



Cooperative Research Centre for
Integrated Engineering Asset Management

Exit Report 2003–2010

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Cooperative Research Centres Program



Note: For ease of reference, the section numbering system used in this report is keyed to the structure of the CRC Program Exit Report Guidelines provided by the Commonwealth Department of Innovation, Industry and Research.

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1. Executive summary

Funding under the Commonwealth Agreement which established the CRC for Integrated Engineering Asset Management (CIEAM I) began in 2003 and terminated on 30 June 2010.

From its inception, CIEAM drove a transformational change in the practice of engineering asset management. The challenges facing CIEAM at the outset were severe.

At the highest level, there was virtually a total lack of recognition of the nature of the problems facing asset owners and operators in managing physical engineering assets. Prior to the establishment of CIEAM, asset maintenance was seen purely as a cost, with maintenance plans being linked to short-term budget cycles, rather than the lifespan of up to several decades for infrastructure such as railway tracks and power grids. CIEAM has developed a whole-of-lifecycle approach to asset management, and the research and development program has been built on these principles.

The cost of asset maintenance is significant and rising. A BIS Shrapnel report in 2000 put the annual cost of asset maintenance in Australia at \$10 billion. Its 2008 report puts the annual cost at \$31 billion. The cost of asset management for Australia in 2010 has not yet been assessed but would be significantly higher. The potential cost savings to be achieved from the adoption of the CIEAM approach are large. Additionally, there are 'triple bottom line' benefits in improved availability and reliability of products and services, lower costs to the community and improved environmental sustainability.

Investment in physical infrastructure opens up new opportunities for economic growth. Based on that premise, CIEAM saw that investments in infrastructure would achieve desired results only if appropriate strategies and support systems were put in place to manage them over their whole lifecycle, including the acquisition process.

The challenge for CIEAM was to expand the technology and practice of asset maintenance to an integrated asset management system/framework. Asset health monitoring and whole-of-life prediction systems, linked seamlessly into the decision-support systems of an enterprise were a key focus of the research agenda. These models and systems have been brought together with engineering asset management information sitting alongside financial and budget information at the Board level.

It should be recognised that CIEAM started from, essentially, a zero base. At the inception of CIEAM there was no academic or research framework built around the concept of engineering asset management. No PhD or Masters level postgraduates were employed as practitioners in integrated engineering asset management. There were few, if any, positions in industry designated as engineering asset managers. The concept of the practice of engineering asset management as developed by CIEAM did not exist.

The CIEAM work program comprised five cohesive and interrelated research programs to create industry-ready tools and methodologies with application from the policy and governance levels to the cutting edge of specific implementation throughout an organisation. Industry focus was assured through the engagement of asset-operators and asset service and software providers in research programs. This approach promoted joint projects to stimulate the rapid uptake of new technologies and the development of products for world markets.

Throughout its life, CIEAM engaged in an extensive program of industry consultation, including a major international workshop in Brisbane in 2007, involving some 80 representatives from research, industry and government agencies, which developed a 'roadmap', known as EAM 2020, as a basis for defining the program ahead.

As part of its delivery strategy, CIEAM conducted an ambitious education program, with a significant throughput of PhD and Masters graduates, as well as professional and para-professional training and short courses in education and training institutions and asset-based organisations. Approximately half of the graduates embracing the program have been placed in industry; whereas before CIEAM, it would have been difficult to find a postgraduate qualified engineering asset management specialist employed as such, anywhere.

CIEAM has developed, accumulated and maintained a substantial Body of Knowledge (BOK) in engineering asset management. This BOK is manifested in several media, including a 12 volume education and training manual which is available as an on-line wiki, a confidential CIEAM website loaded with all research project final reports, and postgraduate theses; and several text books published through CIEAM's relationship with its publisher, Springer-Verlag.

CIEAM has driven a transformational change in the institutional culture surrounding engineering asset management and delivery, at both the national and international level. Through its own research, and active engagement with researchers and practitioners in Australia and overseas, CIEAM has achieved international recognition as having developed a world-class research and development capability in engineering asset management technology, innovation and application.

At the national level, CIEAM led the establishment of the Australian Asset Management Collaboration Group (AAMCoG), to facilitate collaboration between Australia's peak bodies associated with programs in engineering asset management and provide a vehicle for disseminating public good research in this area.

Internationally, CIEAM drove the establishment of the International Society of Engineering Asset Management (ISEAM) as a new international multidisciplinary professional learned society dedicated to the development of engineering asset management as an integrated and important body of knowledge. CIEAM instigated the annual World Congress for Engineering Asset Management (WCEAM), which brings together leading researchers and industry practitioners from around the world to promote the development and application of research and strengthen links between industry, academia and research at a global level, now run under the auspices of ISEAM. WCEAM is now held annually. The last meeting was held in Brisbane in October 2010. The next will be held in Cincinnati, Ohio in November 2011, with following meetings committed in various countries out to 2016.

CIEAM's governance arrangements under the chairmanship of Mr Ted Scott AM, have worked extremely well. The transition to the three-year extension (CIEAM II), granted as a result of the 2009 selection round, has been effected seamlessly.

Despite the considerable progress made in the development of engineering asset management, technology and practice, in many ways the gap between what is currently practiced and what is necessary to optimise the practice across industries has actually widened. The principal impediment is that companies are reluctant to make a significant commitment to a fully integrated approach while still committed to their existing proprietary systems, even while acknowledging that those systems do not fully meet their requirements. To close this gap it is essential to maintain and accelerate the global exposure and outcomes in this field.

Plans are being developed to continue the CIEAM concept in a successor body outside of the CRC Program framework at the conclusion of the current Commonwealth Agreement CIEAM II.

Joseph Mathew CEO

November 2010

2. Report content

2.1 Performance against Commonwealth Agreement

2.1.1 Achievement of outputs and milestones

The Commonwealth Agreement contains a set of *objectives and performance measures* for CIEAM (the Centre), set against the specified objectives of the CRC Program, as follows:

CRC Program Objective 1:

To enhance the contribution of long-term scientific and technological research and innovation to Australia's sustainable economic and social development.

Centre objectives

1.1 To develop and implement technologies and processes in an integrated framework that optimises asset management systems.

Performance measures

Quality of the research program as measured by:

- Numbers of refereed published papers
- International recognition
- Transfer of research outputs to operational systems.

The broad contribution of CIEAM to this CRC Program objective was considerable, and very visible.

Prior to CIEAM, there was no recognition of asset management, in the sense which has been initiated and advanced by CIEAM, as a research or academic discipline.

As discussed elsewhere in this report, CIEAM was successful at both the national and international level in establishing asset management as a recognised discipline, and in drawing attention to its economic, environmental and social importance.

The urgency of the task was described in the original application, which highlighted the growing backlog of asset management applied to Australia's national infrastructure, as the local manifestation of what is recognised as a global problem.

Despite advances in the technology and its uptake, estimates of the annual cost of asset management increased significantly over the life of CIEAM, partly because of the increased recognition of the scale of the problem; and partly because the problem has actually become larger, and is particularly exacerbated by the emerging challenge resulting from inexorable climate change.

CRC Program Objective 2:

To enhance the transfer of research outputs into commercial or other outcomes of economic, environmental or social benefit to Australia.

Centre objectives

2.1 To develop and deliver solutions to specific problems identified by industry, in a form that ensures the ultimate achievement of the outcomes sought by industry users, and industry at large.

2.2 To exploit intellectual property by participants or other entities.

Performance measures

- Quantified reduction in the direct cost of asset management – target 10% pa by Year 7
- Quantified reduction in the total cost of ownership of physical assets
- Increased productivity from asset inventory
- Value of IP licensed or otherwise deployed
- Number of new products derived from research outputs.

CIEAM was successful at the three levels of utilisation and commercialisation identified in the Commonwealth Agreement, and the subsequently developed *Commercialisation and Utilisation Plan* (CUP).

As outlined in the numerous examples described in this report, virtually all research projects involved at least one industry participant, which provided the ‘test bed’ and early uptake environment for the project output.

