University, Industry, Government and International Partnerships in Education and Research to Sustain and Develop the Engineering Profession

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Abstract — *University-community partnerships have a range of objectives and can take many forms. Engineering education and research would scarcely be meaningful without partnerships with industry, for it is within industry that most graduates are employed and most engineering practice actually takes place. The regular partnerships between faculty and industry that ensure contemporary curriculum, provide guest specialist lectures, facilitate workplace experience for undergraduate students, and research contracts and consultancies are not the subject of this paper. Rather, this paper examines a number of more complex partnerships and collaborations, most of which have more than two partners, and have quite complex operating conditions and multiple accountabilities. The first example is an illustration of how university engineering and technology educators can develop a formal partnership with the school education sector to raise young people's awareness of interesting and challenging careers in areas that not often well understood through the normal curriculum. The paper describes a partnership between the University of South Australia and local secondary schools that uses robotics to enhance understanding of high school science and mathematics, as well as raise awareness of further education and careers in the electronics industry. The second example is an Australia-wide consortium (of which the author is the project manager) that involves several universities with the national Defence Science and Technology Organisation that is providing advanced technical programs to that organisation's staff. There are political dimensions to the way in which this consortium has been created, and a feature of the project delivery is the employment of a private, independent management partner to do academic program and course administration. The third example is in international education, using the case of offering a University of South Australia engineering degree in partnership with a private education provider in Singapore. The fourth example of partnership is in research, drawing specifically on examples of two centres funded under the Australian Cooperative Research Centre program. This program supports more than seventy such centres mostly in scientific and technological areas, with express purpose of supporting research to lead towards strong commercialisation outcomes. The author is a Board member of the two described, one in the technology of distributed enterprises, the second in engineering asset maintenance. The paper discusses the benefits of these partnerships to the University's engineering and technology profile, and concludes with comments on the parameters of effective partnership in terms of the need to establish clear partner benefits and agreed joint outcomes, and the value of high levels of trust between the partners.*

Index Terms — *partnerships, collaboration, cooperative research, continuing education.*

INTRODUCTION

Engineers will continue to make critical contributions to nation building and the sustainability of corporate organisations for many generations to come. The profession of engineering is global and dynamic, needing to exploit the latest science and technological knowledge and management processes to solve problems, and create new ideas and products, systems and processes. Meeting the needs of increasingly complex modern societies, with their rigorous accountabilities to environmental, social and economic goals, places high demands on the engineering profession, and its educators and researchers. These complexities and demands make it ever harder for one organisation to "do everything" and business partnerships and collaboration have emerged as a common operating paradigm. Partnerships enable expertise to be shared and critical mass accumulated. In different ways, partnerships between engineering education and research providers and with industry and government have become the norm in many areas, although they take many different forms. (The very emergence of publicly-funded engineering education in the industrial nations more than a century ago could be regarded as an outcome of the political and economic partnership between states and their industrial leaders.) Today, all over the industrialised world, university-based engineering education and research interacts actively with high-schools and engineering industry to achieve many of their goals, and such partnerships may be directly supported or mediated by governments. In general, these partnerships contribute very positively to the maintenance and development of a healthy engineering profession.

This paper reviews a number of partnerships and collaborations that have been developed recently between the engineering and technology division of a large comprehensive public university, the University of South Australia, and the other universities in the State, local high schools, industry, public-sector research organisations, and national and international partners. In their various ways, these partnerships enhance or expand the university's engineering and technology academic outcomes, and thus contribute to the engineering and technology professions. The most effective partnerships are holistic: they achieve outcomes that the partners operating independently cannot, either because they do not have the specific technical expertise, or some aspect of the function is not their core business. Partnerships are dynamic inter-organisational systems and must have adequate governance structures, and the more partners there are, the more complex will be their organisation. Nevertheless, effective partnerships will operate with a high degree of clarity and transparency with respect to the partners' roles. Ideally, each partner has individual benefits stemming from their contribution to the mutually agreed outcomes, and ideally, there will be a high degree of trust and mutual respect between the partners. Not all partnerships are created from this ideal basis, however, and the paper describes research partnerships that have larger numbers of partners than might be ideal, and in which the leadership team has to spend relatively more time in ensuring team cohesion.

