 20 MHz and to augment the performance of 80386-based computer systems.
Austek Microsystems went on to develop chip used in the Cochlear implant.

Lake Technology Corporation
In the late 1980s, the CSIRO Division of Radiophysics and Austek Microsystems co-developed digital signal processing technology for the development of new chips. Two engineers, Brian Conolly and David McGrath, saw a business opportunity in the technology in audio applications, and founded Lake DSP in 1991. (The company was renamed Lake Technology Limited when it later listed on the Australian Stock Exchange.)

Lake Technology's first customer was Bose, the well-known US audio company, which contracted Lake Technology to explore the development of digital audio signal processing products. The products developed under the contract were acoustic research tools which are still marketed to acoustic laboratories in Japan, the USA and Europe.

With the support of a Commonwealth industry R&D grant, Lake Technology developed the Huron Simulation tools, a package of software-based signal processing systems over the period 1993-6. These tools are suited to a range of virtual reality applications, such as virtual teleconferencing, interactive simulation of the acoustic qualities of buildings at the design stage, multi-player games and location-based entertainment for amenities such as theme parks.

The simplicity of the technology means that it can be incorporated in several consumer products. It is also easily implemented in a wide range of digital processing chips, thus opening the door to its use in most situations where headphones are used and leading to the development of the process known as Dolby Headphone.

Dolby Headphone allows people to listen to computer models of room acoustics and experience the sound as if they were present in the space being simulated. In 1997, Lake Technology began to market the headphone surround sound technology. In 1998, Dolby agreed to commercialise the technology as "Dolby Headphone". Singapore Airlines launched the technology in April 1999 for its in-flight entertainment. Lake Technology has subsequently licensed the technology to Qantas, Lufthansa and Cathay Pacific.In the eleven years since inception, Lake Technology has grown to a company employing more than 25 staff and listed on the Australian Stock Exchange in December 1999.

In December 2001, Dolby Laboratories acquired a strategic shareholding in the company, the first such investment by this world-leading company. This is expected to give rise to further licencing opportunities in the future and validates the quality of Lake's audio technology.

Accusound Pty Ltd started designing and manufacturing loudspeakers in 1984 based on the A4 chip designed for audio applications by the CSIRO radiophysics team working on the FFT and VLSI projects. They are now highly successfully developing and selling mid-range speaker systems.

AUSSAT Australia's national satellite company, now Optus Communications Pty. Ltd. provides a wide range of domestic services to the entire continent and its offshore islands. Services include direct television broadcast to homesteads and remote communities, high-quality television relays between major cities, and voice applications for urban and remote areas. In 1993 "Aussat" developed an L-band tracking satellite antenna as a joint project with CSIRO. When "Aussat" became "Optus" work was stopped on this project, although CSIRO continued development to a commercial product.

Radiata is the most successful Australian start-up whose origin lies in radiophysics research. The basic research into realising wireless LAN communications were developed in the 1990s and earlier radio research by many groups worldwide including CSIRO radiophysics and the Department of electrical engineering at Macquarie University. CSIRO funded the development based around 60 GHz given the expertise gained from radio astronomy and microwave landing systems, and developed a broadband wireless system based on the fast-fourier transform and coded orthogonal frequency division multiplexing (CODFM). A US patent (applicable to the '802.11a' standard for WLANs – but also the .11g and .11j standards) was granted in 1995 (O'Sullivan et al, CSIRO). Radiata was formed in 1997 to meet the demand for 5-GHz based wireless LANS. Radiata was purchased by Cisco in 2000 for AUD 567M. The interaction with CSIRO radiophysics continued, with research into indoor radio propagation and antennas in particular.

Auspace Ltd was set up in the 1980s by a group of electronics engineers from Mount Stromlo Observatory (now RSAA), ANU, Having worked on the Starlab project (Australia-Canada-USA joint project) they pooled expertise in electronic cameras and spectrum scanners. Auspace now makes hardware for earth-observation satellites and telecommunications, has been the prime contractor for the re-build of the Gemini NIFS instrument (following the RSAA bushfire) and is a wholly owned subsidiary of EADS Astrium. Ausspace built FEDSAT. Two key personnel have background in astronomy, total workforce ~35, annual revenue ~$7M. About 40% of work from overseas.

Electro Optic Systems Pty Limited (EOS), based in Queanbeyan is a world leader in space research, having adopted the technologies for optical astronomical telescopes for satellite-ranging systems. EOS also now focus on the development of new technologies in space navigation and tracking, employing engineers in electronics, lasers, opto-mechanical and software development. 2 of 3 CEOs have astro background, 3/8 senior managers are astro background out of total of ~85 employees. Annual revenue ~$25M. About 95% of work comes from overseas.
Connell Wagner – already discussed

Poseidon Scientific Instruments The search for gravity waves by the University of Western Australia has led to new commercial technologies. One is an ultra-stable microwave oscillator, now licensed to an Australian company, Poseidon Scientific Instruments (PSI) and through it to US defence contractors. PSI launched as a technology consultancy with close links to university research (UWA) in 1988. In the early 1990's, Jesse Searls, the founder and managing director, recognized the potential of a unique technology then under research at UWA. At the heart of the technology is a high-quality sapphire-loaded cavity resonator which allows low noise signals to be generated directly at microwave frequencies. In 1993, the unique technology and cutting edge performance of the Poseidon oscillators quickly drew the attention of many of the world's largest and most sophisticated defense contractors. PSI’s signal generators were selected and designed into defense systems because they provided a strategic advantage that no other technology could match. In 1996, PSI's first commercially available low noise signal generator was introduced, with a "Shoebox" sized oscillator following in 1998. This totally Australian technology enables systems developers to build radars which can see many times further, with much higher resolution or with much lower system weight and cost than could be achieved with established technologies.

CSIRO Industrial Physics has unique expertise and capability to produce the precision optics (mirrors and beam splitters) required for NASA’s LIGO and SIM missions (see http://www.tip.csiro.au/IMP/Optical/customers.htm). This expertise grew out of its work on solar astronomy (1970s) and the Sydney University Stellar Interferometer (1980s) – both of which required high-performance polished surfaces.

Altium Ltd Develops and sells electronic design automation (EDA) software used to design electronic products under MS windows. Sydney HQ, has 270-employees, 2 key top personnel with astro background. Annual revenue ~A$50M, 98% of its business is with overseas customers. Dave Warren of Altium was keen that the Sydney Univ group use Altium’s FPGA routing/programming software (Protel) for the SKAMP project. There were discussions between Altium & Tim Adams which triggered some amendments/improvements in the software.