Project IP is then further developed for more general application as a stand-alone product, and where appropriate, as a commercial product.

CRC Program Objective 3:

To enhance the value to Australia of graduate researchers.

Centre objectives

3.1 To establish CIEAM as the national research and education centre, to ensure an adequate throughput of quality PhD and masters graduates to meet the industry requirements for Australia’s research base in asset management, and the needs of Australian industry for qualified graduates.

Performance measures

- Maintaining level of research students - target 48 at any one time, 100 over the life of the centre. [This target was reduced to 48 following the Third Year Review]
- Successful placement of graduates in industry or research.

CIEAM delivered a strong performance in this area. In particular, a considerable number of PhD graduates found placement in industry, where essentially there had previously been no engineering asset management specialists of a PhD level.

CRC Program Objective 4:

To enhance collaboration among researchers, between researchers and industry or other users, and to improve efficiency in the use of intellectual and other research resources.

Centre objectives

4.1 To develop strong strategic, operational and synergistic collaboration between participants.

4.2 To deliver quality education and training for industry professionals and technical staff.

Performance measures

- Enhancement of existing links between researchers and between researchers and industry
- Number of projects with at least three participants – target 70%
- Number of projects with at least one industry participant – target 90%.
- Numbers of Masters courses and short focused workshops on specific topics matched to industry requirements
- Number of graduates of graduate courses for industry – target 1000 over the life of CIEAM.

CIEAM developed from the outset a strong framework for collaboration between researchers, and between researchers and industry. This framework drove the strong industry focus of the research program, and ensured that the necessary cross-disciplinary capabilities were brought to the research projects.

CIEAM established a formidable inventory of popular industry Masters programs and short courses.

Additional matters about CIEAM project objectives

The Centre's objectives and performance measures translated into a set of identified *outcomes, outputs and milestones* for each of the five research programs, as well as the Education and Training program, and the Development and Commercialisation program.

A revised set of outputs and milestones was agreed with the Commonwealth after the Third Year Review of CIEAM.

This set of outputs and milestones, related to outcomes, together with performance information, is shown in *Attachment 1*.

Some changes in the program structure reflected changes in realities and priorities. However, the majority of the original project material survived the revision process, suggesting that the original program structure was quite robust.

Many of the projects extended into the CIEAM II structure, as discussed under Section 2.7.

2.1.2 Financial performance

The CRC completed its term in a strong financial position and was able to meet all its debts as and when they fell due.

In the first three years of operation CIEAM experienced some difficulty in meeting the in-kind commitments contained in the Commonwealth Agreement. This difficulty was in part due to problems in correctly valuing in-kind commitments rather than in a failure to

deliver. However in subsequent years this short fall was addressed with rigorous collection strategies which fully made up that shortfall.

The result over the seven-year period of the Agreement reflected financial targets being actually exceeded, as shown in the following table.

Actual financial results for the 7 years ending 30 June 2010

Type	Actual \$million	Commonwealth Agreement \$million	Variance \$million
In-kind	\$ 61.048	\$58.533	+\$1.534
Cash	\$27.662	\$26.320	+\$1.342

Other significant highlights were that contract revenue raised during the seven years amounted to \$2.331 million compared to the Commonwealth budgeted pledge of \$0.845 million, a \$1.486 million increase over budget. These pleasing results confirm the participants' confidence in CIEAM research.

Detailed financial tables were submitted as an integral part of the annual reporting process.

2.1.3 Governance and management

CIEAM was established as an unincorporated joint venture (CIEAM) with an associated incorporated management company limited by shares (CIEAM Pty Ltd), responsible for the overall management of CIEAM. In particular, CIEAM Pty Ltd managed the intellectual property created by CIEAM on behalf of all participants.

The Centre Board was established with 10 members, with an independent chair, and including six elected board members, three for each of the industry and research provider groups.

CIEAM Centre Board of management composition

Centre Board of management	
Independent Chairman	1 Director
Sponsor Director (QUT)	1 Director
Industry Research Group	3 Directors
Research Providers Group	3 Directors
SME's Representative	1 Director
Independent Director	1 Director

A Research Committee was established with representatives from all participants providing the opportunity for all participants to contribute to the development and design of the research and other programs.

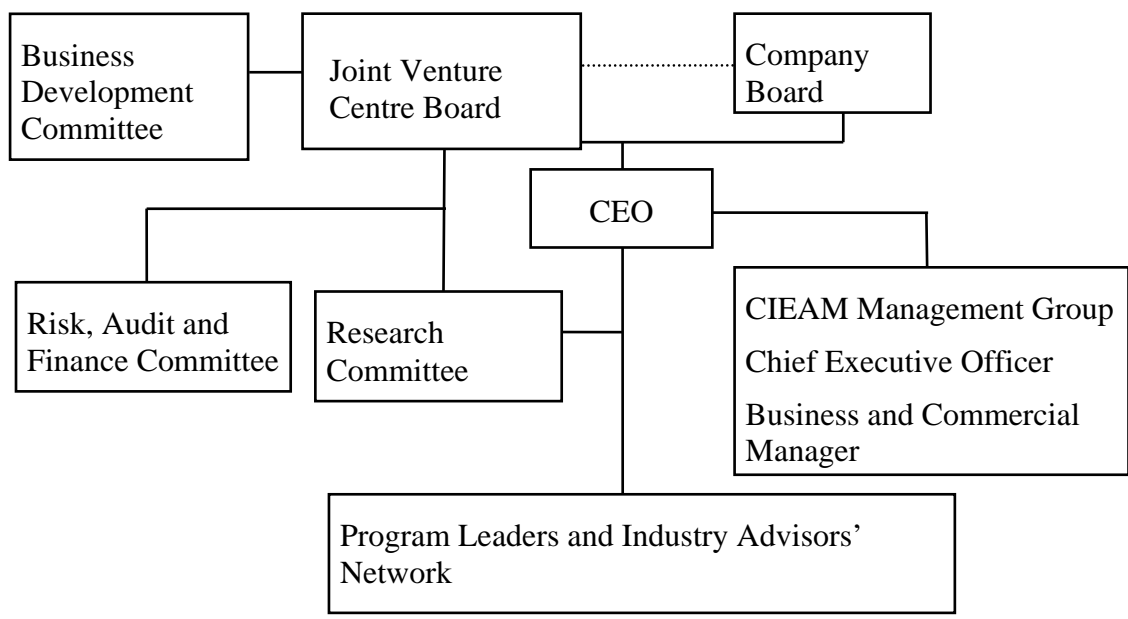
In its first year, the Centre Board established a Risk, Audit and Finance Committee, chaired by one of the industry group members, to advise on financial and risk issues affecting the CRC.

Also in its first year, the Centre Board established a Business Development Committee chaired by the Independent Director, to oversee and work with CIEAM’s CEO to identify and attract new participants into the CRC.

As identified in the Commonwealth Agreement, linkages with industry participants and industry at large were identified as high priority activities. Within CIEAM, those links were developed and strengthened through the Research Committee. Additionally, an industry advisor, drawn from the industry participant group was attached to each research program, to maintain an industry perspective on the program, and provide a link to the Research Committee.

The CEO was also supported by a Program Leaders’ and Industry Advisors’ Network (PLIAN), comprising the research program leaders, industry advisors, Business and Commercial Manager, Education and Training Manager, Research Administrator and Communication Officer. The PLIAN met at least bi-monthly and its main functions were to review project progress against milestones across all research programs, review and revise forward budget estimates, and advise the Centre Board on the operations of CIEAM.

CIEAM organisational chart



During 2009-2010, 15 organisations were involved in CIEAM. Of these, 12 organisations were core participants; one was a supporting participant, and there was continuing engagement from two third-party participants. The following table outlines CIEAM’s participating organisations over the year.