THE UNIVERSITY OF SOUTH AUSTRALIA IN CONTEXT

Some characteristics of all the partnerships are related to the socio-economic and political contexts in which engineering and technology at the University of South Australia (UniSA) operates. This section provides a brief description. Australia is a federation (also described as a 'Commonwealth') of five large mainland states and two territories, and the island state of Tasmania. The total population around 20 million presents a complex mix of higher education needs. The state of South Australia, with its capital city of Adelaide, is geographically central, but relatively remote from other population centres. Each state and territory is responsible for the provision of primary and secondary education, but the funding and regulation of higher education is a federal matter. Economic development is, of course, both a national and state concern.

South Australia has a population of about 1.5 million, of which nearly 75% live in the metropolitan city of Adelaide. On most measures, the State is a successful regional economy. Adelaide scores quite highly on many indicators, such as those related to *talent*, *technology* and *tolerance*, as proposed by Florida [1] in his analysis of the drivers of successful 'creative' economies. The State was rated as "*the most competitive city in the Asia Pacific*" in a recent international survey [2]. Adelaide is home to Australia's defence manufacturing industry, has a rapidly growing information and communications (ICT) sector, and a growing number of new bio-technology companies. Being a state of small and medium sized businesses (SMEs), several sectors, including manufacturing and defence, have adopted industry clustering models for export-oriented development. The state's three comprehensive publicly-funded universities make significant contributions to the local and national economy through educating local students and attracting international students, mostly from SE Asian countries, and mostly to study in business, information technology and engineering. Indeed, Australian universities provide a strong base for the nation's research effort, and the three South Australian combined universities' research productivity is above the national average. The state's science and technology parks have incubated several many new and innovative companies. The state government recently instituted a Science and Research Council and adopted a progressive '*10-year Vision for Science, Technology and Innovation* [3].

But against this generally positive picture lie trends that may compromise the sustainability and quality of the economy and that impact directly on the universities and the science, technology and engineering professions. First, there is a net migration of skilled graduates to other, more highly populated Australian states, and overseas. This presents problems to the long-term sustainability of key industries, as well as to the universities. (In fact, the net outward *national* migration of Australian graduates has been sufficiently strong for the federal government to create incentives to attract back top-rank scientists and engineers to lead research programs.) Secondly, the demographic trends will result in significantly fewer school leavers in coming decades, and a corresponding ageing population for the economy to support. Thirdly, student preference trends away from physical sciences and mathematics, and since 2001 from ICT, give considerable cause for concern amongst the manufacturing and other technologically-based industry sectors, as well as the universities. While many of these factors and trends are common to most advanced industrialised economies, they are more challenging in a regional economy like South Australia. Partnerships between the universities and the local community are perhaps more important than in larger economies; and national partnerships can ensure that external expertise and business can be brought into the local community at reasonable cost.

The University of South Australia (UniSA) is a multi-campus institution with a focus is on educating in applied sciences, engineering and technology, built and natural environments, the health professions (other than medicine and dentistry), teacher education, social work, business and management, and journalism and creative visual arts. The University's Australian-resident student population is predominantly drawn from the state: in 2003 there were approximately 21,000 Australian students, about one-third studying part-time and many studying in external mode. In addition, there were about

3,500 on-campus international students and 7000 international students studying UniSA programs outside Australia, making UniSA one of the largest providers of such export higher education services. Although Australian universities are public institutions in several senses: they receive government funding for a regulated number of places for Australian students, and operates within a national quality framework, they also have considerable financial and business freedom.

UniSA's engineering and technology programs are provided by the Division of Information Technology, Engineering and the Environment, of which the author is the head, as a university Pro Vice Chancellor and Vice President. Education and research programs are operated by the division's five schools. The School of Computer and Information Science is the largest state provider of computing and information technology graduates, and the School of Advanced Manufacturing and Mechanical Engineering and School of Electrical and Information Engineering are the major providers of graduates in manufacturing engineering and systems-oriented electronics, computer systems and telecommunications engineering, respectively. The division's research programs are oriented towards working with local, national and international industries on fundamental and applied problems. Areas of expertise industrial applied mathematics, satellite communication systems, computer systems engineering, wearable computing and virtual reality applications, systems engineering, environmental remediation, transport planning, intelligent manufacturing. A number of university-wide initiatives have underpinned the development of multidisciplinary approaches to education and research for the emerging important areas of complex systems, sustainability, and healthy lifestyles. The future growth of the Division is highly dependent on intensifying these research areas and growing program demand through partnerships, such as those described in the remainder of the paper.

ROBOTICS IN SECONDARY SCHOOLS – INDUSTRY-SUPPORTED PEER MENTORING BY UNIVERSITY STUDENTS

The Need to Reverse the Decline in Prospective Student Interest in Science and Technology

Although most of the population habitually uses many of the products of information technology and engineering, such as mobile phones, DVD's, note-book computers and their software applications, and microwave ovens every day, the technologies through which they work and the design and manufacturing processes through which the products and systems have been formed are rather obscure and remote. The formal underpinning sciences of these products and systems, namely quantum physics and materials science, electromagnetism, and computer science, are far from intuitive, and are perceived by most people to be hard and complex challenges to grasp. A progressively lower proportion of secondary school students is studying mathematics and science in the secondary school leaving certificate, and fewer of those that do take these courses choose to take degrees in 'traditional' science and engineering areas. The steady increase in tertiary enrolments in the information technology area that took place in the late 1990's has been reversed after the 'dot.com' collapse in the early years of the present decade. The issue is sufficiently critical for the influential South Australian Electronics Industry Association to identify the prospective skills shortage as '*the single most significant impediment to the growth and development of the [electronics] industry* '.

The Robotics Program

In 2002 academic staff from the School of Electrical and Information Engineering at the University of South Australia, together with staff (including the CEO) from a local engineering company, eLabtronics plc, developed a novel educational program for secondary school students and their teachers around an industry-standard microcontroller and its software, Corechart. The robotics in schools program introduces the students to the technologies of electronics hardware, computer systems, instrumentation, mechatronics, and software that are the basis of much manufacturing, defence and ICT industry. The robotics system and subsystems technologies can be linked to school science, mathematics and technology curriculum elements. The curriculum has been designed for school students in Years 9-10 spending 2 hours per week for 10 – 13 weeks. At the program's most basic level, the students construct and program a robotic vehicle under the guidance of their teachers, but with trained university students from Electrical and Electronic Engineering programs acting as mentors to students and teachers. An extension module that involves finer control of the motor and exploration of the some of the basic mathematics and science of the robot is also available. During 2003, with the financial support of the state's Centre for Innovation, Business and Manufacturing, the Electronics Industry Association, and several manufacturing companies, the program was delivered to more than 200 students in 13 secondary schools in South Australia, including some in rural areas, and several that are relatively educationally disadvantaged.

Program Benefits

The program's benefits to each of the partners are as follows:

- **Schools:** teachers understand more about contemporary technology and a more innovative curriculum, and have closer connections to the university and industry;
- **School students**: gain greater understanding of how science and mathematics are exploited in modern technology; acquire team-based project work skills and inter-group competition; gain greater knowledge of careers in industry; and establish links with the university, particularly with students whom they can regard as role models for post-secondary school;
- **Education Department:** gain assistance and experience in developing contemporary curriculum with university and industry support;
- **Industry:** has greater engagement with university staff and students and prospective students and teachers, to facilitate understanding of career opportunities;
- **University academics:** have direct engagement with industry and schools (the 'bookends' between which a university engineering school operates); their engagement with secondary-school education processes have the potential to raise awareness and aspirations of school students in engineering education and careers;
- **University students:** as paid mentors to teachers and school students, gain confidence in their understanding of science and technology, and develop inter-personal communications, mentoring and professional skills.