CIEAM participating organisations 2009-2010

Organisation	Participant status
ASC Pty Ltd	CRC core participant
Australian Nuclear Science and Technology Organisation (ANSTO)	CRC core participant
Defence Science and Technology Organisation (DSTO)	CRC core participant
Delta Electricity	CRC core participant
Monash University	CRC core participant
Queensland Rail	CRC core participant
Queensland University of Technology (QUT)	CRC core participant
Rio Tinto Alcan	CRC core participant
Sunwater	CRC core participant
University of Newcastle	CRC core participant
University of South Australia	CRC core participant
University of Western Australia	CRC core participant
Curtin University of Technology	CRC supporting participant

Third party participants 2009-2010

Organisation	Participant status
Queensland Department of Main Roads	Third party participant
CRC Rail	Third party participant

2.2 Outputs of the CRC

2.2.1 Key outputs of the CRC (including IP, new processes)

Australia's economic and social viability is critically dependent on the productive capacity of the major physical assets which underpin the industrial, social and economic environments, to function soundly and to meet quality performance management standards. Security of the services provided by these assets is fundamental to our lifestyle and economy as well as the health of our social and environmental fabric. The broad target for CIEAM was to establish in

Australia an asset management environment that would improve the effectiveness of, and reduce the annual costs of maintenance and asset lifecycle considerations with direct savings to industry, resulting in a significant economic, environmental and social benefit and the potential for significant concomitant commercial outcomes.

The broad commercial objective of CIEAM was to deliver a range of products and services that would drive Australian industry to achieving a substantial reduction in the whole-of-life cost of engineering assets across all industry sectors, and enable the exporting of those products on a global basis.

CIEAM's activities produced a range of sophisticated asset management tools, models and systems such as:

- advanced fibre-optic and piezoelectric sensors and actuators that continually monitor wear, corrosion and other forms of degradation in both fixed and mobile industrial and defence assets
- high-level data acquisition, quality and management systems that integrate with other corporate systems to optimise business decision making, within a capability to much improve the quality from which decisions are made
- fully integrated models and processes that facilitate asset management decision making from plant through to corporate level, and in some applications, automate it completely
- engineering asset management education and training programs for all levels of technical and professional staff, ensuring levels of skill that will optimise the technological advances achieved by CIEAM's other research outcomes, maximising assets' productive life, and minimising overall costs of ownership.

Specific achievements included:

- publication of 294 refereed journal and conference articles
- conducting 43 Centre and third-party projects with several leading to utilisation of its outputs at this time
- conducting six public benefit projects
- development of a comprehensive technology roadmap for Engineering Asset Management facilitated by the University of Cambridge, UK
- graduation of 21 doctoral, four Masters and one Honours candidates out of a total of 62 postgraduate students.
- development of an integrated engineering asset management strategic framework and an accompanying 12 point body of knowledge, which was made available globally on the CIEAM website, as a wiki
- conducting 12 professional development and training workshops
- creation of the new International Society of Engineering Asset Management (ISEAM)
- creation of a new global forum, the World Congress on Engineering Asset Management, to facilitate exchange of information and technology transfer in EAM
- attracting Springer-Verlag, a global leading engineering and science publisher, to publish the proceedings of WCEAM

- initiating a new journal review series, with the EAM reviews to be published by Springer-Verlag through ISEAM, as a regular journal.

As discussed under 2.3.1, RMDSTEM conducted an independent and objective economic impact assessment which placed a value of in excess of \$2 billion on CIEAM technology once introduced into the market place. These findings were used as frameworks for the CIEAM II round of projects that have comprehensive utilisation and commercialisation imperatives.

Governance of CIEAM IP

CIEAM intellectual property (IP) resources were managed at two separate levels: firstly, at the organisational or governance level, and secondly, at the project management level. Both levels required different techniques to ensure IP was not only managed and protected but also utilised in a manner that brings maximum benefits to CIEAM participants, and to the nation as a whole.

CIEAM was established as an unincorporated joint venture and formed a company (CIEAM Pty Ltd) to manage the activities of the CRC and to hold the IP produced by these activities in trust for the participants of CIEAM.

A spin-off corporate vehicle was established, Assettek Pty Ltd, to manage IP with commercial potential as it emerges. These strategies will be comprehensively applied within the CIEAM II round of projects.

CIEAM maintained a comprehensive IP register and completed a comprehensive review of all IP which will continue until the completion of CIEAM II projects. All IP was assessed and prioritised in terms of its market utilisation potential. As an integral part of that process, IP protection was considered and action was taken to safeguard all IP that had significant utilisation and commercial potential. The status of the IP register is shown in **Attachment 2**.

Over the last two years, CIEAM engaged the Australian Institute of Commercialisation (AIC) to undertake a comprehensive review of all IP created under CIEAM projects to mine potential innovation that would have market place potential. CIEAM also engaged QUT Bluebox to assist the CIEAM management in the process of interacting with the researchers on the technical aspects of the projects and to assist in the process of progressing these technologies to market-ready products. Reports produced by Bluebox identified innovation having market potential.

The appointment of a senior Commercialisation Manager will ensure that the commercialisation strategies that are predicated in the CIEAM II milestones and deliverables are realised. Urgent action will be implemented to place market-ready technology in the market place.

2.2.2 Uptake by end users of the outputs

The broad commercial objective of CIEAM was to deliver a range of products and services that would assist Australian industry to realise a substantial reduction in the whole-of-life cost of engineering assets across all industry sectors in Australia, and would enable Australian industry to export those products on a worldwide basis.

The principal products produced through the activities of CIEAM were:

- advanced sensors, for measuring vibration, stress and strain in structures

- advanced data acquisition and handling systems
- asset management systems, incorporating the data acquisition and handling systems, and linking to other management and decision support systems, such as financial systems
- software packages to implement the components of these systems
- education and training programs at all levels, to bring the human dimension to bear on the achievement of the overall outcomes.

Models and Decision Systems program

Seven projects in this program were successfully completed. A number of extension and transitional projects are continuing in CIEAM II. A number of excellent research outcomes were produced through a strong collaboration between CIEAM's research and industry participants. Some of these innovative outcomes were applied to the utilisation/testing processes with real cases. A brief summary follows.

- Following a successful development on power station Economiser tubing system renewal decision support tool, a new decision option prioritisation model was developed based on Decision Tree Theory. The model was validated using industry case and field data. The results showed that the model outperforms some decisions made in the past.
- The software tool generated from MD302 on skid-resistance and road asset management was deployed in Queensland's Department of Transport and Main Roads (DTMR) and the system is being further improved in CIEAM II. As a result of the project, DTMR was very satisfied with CIEAM and has become a participant in CIEAM II.
- A set of comprehensive and innovative data models covering a wide spectrum of asset management were developed and formally adopted by MIMOSA, an international open standards organisation for asset management.
- A pipeline renewal tool developed for SunWater is now deployed on 57,000 km of pipelines belonging to Allconnex Water (a new CIEAM II participant). The new parameters and models developed to deal with the new case are significantly enhancing the software functionality.
- A Mean-Variance Tool (MVT) passed DSTO's tests and is currently being prepared in CIEAM II for utilisation in the Australian Navy.
- A new tool, Justification and Optimisation of Budgets (JOB), was developed under the guidance of the General Manager (Production), Delta Electricity and by the MD301 team. The tool is undergoing testing in CIEAM II using generator boiler overhaul data as inputs.

Advanced Sensors program

The research activities relating to the milestones set out for the Advanced Sensors program were substantially achieved and will be completed during the first year of CIEAM II. Additional funding to the project on Industrial Applications of Corrosion Sensors was provided by the DSTO during this period. A list of the major achievements follows.

- Electrical resistance-based corrosion sensors were designed (including several updates), manufactured, and deployed, tested and refined at a number of participant industrial and defence locations. Sensor suites to monitor environmental parameters critical to corrosion of steel infrastructure were developed. Field trials were undertaken to validate the sensor outputs and data management equipment. Several of the developed sensor suites were

deployed at a number of participant locations throughout Australia and at third-party sites in the US for the US Department of Defense.