Surveys of the first groups of participating school students and university students indicate very positive responses to the program. The school students involved have certainly enjoyed the camaraderie and competitiveness of making the robots work and follow a track. At one rural school they have also explored potential applications of the microcontroller to the school's viticulture and aquaculture activities. At this and other schools, teachers have used the program as a stimulus to innovative thinking. The program achieved national recognition by winning the 2003 *Australian Engineering Excellence Award for Innovation* , and has since won further funding from the state government to expand it to 1000 students in 30 schools by 2006, and develop related curriculum for Years 9 -12, and explore the programs' national and international potential.

Partnership Management

This program is an example of a collaboration in which each partner is essentially doing its core business, but is extending its scope across a new interface and is gaining knowledge and enhancing some aspect of their business in that process. Programs of this type will generally operate on a small scale through the combined enthusiasm of the initiating partners, but scaling to engage the interests of all partners may require a formal governance and management structure. This is especially important to provide accountability for expenditure of public funds. In the case of this project, the University has taken the lead in coordinating the project and provides supporting infrastructure, such as financial systems, to ensure its effective operation and accountability against milestones set in the funding agreement from the state government. However, the coordinating committee of the partners continues to operate in a fairly informal way. The schools own the robotics kits and software licence, either through purchase or industry sponsorship, obviating any problematic intellectual property ownership issues.

POSTGRADUATE EDUCATION FOR THE AUSTRALIAN DEFENCE SYSTEMS AND TECHNOLOGY ORGANISATION

The Australian Defence Science and Technology Organisation (DSTO) is a large Commonwealth government institution formed to provide independent technical advice to the Australian Department of Defence. It has establishments in several Australian cities, with its electronics systems, and information technology divisions headquartered in Adelaide, being a major employer of ICT professionals. A number of major global defence industry companies have also located in the Adelaide area, and DSTO itself has spun-out several manufacturing and service businesses there. The DSTO establishments in other cities undertake research and development work in mechanical systems and materials, and human operations. DSTO has close links with many Australian universities, mostly through joint research programs and projects. While the 'scientific' staff in DSTO mostly have PhD's, the supporting 'professional' staff mostly have four-year bachelor degrees in science, technology or engineering. In 2001, DSTO decided that to meet the technical and scientific demands of their work, it would be highly desirable for the all professional staff to have at least a Masters degree. DSTO management judged that their existing scheme that provided for staff to have time release and fees paid for undertaking Masters degree studies at a university of the staff member's choice was inadequate to meet this continuing education goal. To build a national continuing education system, DSTO turned to the three local universities, acting as a consortium, to manage the proposed national program.

The three South Australian universities had formed the South Australian Consortium for Information Technology and telecommunications (SACITT) in 1997 in order to develop and collaborate on the information technology and telecommunications research. State funding had assisted this development by providing funding for professorial positions at each university in complementary areas. SACITT reports formally to the committee of University Presidents. In 2001 SACITT was formalised as a legal entity, and since 2002 has managed a number of State research infrastructure projects in high performance computing and broadband infrastructure. Since its inception SACITT has an active Industry Advisory Board on which DSTO and several of the local defence companies are members and this has run workshops on research capabilities, and ICT careers promotion. So it was natural for DSTO to turn to SACITT to manage its proposed continuing education initiative. Nevertheless, being a national organisation with close working relations with many of Australia's universities, DSTO did not wish to have all its Masters programs be operated by the universities in a single state, let alone by one university.

The DSTO Continuing Education Program – Development, Management and Governance

DSTO's internal analysis had revealed that a suite of seven master's programs would be needed to cover its requirements, including several in the electronics, systems and information technology and engineering areas, human factors, operations research and mechanical engineering. DSTO established internal working panels to define the content in each program, and to choose the preferred university supplier. The chosen programs were mostly based on course selections from existing programs with which DSTO staff had experience: indeed several had previously been developed for DSTO as short-course modules. The need for new courses was also identified, including two core ones (included in all programs) on Systems Engineering and Multidisciplinary Research Methods that are critical to DSTO's mission. In the event, the Masters programs are drawn from five universities, with courses taken from twelve. Study is part-time, so that a Master's program, including the thesis would normally take three calendar years to complete. DSTO also sought to have a student administration process whereby once a DSTO staff member had been identified to take a particular program, the student management and administration with the universities' systems would be handled externally to DSTO. DSTO also sought to have the course level financial transactions with the provider universities handled as 'corporate group enrolments'.

In discussions with DSTO, SACITT realised that it would be hard for any one university's student administration and financial system to manage these requirements. With DSTO's agreement, SACITT subcontracted the program and student management to a corporate education and training company, AITEC plc based in Adelaide. The author is the SACITT Board member responsible for overall management of the program. AITEC manages the interfaces with DSTO and provider universities on behalf of SACITT, although SACITT issues the course contracts with the provider universities. While this may seem unduly complex, it ensures the required degree of independence of the SACITT Consortium, and the three consortium universities operating as program and course providers. AITEC also manages student feedback. Regular meetings between DSTO and AITEC, and between AITEC and SACITT ensure effective management, and these are backed up by an annual review by DSTO, SACITT and AITEC.

The program has been successful. Since its inception in 2002, more than 200 DSTO staff members have taken course units, and the first graduates will complete their masters' degrees later this year. DSTO has commissioned a number of new courses. The program has recently been opened up to staff in the local defence industries. More highly educated staff enhance the organisation's capability in science, engineering and technology. The universities providing the programs and courses are pleased to have the additional enrolments and closer relations with the defence industry. The provision of management and administrative services across Australia is good business for the private education and training provider. From a partnership perspective, it looks simple: each partner is essentially doing core business. The operation of the partnership is governed by detailed contracts, and these and regular reports ensure appropriate accountability. The organisational complexity described above minimises conflicts of interest and ensures national interests are met.

TRANSNATIONAL ENGINEERING EDUCATION

The provision of university places in many countries is inadequate to meet local demand, and many universities in industrialised countries have benefited from taking international students. In addition, the international movement of students (and academics) is a very important element of intercultural understanding and globalisation. But financial and other constraints limit the availability of this 'on-shore' model of international education. The alternative model, known as 'transnational' education, is for universities to offer their degrees in countries where there is unmet demand. UniSA has developed this model during the 1990s, and by 2003 had more than 7000 students studying UniSA degrees in Hong Kong, Singapore, Malaysia and Taiwan. The UniSA model is to develop these programs as partnerships with universities or private education providers in the 'host countries', rather than build UniSA campuses. This model allows flexibility with respect to changes in higher education regulations and other operating matters, such as regulations regarding the holding of foreign assets. The host country partner normally has the contractual obligation to manage local matters, while UniSA is responsible for the academic material and its delivery. About 70% of UniSA's transnational students are undertaking MBAs and other business degrees, but the Division of Information Technology, Engineering and the Environment runs masters programs in Project Management and Manufacturing Management and bachelors degrees in Computing and in Mechanical and Manufacturing Engineering. The provision of a transnational professional engineering degree poses particular challenges, some of which are described below.

UniSA's B.Eng in Mechanical and Manufacturing Engineering in Singapore

This degree program is managed in Singapore with a private management education company, APMI, with which the university has a long standing partnership. The B.Eng. program is restricted to holders of Diplomas in relevant disciplines from the Singapore polytechnic system who have significant work experience, and are employed in manufacturing. The students admitted to the program are given appropriate credit for their educational qualifications and work experience, so that to gain the degree requires completion of 12 course units of study in Singapore, plus a short period of study, with a focus on laboratory work, at the home campus in Adelaide. This study pattern ensures that the program is equivalent in content to that offered at the home campus in Adelaide to students of similar background. The taught courses are presented in block-mode in Singapore by the Adelaide-based staff, with some local support from adjunct staff based in Singapore. (The success of this teaching mode resulted in the Adelaide campus-based program changing to block-mode delivery for the final two years of the program from 2003. This suits the lifestyle of many of our students who are in employment in the manufacturing industry.) The course materials and assessments are identical to those provided on the home campus. Project work is undertaken in the industry setting, under the joint supervision of an Adelaide-based and local staff member.