- Research into novel corrosion sensors was undertaken on a variety of concepts including: optical fibre corrosion sensors, paint degradation sensors and sensors to detect microbiologically influenced corrosion. Sensors were deployed and evaluated in an RAN submarine.
- Background research into several environmental areas of corrosion of industrial interest, such as microbiologically influenced corrosion, was concluded. The results were presented at conferences on microbiologically influenced corrosion and corrosion modelling. Corrosion sensors were deployed and tested in both laboratory and field trials with the aim of providing data to be used in empirical corrosion models. Software for corrosion rate calculations and modelling was tested and refined and applied to real infrastructure. Systems and sensors to map corrosion rates across an industrial site, and interface technologies to allow for remote logging of electrical resistance corrosion and environmental sensors were developed.
- Fundamental work was undertaken into crack propagation in complex structures, such as aircraft wing structures. This led to a series of review papers on the growth of cracks from near-to-micron size defects and extended the generalised Frost-Dugdale Model to account for these effects. A review paper on the application of this technology to F/A-18 structural materials was also published as an internal DSTO report.
- The analysis methodology was validated by comparison with full-scale tests performed at DSTO and laboratory tests at Monash University. The transitioning of the prognosis technology to DSTO was finalised and presentations were made both to the RAAF Directorate General Technical Airworthiness and to Defence contractors.
- A test program on the effect of corrosion-preventative compounds (CPCs) on structural integrity was completed under contract to CASA and the results presented at the 2010 Aircraft Airworthiness and Sustainment Conference in Brisbane. This work revealed the potential for CPCs to increase crack growth in a typical fuselage lap joint.

Systems Integration and IT program

The program developed and provided research leadership in information and communication technologies to support optimised engineering asset management activity. Capability evolved from research in asset lifecycle management specifically related to data quality issues, to data integration, interoperability, wireless sensor networks, and the harmonisation of engineering asset management standards.

Substantial progress was made in achieving the majority of its stated milestones and objectives (*Attachment 1*). The program outputs are moving to a utilisation and commercialisation track in CIEAM II.

A major focus was on asset-specific information management, which was spread over a range of aspects of asset lifecycle management, including data quality, information acquisition, storage and exchange, information integration, and information architectures. During the period, some of the major CIEAM projects were completed and utilisation and commercialisation opportunities pursued. This provided a much greater insight into commercial information quality issues faced by engineering asset managing organisations, and opened up new areas of further research.

The research also investigated data cleansing and data profiling. This work investigated data integration issues between an Enterprise Resource Planning and computerised maintenance management system (CMMS) at ANSTO, successfully developing a generic data bridge. The research developed into new projects with ANSTO, investigating the integration of condition monitoring systems for the newly acquired OPAL reactor with the existing organisational information systems. The project used a service-oriented architecture approach as a generalisation of the prior data bridge project. The project investigating information architectures and related issues for infrastructure assets also progressed well.

Intelligent Diagnostics and Remnant Life Prediction program

Several projects were completed to provide an integrated suite of tools and techniques. As projects reached technical maturity, there was an increasing proportion of activity directed towards the application of technologies to target industries and facilities through case studies and industry trials. The integration between projects was driven primarily through a central project of the program to develop an integrated Asset Health Manager within the Models and Decisions program. The Asset Health Manager formed a central hub for the program outputs, while the technical projects formed spokes leading into this hub. The emerging 'hub and spoke' model became a central theme for integration of CIEAM projects, and this approach was central to the successful CIEAM II re-bid.

Workshops involving all programs and partners were conducted to coordinate and align research activities with industry expectations and needs, particularly through extensive use of case studies involving CIEAM's industry partners. This facilitated the trial, demonstration and implementation of developed techniques in an industrial environment.

A list of key research achievements follows.

- The Asset Health Manager developed into a flexible framework to facilitate multi-criteria decision support for a variety of industries and engineering systems. The flexibility of this system allowed integration of the outputs from the technical projects of CIEAM, and also provided a platform for emerging applications in a wide variety of industries. It therefore became a tool to enable rapid implementation of industrial research through use of a common framework.
- A central project to allow diagnosis and prognosis of transformer condition and remnant life continued to build a comprehensive suite of health monitoring tools, having now expanded to incorporate researchers from four university partners and numerous industry partners into the research team. Given the importance of this project to a wide variety of participants and industries, commercialisation through a larger and more expansive project will be conducted in CIEAM II, ensuring both deep and broad penetration of CIEAM technologies into industry and a major commercial outcome.
- A project to develop condition assessment tools for civil infrastructure to assess the health of concrete infrastructure using vibration data proved to be of strategic importance to the expansion of the scope of CIEAM into civil infrastructure, facilitating the involvement of additional industries and partners in CIEAM's forward planning. This project is being carried forward in CIEAM II and will be incorporated into a Building Information Management system.

All the milestones for the research program were achieved for the particular target applications and equipment relevant to the current industry partners involved in the project. Furthermore, systems and processes were developed to allow extension of these methods to new partners, applications, equipment and industries as they emerged.

The program maintained an extremely high level of activity and continued to deliver on the targets originally established for the current industry participants, and build toward a wider base in the future. The process of integration of all CIEAM projects allowed CIEAM to extend its developed capabilities to a wider range of industries and applications. The program, enhanced in CIEAM II, will continue to provide a framework to enable broadening of the range of applications of project outputs in order to maximise the benefits to a wider audience and range of industry in the Australian economy.

Strategic Human Dimensions program

The Strategic Human Dimensions program focused on organisational strategy, human resource capability, engineering asset management culture and managing large-scale culture change in asset-intensive organisations as priority research areas.

The projects commenced in 2008 are completed. The first project investigated the skills and capabilities of asset managers in asset-intensive organisations and was completed in early November 2009. The second project, Maritime Systems Division Materiel Logistics Strategy Development, delivered a series of workshops to senior DMO staff, as well as delivering the resulting strategy for the development and sustainment of complex assets to MSD, with its proposals for the improvement of processes for sponsoring, developing and coordinating research projects within the organisation.

A list of key research achievements follows.

- The data quality component of the HD 103 project and the final report on the Strategic Work Design project were completed.
- The Maritime Systems Division Materiel Logistics Strategy Development project HD505 made significant progress and developed strategies for cost effective sustainment of a diverse portfolio of assets. In conjunction with MSD supply, engineering, procurement and maintenance experts, the project developed frameworks to better understand the root cause of trade-offs in strategic sustainment.
- The program continued its focus on developing research capability around the governance, policy and strategy particularly relating to mobile assets such as fleet asset management.
- The program built up significant research in the understanding and improving of data quality for EAM performance, engineering asset management culture, skills and capability, asset management strategy and, asset governance and policy.

2.2.3 Key educational outputs

CIEAM's Education and Training (E&T) program was based on the two principal objectives of:

- establishing CIEAM as the national/international research and education provider to ensure a throughput of quality PhD and Masters graduates to meet the requirements of Australian industry, developing and maintaining a high level of knowledge and skills in all aspects of asset management technology in Australia. This was achieved by delivering quality education and training services for industry professionals and technical staff, ranging from Masters courses through to short-focused workshops on specific topics
- providing a national body of information about asset management-related issues for the industry, government and the public sector.

CIEAM's E&T Business Plan was a significant contributor to enhancing collaboration across the CRC. It followed five concurrent pathways, incorporating several significant initiatives and innovative approaches, enabling industry and researchers to work closely together, through:

- formal tertiary education
- vocational education and training
- industry professional skills training
- scheduled in-house short courses
- ad-hoc public courses and conferences.

Key to the success of this plan was the scholarship program. At CIEAM's completion, 62 scholars had participated in this program, with 26 having completed their degrees. Of these, 11 PhD graduates were placed in industry, and the others remained in research and academia.

An integral part of CIEAM's E&T program was to host workshops, forums and other events to develop the capability and skills of the research teams and scholars.