The program operation thus relies on the contractual partnership between the UniSA School of Advanced Manufacturing and Mechanical Engineering and APMI. The program is also subject to UniSA's rigorous transnational program administration and review processes. AMPI provides recruitment and local student and course administrative services, teaching and examination arrangements, information technology services and other resources management, as it does for other UniSA transnational programs. In addition, for this program, APMI has assisted with the establishment of a Industry Advisory Committee to ensure adequate industry liaison to ensure the quality of the project work conducted in industry, and to provide the university with advice on relevant local industry and professional matters. The engagement of the local engineering community as a formal committee is effectively the third arm of the partnership. The program is now in its third year of operation, having had its first graduates complete their studies in 2003, and its 8th cohort of 30 students commenced the program in July 2004.

This partnership program successfully fulfils a number of goals: it is a good education business for both UniSA and APMI and provides a much sought-after degree qualification for professionals working in the industry in Singapore without their having to finance full-time study overseas. The program contributes to the breadth of UniSA's internationalisation profile, and enhances the professional links between South Australia and Singapore in the manufacturing engineering field. The partnership operates through formal contractual arrangements and university policies and procedures, but its success also owes much to the mutual trust and respect between its managers that has developed over the years.

COOPERATIVE RESEARCH CENTRES

Having provided three examples of collaboration that are concerned with the university's engineering and technology education mission, this final example focuses on collaborative research geared to commercialisation. Australian science and technology research has a high international profile from the outputs of the universities and government research establishments, but the rate of conversion of ideas to commercial outcomes has been generally lower than desired. Linked to this, and a partial explanation, is that public research funding is relatively high, at 0.7% of GDP, ranking 5th in OECD statistics for 2000, but business R & D funding is much lower, at 0.8% of GDP , ranking 15th in OECD statistics in 2001, as reported in a recent Australian government paper [4]. Of the several Australian Commonwealth schemes that have been developed to improve industry investment in R&D creation and exploitation, the national Cooperative Research Centres (CRCs) program has been one of the most successful.

The CRC program was created in 1990, and has funded more than 70 focussed research centres that bring together university research, publicly-funded research bodies such as DSTO, and industry. Essentially, the CRCs create entities of critical mass to achieve important applied science, technological and engineers goals by drawing on the capabilities of existing research groups and connecting them to relevant industries. The programs' objectives have been recently restated as

'*To enhance Australia's industrial, commercial and economic growth through the development of sustained, user-driven, co-operative public-private research centres that achieve high levels of outcomes in adoption and commercialisation*' [5]. The CRCs receive Commonwealth funding for periods of seven years, with major reviews points during that period, and the opportunity to re-bid for subsequent funding. Winning a CRC is a time-consuming and rigorous process first of partnership building to ensure the bid has best available expertise and management structure to achieve the goals, and then convincing the CRC Committee of the bid's merits. Only about 25% of the bids in each biennial funding round succeed.

A typical CRC in the ICT or engineering area operates with an annual revenue of about Aus$15M, with $3M from the Commonwealth and the remainder as cash and in-kind funding from the industry and university partners. State governments often contribute to the industry cash component in order to support specific technological industry development. A typical CRC would have about 60 research staff and 50 postgraduate research students. The operation of a CRC's research programs and projects and commercialisation processes is dependent on developing and working to contracts that are developed by agreement amongst the CRC partners. The CRC reports quarterly to the Commonwealth on financial performance and program progress against milestones set in the funding agreements. The program as a whole has been judged largely successful, with a number of CRCs spinning off highly successful new businesses, as well as generating IP for their partners. Doctoral graduates from CRCs are sought by industry for their particular skills in applied areas and their experience of working with industry. Several CRCs have been refunded. Most are established as corporate businesses.

The University of South Australia is currently a partner in ten CRCs. The following paragraphs briefly describe two CRC in which the author is closely involved as a Board member.

The CRC for Enterprise Distributed Systems Technology (EDST)

This CRC was formally created in 1999, although it had existed in a different form from 1992. Its object is to research and develop software technologies and tools to support secure distributed business and government enterprises. The University of South Australia formally became a member in 2003 in order to create a South Australian node with DSTO and State government support and intensify the defence technology programs. The CRC now has 8 industry partners, 6 universities, 3 government research entities, and support from 3 State governments. One of the industry partners is the operating business of the CRC itself. Thus the CRC operates as a joint venture and also has a company business structure. Governance is unified by a common Board for the two entities. The operational and research management of the CRC are led by the CEO and Research Director through management and research committees that involve all the participants. The CRC researchers are employed by the CRC business itself rather than by the partner's institutions, as is the case in many other CRCs. Maintaining multi-partner research programs and projects that are distributed across locations requires considerable trust between partners, as well as considerable travel and communications. The operation of this CRC exemplifies its very topic – as a distributed enterprise – and it has achieved a number of excellent technology demonstrations, notably in the area of software systems for managing Electronic Health Records [6].