CIEAM built an online wiki entry on engineering asset management based on the Body of Knowledge it developed. This wiki was designed for CIEAM industry participants only but its usage will be extended to a wider group of industry and international users in CIEAM II. The wiki will also form a knowledge base for future graduate courses, industry training and online course offerings for CIEAM II.

Scholars' workshops and training program

CIEAM ran a number of workshops for scholars including:

- a one-day workshop module on research methodology in the context of integrated asset management, research design and validation of research results, as well as intellectual property issues
- professional skills training courses developed in accordance with CIEAM's 12 element integrated engineering asset management framework. These form the basis of a Master's degree award course in integrated engineering asset management.

Industry education

A series of industry short courses for professional skills training was developed to ensure a gradual and sustained progression towards the establishment of integrated engineering asset management education within the organisations of public and private sector asset owners and operators.

A professional skills one-day training course, An Introductory Overview to Integrated Engineering Asset Management, was developed as organisational awareness training for selected senior executives from state government bodies, local government authorities, research institutions and industry.

A five-day professional skills training courses for senior delegates from state government bodies, local government authorities, professional organisations, research institutions and corporate industries served as a decision-making introduction to the implementation of organisation-wide comprehensive training on integrated engineering asset management.

Organisation-wide, comprehensive training in integrated engineering asset management was covered in 12 asset management modules (strategic planning, risk management, budgeting and costing, data management, condition monitoring, tactical planning, usage lifecycle, performance measurement, ownership/stewardship, financial management, information systems, and human resources planning), each of three-days' duration. This training was, likewise, for delegates from state government bodies, local government authorities, professional organisations, research institutions and corporate industries, usually following on from the overview courses.

2.3. Impacts to date

CIEAM developed a world-class research and development capability in the field of engineering asset management to enhance business solutions, focused on addressing real asset management problems faced by today's industry.

Participant organisations, Delta Electricity, SunWater, the Australian Nuclear Science and Technology Organisation (ANSTO), the Defence Science and Technology Organisation (DSTO), Queensland Rail and Rio Tinto Alcan leveraged their R&D investment by partnering in CIEAM-led research projects which achieved several outcomes:

- development of analytical and visualisation models for asset management decision support processes from operational to corporate levels
- development of training materials for award courses as well as professional and technical in-service training
- development of a sensor network to improve failure detection and tracking of reliability and environmental risks
- development of methods for assessing data quality and complementary management practices to improve data collection and error checking
- assessing weaknesses and deficiencies of current data cleansing tools and developing data quality models and frameworks
- development of condition-based prediction as a continual process for determining asset health based on condition monitoring trends, maintenance events, and process and reliability information
- development of a standards-based information integration strategy
- development of key integration points, harmonised methodologies, and unified software structures.

Overall, the outputs from this research agenda helped industry to better manage their assets for the whole of operating life through the more accurate capture of data, and systemised methodologies for managing, processing and exploiting this data to optimise asset availability and performance.

2.3.1. Economic benefits to end-users through development of new products

As evidenced by the high level of industry participation in research, all CIEAM projects were agreed by industry participants as being of value to the participants, and usually to the

relevant industry as a whole. In many cases, the benefits flowed to end-users serviced by industry, such as in the case of electricity or water companies.

CIEAM commissioned an independent consultant, RMDSTEM, to evaluate the commercial and economic benefit of seven specific industry projects, as well as the benefit of CIEAM's involvement with the International Society of Engineering Asset Management (ISEAM), and the World Congress on Engineering Asset Management (WCEAM), both of which were initiated by CIEAM.

The evaluation process for the impact assessment followed the framework developed by Deloitte for the CRC Association. This framework contains five stages from inputs to impacts which articulate how, and by what mechanisms, planned activities will affect the intended impacts.

In the case of CIEAM's association and affiliation with ISEAM and WCEAM, RMDSTEM looked at the three stages of *outputs*, *usage* and *impact* to assess the value of those activities as they created more public goods in the short term, while in the long term more economic benefits could be obtained as a result of those activities.

The key measures obtained through the methodology used were the *potential value*, and the risk-adjusted *expected value*.

For the seven industry projects, the total potential value was estimated at \$7 347 million, while the expected value was estimated at \$377 million. The order of magnitude difference was, of course, due to the large uncertainties involved in estimating commercial and economic outcomes at such an early stage in the product development.

The corresponding figures for CIEAM's involvement with ISEAM and WCEAM were \$226 million and \$56 million. The proportionally smaller relative difference was due to the lower level of uncertainty about the path to benefit.

The high levels of risk notwithstanding, these were impressively significant amounts, and attested to the strong focus within CIEAM on the potential benefits of its research program and other activities.

2.3.2 Economic benefits such as risk mitigation

The Deloitte methodology used included elements such as risk mitigation, reduction in costs, capability enhancement, and business growth as they apply to the individual projects.

2.3.3 Commercial arrangements involving the CRC's IP or other assets (royalty streams, licence fees, profit shares)

CIEAM II is completing the process of patenting a Decision Support Tool developed under the Models and Decision Systems program.

Several other potential products are also being developed to commercialisation stage in CIEAM II, and form a significant part of the new Centre's work program.

2.3.4 Operational status and current valuations of spin-off companies established to commercialise the CRC's research

N/A

2.3.5 Case studies' commercialisation/utilisation

CIEAM made progress on its commercialisation objectives through QUT Bluebox, which reviewed three CIEAM projects as having potential for commercialisation, and made recommendations regarding future commercialisation of the intellectual property developed in the following projects:

- AS302 / SI203 Industrial applications corrosion sensing / Wireless Prognostics, Wireless capture: Dr Tony Trueman, Dr Scott Wade, Professor Bruce Thomas, and Dr Geoffrey Will
- CIEAM Asset Management Body of Knowledge (AMBOK) wiki: Dr Fred Stapelberg
- MD301 Decision Support Tool: Prof Lin Ma, Dr Yong Sun, Mr Michael Purser, and Dr Avin Mathew.

Bluebox undertook a series of meetings with the research teams involved in the projects, and reviewed available information including project reports, software demonstrations, draft patent applications and legal agreements, as well as undertaking a scan of the competitive landscape. Bluebox reached the following views on the three projects as set out below.

AS302 / SI203 - Corrosion monitoring: Recommendation

Assuming robust IP protection could be obtained, advice was to license the IP rights to an existing manufacturer and/or distributor of sensor systems.

The commercialisation path chosen would depend heavily on whether robust intellectual property protection could be obtained. At Bluebox's suggestion CIEAM II will seek advice from Spruson & Ferguson patent attorneys regarding patentability of aspects of the system, as well as on assessing ownership of those elements of the IP (given substantial background IP appears to be owned by DSTO).

CIEAM began negotiations with DSTO to secure a licence on their background IP as a prerequisite requirement to pursuing a licence over the technology for a manufacturer and/or distributor to market the system. Conversely, if a strong patent position did not transpire, it may be preferable for CIEAM II to exploit the corrosion sensor system by providing a consulting service to end users. Under this model, CIEAM II, or a contracted manufacturer, would provide the sensors as part of a full-service offering; including the provision of expert corrosion monitoring and management advice, assuming such service delivery activities were consistent with CIEAM II's strategic objectives.

The CIEAM AS302 Industrial Applications of Corrosion Sensors project continued in collaboration with AS302 investigators at the University of South Australia via the CIEAM SI203 project (Wireless Prognostics) to further develop wireless logger units for use with the corrosion sensing technologies.

CIEAM collaborated, under a sub-contract, with the US company, Concurrent Technologies Corporation, which was awarded a US Army contract, to implement a project for detecting corrosion on steel bridges. CIEAM provided support for the demonstration and validation of state-of-the-art and emerging innovative technology for the remote structural health and corrosion degradation monitoring of steel bridges (AS302/SI203). The corrosion and environmental sensing equipment developed attracted significant commercial interest, both locally and internationally. The project validated the potential benefits for future possible application by the Department of Defense (DoD USA) in general, and the Army in particular, and has significant potential for translation to the US Rail system that is in the process of

mandating the application of corrosion sensing tools including electrical resistance on all railway bridges. This technology will be further enhanced within CIEAM II with a view to having commercialisation outcomes generated at the earliest possible time.

CIEAM AMBOK wiki: Recommendation

The advice was to make the AMBOK content freely available to CIEAM participants.

The CIEAM Asset Management Body of Knowledge (AMBOK) wiki could be a useful resource for a range of organisations with an interest in asset management. However, it did not appear to represent an opportunity for CIEAM to generate commercialisation income. Making the content freely available as a public good would recognise the contribution made by CIEAM participants to the creation of the resource. If made widely available to a range of public and private sector organisations, the AMBOK could be used to advertise CIEAM II's continuing expertise and to generate new commercial opportunities from potential consulting clients.

MD301 – Asset Management Decision Support Tool: Recommendation

The advice was to further develop the tool in conjunction with CIEAM participants and exploit the IP via provision of support services to end users and provide the tool under an open source and/or proprietary software licence.

As with other complex software tools, the Asset Management Decision Support Tool (DST) is only one component of the value proposition to the end user, and does not lend itself (at least in its current form) to being sold as a 'shrink-wrapped' product. Widespread adoption of the DST by asset-intensive organisations would require provision of substantial expert input in some or all of the following activities for each new user:

- providing a full understanding the organisation's asset management objectives and operational constraints
- acquiring, assessing and cleansing data from the organisation
- customising the DST for the organisation's particular needs
- training and educating the organisation's staff in use of the tool
- deploying the tool and supporting its use
- supporting the organisation's decision-making process.

2.3.6 Environmental and social benefits to end users

Part of CIEAM's research focused on addressing the asset management challenges being faced by Australia's utilities each day.

Participant organisations, SunWater, Queensland Rail, Delta Electricity and the Australian Nuclear Science and Technology Organisation (ANSTO) leveraged their R&D investment by partnering in CIEAM-led research projects that would deliver industry solutions. Project outcomes included:

- developing hybrid reliability prediction models at scheme, system and sub-system levels, integrating asset management and maintenance with business operation processes to optimise decision making for a range of engineering asset classes allowing more efficient operating decisions to be made reducing service outages and environmental impact

- developing an integrated asset management framework for utility industries
- delivering successful management functionality for asset managers through the development of effective, internationally benchmarked strategies and procedures
- developing a methodology for identifying true data requirements and improving data quality.

This research helped provide an integrated asset management system, from the identification and management of accurate and relevant field data through decision-support models and diagnostic tools to better understand and manage Australia's engineering assets and infrastructure supply, demand and maintenance requirements.

An environmentally sustainable Australia

Making our communities better, safer and more sustainable places to live, work and engage in recreation requires innovative planning and informed decision making. Many different and diverse organisations have a role in planning, building and sustaining engineering assets, promoting benefit for our community. In order to make wise and knowledgeable decisions they all needed to access timely and appropriate knowledge about the services and the infrastructure assets that support our communities, for example, in planning future investment in land and water usage, in mitigating fire hazards, in responding to emergencies, in planning for major events and in mitigation and safeguarding against the incident of major catastrophe.

Currently, there are no agreed reference frameworks that consistently describe community infrastructure and assets, albeit that they are now under consideration and being planned. When attempting to collect data across municipal boundaries, agencies are faced with the challenge of aggregating a diverse range of interpretations. Likewise, when councils provide information to third party agencies they find themselves undertaking a massive amount of duplicated effort as each agency describes the problem from its own perspective.

CIEAM undertook a public benefit project that sought to solve the problem by:

- implementing technologies and develop processes in an integrated framework that optimises asset management systems
- developing and delivering technologies which ensured the ultimate achievement of the outcomes required by industry users, and industry at large
- contributing towards national capability in research, postgraduate education and training, and service provision that can meet the national requirements.

2.3.7 Uptake of new knowledge, products or processes reducing the call on the Commonwealth budget

Several of CIEAM's research projects addressed engineering asset management problems specific to the defence industry.

Participant organisations, the Defence Science and Technology Organisation (DSTO), the Defence Materiel Organisation (DMO) and the ASC Pty Ltd leveraged their R&D investment by partnering in CIEAM-led research projects that would result in:

- reducing the logistics costs of ownership of maritime assets through improved data management and decision making

- developing a range of sensors for the early detection of differing forms of degradation such as cracks, corrosion and delamination, and of pipe-wall thicknesses, scale build-up and blockage locations
- developing methods and tools for remote condition monitoring
- developing technologies for assessing structural health of welded assets and methods for their improved management
- a greater understanding of corrosive processes, and developing monitoring and testing methodologies
- formulating new or improved repair and replacement strategies
- developing a comprehensive Materiel Logistics strategy for the Maritime Systems Division (MSD) of the Defence Materiel Organisation (DMO).

Overall, the findings from this research helped improve asset availability, reduce maintenance down-time and reduce the whole-of-life costs associated with ownership of mobile and fixed assets.

Case study – Combat aircraft maintenance

An outstanding example of work that resulted in a reduced call on the Commonwealth budget was in the area of combat aircraft maintenance.

An output of the Advanced Sensors program was a new mathematical model used to predict metal fatigue resulting from microscopic cracks in the aircraft fuselage. The technique relies on the early detection of such defects, and predicting their growth patterns, enabling an improved prediction of the service life of the aircraft. The application of this model has resulted in some aircraft flying safely well beyond the manufacturer's expected retirement date. As a result, the aircraft can remain in operation for longer periods, with an estimated saving to the maintenance budget of \$400 million.

2.3.8 Case studies – Non-monetary benefit

There were several outputs from CIEAM activities that represented significant benefits that did not readily translate into monetary measure, although ultimately many aspects of the outcomes derived from these outputs would have an economic impact.

CIEAM made a significant effort to formalise the process of developing a documented Body of Knowledge of asset management technology and practice. Known as the CIEAM Asset Management Body of Knowledge (AMBOK), it was loaded into a Wiki system that was made available to CIEAM participants. Consideration is now being given to making it more widely available, as it would be a very useful resource for a range of organisations with an interest in asset management.

Making the content freely available would recognise the contribution made by CIEAM participants to the creation of the resource. If made widely available to a range of public and private sector organisations, the AMBOK could be used to advertise CIEAM's expertise and generate new commercial opportunities from potential consulting clients in CIEAM II and into the future.

The process is very much a work in progress, but already has provided the basis for education and training material and courses that were commercialised by two spin-off companies.

As described elsewhere, CIEAM was prominent in promoting the need for, and availability of, best practice approaches to asset management at both the national and international levels.

CIEAM initiated and established vehicles to engage industry, government and research organisations both nationally and internationally. CIEAM established the Australian Asset Management Collaborative Group (AAMCoG) which includes peak bodies and government agencies. Through AAMCoG, CIEAM hosted three national forums in Engineering Asset Management and collaboratively published three significant project-based reports for public benefit.

CIEAM established the International Society for Engineering Asset Management (ISEAM) as a global thought-leaders' forum and each attendee was conferred with life corporate membership. ISEAM is therefore supported by 25 eminent foundation fellows selected from leading international research centres and institutions, in addition to 12 fellows inducted in 2010.

CIEAM also initiated the World Congress on Engineering Asset Management (WCEAM) which is now a successful annual event. WCEAM 2010 was held in Brisbane in October 2010, with over 325 participants, including 85 international registrants from 22 countries. The proceedings of these events were published as review volumes by Springer-Verlag publishers.

Through Springer-Verlag, ISEAM established the Engineering Asset Management Review Series. The first volume, *Definitions, Concepts and Scope of Engineering Asset Management* was published in October 2010. This series is a forerunner of a planned future *International Journal for Engineering Asset Management*.