CRC for Integrated Engineering Asset Management (CIEAM)

This CRC came into being in 2003, with seven university partners, four industry partners, two government research partners and one state government partner, the operator of the state's rail network. Its object is to undertake research and develop technologies and tools to monitor the operability and state of major physical engineering assets, such as those in defence, mining, water and power industries, and integrated decision support for systems maintenance. CIEAM's goal is to assist to reduce the cost of asset maintenance and increase its life while not increasing risk. The human dimension of maintenance is a critical issue included in the research and education program. Like EDST, CIEAM also has both a joint venture and management company structure, but has chosen to make the management small, and have the research partners employ the researchers. The CRC's research program commitments, IP management and commercialisation plans are the subject of contracts and policy that have been developed in the first year of operation. Also like EDST, the programs of this CRC are quite multidisciplinary, making research program management intrinsically harder than would be the case in a purely technological R & D enterprise. On the other hand, multi-disciplinarity is the nature of most practical engineering situations, so these CRCs emulate 'real-life' and provide rich experiences for their doctoral students and research staff.

CONCLUSIONS

The paper has described four collaborative activities that are enhancing UniSA's engineering and technology education and research. The partnerships extend the university's influence and contributions to the profession in different ways. They have also come about in different ways. The CRCs are somewhat formula-driven by the specific requirements of the funding CRC program, but like most partnerships were the result of the inspiration and hard work of a small number of individuals who have worked up the research and business cases to the level required, without necessarily, having had prior collaborations. The partners have come together because of their complementary expertise, shared vision, and perceived value to their own organisation. The teaching program partnerships have similar attributes, although they have grown from locally generated ideas and prior knowledge of potential partners' interests and expertise. These partnerships may then have increased their membership and formality to meet political constraints or accountabilities and gain external support. There is no doubt that the more partnering entities in any one collaboration, and the greater the level of funding, the more complex will be the partnership to administer. One might suggest that if the costs of managing the partnership (rather than its programs) becomes more than say 20% of the partnership revenue, then the number of partners may have become too large for the level of its business: this deserves further study.

The author is mindful of the literature on successful partnering, such as that referred to at the ICEE-2003 Workshop by Dray and Scalzo [7]. These authors propose a set of 'Blueprints' to assist finding good partners by posing key questions in the areas of partnering goals and criteria, shared intent, self-interest, and partnering vision. An evaluation of all of the partnerships described here validates this approach even though in none of them did the partners go through a process of explicitly answering such a question set.

In conclusion, universities – not least in engineering and technology education and research – are likely to increase their collaborations with external communities to meet their own and the communities' needs. The modern media of the Internet and increasingly of Access Grids will facilitate larger and more complex collaborations, and managers' skills in partnering will continue to develop. Fundamentally, however, the most successful partnerships will continue to prosper from the mutual trust, respect and satisfaction that comes from working together to achieve shared goals.

ACKNOWLEDGEMENT

The author is grateful to the following colleagues at UniSA and in the collaborating organisations referred to in this paper for their contributions to the development of the partnerships and the author's thinking: Alan Bradley, Adrian de Brenni, Neil Bryans, Andrew Chen, Peng Choo, Rob Cook, Stephen Cook, Reg Coutts, David Cropley, Brenton Dansie, Geoff Ewens, Mark Gibson, Ozdemir Göl, Andy Koronios, Jason Kuchel, Lee Luong,, Chris Marlin, Joe Mathew, Angela Murray, Andrew Nafalski, Zorica Nedic, Tony Parker, Steve Pendry, Bruce Thomas, Jim Warren, Ian Young.

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