CIEAM established itself as the hub of a formidable network of international asset management-related organisations including the British Institute for Non-Destructive Testing; the Center for Fault Diagnosis and Self-repair of Beijing; the Chemical University of Technology, VTT Technical Research Centre of Finland; the Next Generation Infrastructures Foundation in Delft Technical University; the Centre for Industrial Asset Management, Stavanger University, Norway; the Intelligent Maintenance Systems Centre in Cincinnati, USA; the Intelligent Diagnostics Center at Pukyong National University and the Korean Standards Association, in Korea; and the Botswana Technology Centre in Gaborone, Botswana, Southern Africa.

CIEAM was heavily involved in the development of international standards for asset management through its CEO, who chairs the International Standards Organisation (ISO) Subcommittee TC108/SC 5, 'Condition Monitoring and Diagnostics', which has so far published 18 international standards.

As described in 2.3.1, the potential economic benefit of CIEAM's international connections is considerable. However, the non-tangible benefits of the promotion of the emerging asset management agenda, both nationally and internationally, is having a significant impact on global practice, with flow-on benefits in social, environmental, and economic terms.

At a local level, the effort of CIEAM in promoting a new asset management agenda clearly led to an increasing maturity in the level of interaction at the corporate and institutional levels. For instance, feedback suggested that this maturity was reflected in an enhanced quality of tender documentation related to asset management requirements prepared by CIEAM participants.

In the work place, a specific project at ANSTO, a participant in CIEAM, developed a *Pocket Guide to Change*. This guide was provided to staff to help develop and implement a process

for change management, whether confined to a local area or across the organisation. This process was developed and followed by ANSTO to successfully deliver a change to the organisation's OHSE Management System.

2.3.9 Compare current economic, environmental, social benefits to Commonwealth Agreement

The Commonwealth Agreement identified several areas of potential economic benefit from projected CIEAM outputs and outcomes including:

- reduction in maintenance costs
- reduction in total cost of ownership of engineering assets
- improved reliability and availability of engineering assets.

For CIEAM, these savings ultimately translated into reductions in costs to consumers of these products and services. As described at several points in this report, the whole CIEAM research effort was directed towards achieving these objectives and delivering broader economic outcomes.

As identified in the Agreement, improved safety and security of the services provided by these assets particularly in the utilities and services sector is fundamental to our lifestyle as well as the health of our social and environmental fabric.

During the life of CIEAM, a greater recognition emerged for the need to focus on environmental sustainability in management of engineering assets. This factor was emphasised particularly in the Strategic Human Dimensions program, particularly in relation to culture change within asset-owning and asset-operating industries.

2.4 Impact of education processes to date

2.4.1 Graduates and employment

CIEAM's Scholarship Program supported 62 postgraduate scholars in total in its seven participant universities, 26 of whom have graduated. The remaining 36 postgraduates and the remaining scholarship funds are continuing in CIEAM II and the scholars will finish their studies by 2012. In the majority of cases, CIEAM offered top-up scholarships for those students who had already been awarded a competitive scholarship from a host university. This provided an acceptable level of financial support and stability to attract the best students.

CIEAM conducted an annual internal conference to bring together its research PhD students, key researchers from universities and participating industry, to share research outcomes and seek applications.

Of the 26 scholars who completed their degrees, the majority are employed either in industry or academia. They form a significant part of the intellectual capability Australia has developed in recent years in engineering asset management with researchers, industry managers, and practitioners in CIEAM-participating universities and industry firms. The industry employers of CIEAM graduates include: Bechtel Corporation, Downer Rail, GHD Pty Ltd, APA Group, Price Waterhouse Coopers, SKF, SunWater and Western Power.

One of CIEAM's postgraduates, David Mills, presented a paper in April 2010 at the 14th International Research Society for Public Management (IRSPM) conference in

Switzerland and was awarded the ‘Highly Commended’ title by its New Researchers Panel. His paper is titled ‘Can Stewardship Theory Produce Better Stewardship of Privatised Water Infrastructure?’

CIEAM Scholar, Avin Mathew, set off to the University of Cincinnati in the United States in 2006 as the Centre’s first Fulbright Scholar and has since completed his PhD. He is now employed in industry.

A complete list of graduated and continuing postgraduate students is at ***Attachment 3***.

As in previous years, CIEAM held a workshop for all of its postgraduate students during the CIEAM conference at the Sheraton Mirage Gold Coast in April 2010 during which a comprehensive commercialisation paper was delivered by QUT Bluebox. The aim was to educate CIEAM’s scholars on the basics of commercialisation and develop fundamental skills covering the potential that commercialisation has in respect of their research output.

The CIEAM conference provided an ideal opportunity for the postgraduates to present their research, network among themselves, and solicit feedback from industry on their work. Each student produced a poster. The poster displays were viewed and critiqued by industry participants attending the conference as well as by fellow students. Poster competitions were organised and a panel of four industry experts reviewed all posters and selected the winners of the competition. Both the poster competition and the commercialisation workshop were well received by the postgraduates and appraised by industry participants.

CIEAM began a process to inform its past and present industry participants about forthcoming completion of its graduates, the aim was to assist its industry participants in employing CIEAM graduates so the research outcomes derived and skills developed during their study can be directly beneficial to the participants. CIEAM continues to monitor employment destinations of its graduates. Currently, about half of its graduates are employed by industry and the other half remain in academia or research.

2.4.2 Education and training programs/skill shortages

Before CIEAM’s inception, there had been a recognised shortage of understanding and knowledge in asset management both in Australia and the world. CIEAM provided unique PhD research opportunities in engineering asset management to students from different backgrounds, university graduates, industry, and government. A majority of these researchers made regular publications in international conferences and journals. CIEAM’s trainers in engineering asset management have also published two dedicated books, published by Springer-Verlag, which have assisted industry to introduce asset management into their business.

Short courses

In order to provide the maximum flexibility in training offerings, material was developed for a series of one-day or two-day courses as follows:

- engineering asset planning and budgeting
- lifecycle support and costing
- maintenance planning and budgeting
- risk analysis and risk management
- reliability, availability and maintainability

- reliability-centred maintenance
- spares and consumables inventory management
- asset management with PAS-55.

CIEAM conducted regular short courses for industry such as the course in Melbourne on asset and maintenance budgeting, attended by several industry and government institutions, in August 2009.

CIEAM's online wiki on engineering asset management was designed for CIEAM's industry participants only but its usage will be extended to a wider audience of industry and international users in CIEAM II. It will also form a basis for future graduate courses, industry training and for online course offerings that are under consideration.

2.4.3 Case study – How education offered by CRC has influenced new knowledge

Since the inception of CIEAM eight years ago, Australian industry has seen a culture change on asset management. Asset manager or general manager for asset management were position titles almost non-existent prior to CIEAM's formation. The old concept of asset management was maintenance. However, nowadays leading industry companies have made asset managers and general managers for asset management an integrated part of their management structure. This change reflects industry's recognition of the concept of asset management and its willingness to implement it.

Case Study – Venkat Reddy PhD

Venkat Reddy undertook his PhD studies at the Queensland University of Technology. His research on the Development of an Integrated Model for Assessment of Operational Risks in Rail Tracks to Enhance Rail and Wheel Life addressed problems associated with higher axle loads, wear, rolling contact fatigue, rail defects leading to early rail replacements, rail breaks and derailments.

His work covered the development of failure models and estimation of parameters considering operational and environmental conditions. He developed an integrated model for estimating expected total cost for these decisions and associated operational risks.

Venkat's research provided significant benefits to industry, including the development of:

- failure models and estimation of parameters considering operational and environmental conditions
- economic models for rail grinding decisions linking cumulative MGT, axle load, curve radius and operating conditions
- cost models for optimal lubrication strategies
- risk-based cost-benefit model for optimal inspection decisions considering detected and undetected defects using non-destructive ultrasonic testing
- integrated models for estimation of expected total cost and associated risks for grinding, lubrication, inspection, rectification and replacement decisions.

Venkat Reddy is now working directly with industry, taking up a role with GHD, an engineering consultant company. Being involved with CIEAM through a scholarship gave Venkat the financial and research support he needed to present his research at several national

and international conferences and research workshops. This opportunity, in turn, helped him to develop a strong network with other universities and industry.

2.5. Impact on collaboration

2.5.1 Collaboration with sector/industry

The operation of CIEAM was characterised by an extremely high level of collaboration between industry and researchers, between researchers, and between CIEAM and external organisations, including national and international research and industry organisations.

Industry participants included large asset-intensive organisations including defence, utilities, transportation, physical infrastructure, and manufacturing. Research was developed to meet their needs, targeted to significant applications that required utilisation of the outputs of the CRC. Organisations in these industries operate static, mobile and linear assets. They introduced their asset value chain partners to CIEAM and sought involvement from others in their industries. This collaboration was necessary and relevant to meet the challenges across the broad range of assets and their application in the national inventory.

CIEAM also included software and services providers to the asset management industry. These were principally SMEs that worked as a ‘delivery vector’ with the asset-intensive organisations, delivering utilisable outputs and commercialising them as products and services.

The research institutions comprised the leading research expertise in asset management in Australia. They included complementary experts in business, engineering, information technology and science, to bring a truly multidisciplinary approach to the research. This combination of human, engineering and information systems expertise provided the best opportunity for not only developing technology but for finding ways to introduce it effectively into the asset-based industries.

Overall collaboration was led by an experienced and innovative leadership team that drove the process, including national and international partnerships to develop recognition, support and new opportunities.

All program leaders strengthened integration links between projects across all the programs. Workshops were held to develop integrated research outputs into specific industry participant organisations. This process led to a more direct utilisation of research outputs and commercialisation opportunities. Detailed linkages between researchers and end-user participants are described in detail under the program descriptions in Section 2.2.2.

The benefits were assessed for industry and SME end-users and are now being tailored to deliver comprehensive utilisation and commercialisation outcomes of benefit to end-users in CIEAM II.

The simple fact is that before CIEAM, there was little or no effective collaboration in the broad area of engineering asset management research and innovation, apart from industry-specific activities in such organisations as the CRC for Rail Innovation and CRC Mining.

2.5.2 Participants

Participants derived value from their involvement in the CRC in several ways. There was an increasing recognition of asset management in industry, as expressed by the support for the 2009 application, in that CIEAM was developing technology and IP in engineering asset management not available elsewhere.

Participants had a strong influence on the definition of research projects, and privileged access to information and IP produced by those projects. Participants, both industry and researchers, were exposed to new ideas and approaches through several channels, from normal informal interactions to the formal processes of CIEAM, such as the regular Research Committee meetings, and the annual CIEAM conference.

The annual CIEAM conferences were successful three-day events with much positive feedback from industry, Commonwealth representatives and internal staff alike. The research presentations were held over two days with PhD poster displays held on the first night. Keynote speakers delivered expert industry perspectives on management from a business environment and reliability improvement strategies and procedures.

Models and Decision Systems program

The collaborative culture and activities associated with the MD program within CIEAM, and externally, were very successful. This was made evident by the projects integration with decision-support models on a common platform. The collaboration between researchers and industry partners brought about more fruitful outputs at this time. Models and tools were tested using real data and real cases from two major generation sites in Delta Electricity and the Navy and will be continued in CIEAM II in Allconnex Water and the Queensland Department of Transport and Main Roads.

Several combined program workshops were held over the life of the Agreement including two in 2009-2010 conducted by Programs 1, 3 and 4.

Advanced Sensors program

The Defence Science and Technology Organisation (DSTO) was a major partner in the advanced sensor projects, and provided expertise and guidance on corrosion, structural integrity and smart structures and sensors. The majority of the sensors developed in the project were tested initially in the laboratory and at various field locations both nationally and internationally. Rio Tinto Alcan, the aluminium smelter at Boyne Island, Queensland, provided one of the early test sites. This site provided a very harsh environment which assisted in sensor redesign for future commercial development of the corrosion modelling systems.

The University of South Australia developed interface technology which allowed field testing of various prototype sensors to be carried out at the University of Western Australia for a wide range of applications, signal types and power and time requirements. This work was undertaken as there were no commercially available systems that were flexible and adaptable and provided accurate low-cost monitoring of our sensors.

ASC Pty Ltd has a major interest in microbiologically influenced corrosion. The collaboration with them focused on the development of a sensor to indicate the presence of an environment conducive to microbiologically influenced corrosion.

Work at the University of Western Australia focused on the development of sensors to monitor the breakdown of paint coatings. Knowledge of the degradation of paint coatings is one of the fundamental requirements to understanding the corrosion process.

Several of the sensor suites measuring corrosion parameters were deployed at a number of locations throughout Australia and at third-party sites in the US, principally on steel bridges, with suites on other structures planned in CIEAM II.

Intelligent Diagnostics and Remnant Life Prediction program

The development of the program saw progressively increasing levels of activity toward application of technologies to target industries and facilities in line with the proposed activities within CIEAM II. There was a focus on integration between projects within the intelligent diagnostics program, and with other programs, primarily through the central project of the program to develop an integrated Asset Health Manager and the emerging service hub concept (the “HAMISH project”). In addition, the technical outputs from projects enhanced the industrial applicability and scientific merit of the approaches being used.

Workshops involving all programs and partners were conducted to coordinate and align research activities with industry expectations and needs, particularly through the extensive use of case studies involving several industry partners. This process allowed both trial and demonstration of the developed techniques in an industrial environment, and provided a growth path to ensure greater penetration of the technologies to additional industries and partner organisations in the future.

Key research achievements included the following elements.

- The Asset Health Manager evolved to become a central platform which provided a framework for all projects within the program. This unified approach was essential to facilitate multi-criteria decision support for a variety of industries and engineering systems. It also became a focal point for the integration of techniques and technologies emerging from projects aimed at resolving particular issues and problems in a range of industries.
- An ongoing project to examine transformer remnant life continued to build a comprehensive suite of health monitoring tools, having expanded to incorporate researchers from Monash University into the research team. Given the importance of this project to a wide variety of participants and industries, it will facilitate a larger and more expansive project in CIEAM II, and has now attracted significant new industry interest with strong commercialisation potential.
- A project to develop condition assessment tools for civil infrastructure to assess the health of concrete infrastructure using vibration data proved to be of strategic importance to the expansion of the scope of CIEAM into civil infrastructure, facilitating the involvement of additional industries and partners in CIEAM II.

The program maintained a high level of activity and continued to deliver on the targets originally established for the industry participants. The process of integration of all CIEAM projects accelerated and will allow CIEAM II to extend its developed capabilities to a wider range of industries. The program continued its focus on broadening the range of applications of project outputs in order to facilitate the growth of CIEAM and maximise the benefits to a wider understanding and range of industry and the Australian economy.

System Integration and IT program

The program maintained collaborative activities with both internal industry partners as well as external and international collaborators. The research relationships with DSTO and ANSTO were strengthened with solid research outcomes. Furthermore, involvement in QR's Information Management research and development program began, as did collaborations with ASC. A recent development which was explored was collaboration with DMO/DSTO's initiative on integration through Dr Nanda Nandagopal and his Defence Systems Integration – Technical Advisory.

Internationally, collaboration continued to develop with MIMOSA, and with EPFL through Dr Dimitris Kiritsis LICP/EPFL in Switzerland. Recent collaboration in information quality for asset management also began with the Distributed Information and Automation Laboratory (DIAL) of the Institute of Manufacturing at Cambridge University in the UK.

Other international CIEAM-related activities included the co-chairing of the MIT International Conference in Information Quality, several invited keynote addresses on data quality for engineering asset management, and knowledge exchange interactions with a number of other universities and research institutes.

The ongoing collaboration with Concurrent Technologies Corporation (CTC) and the US Army's ERDC-CERL Bridge SHM project resulted in the deployment of the electrical resistance-based corrosion sensors in bridges in the United States.

Strategic Human Dimensions program

ASC and ANSTO were involved in research activity relating to strategic decision making in engineering asset environments, and provided organisational support for undertaking case studies to develop and test decision models.

The work with DMO on the MSD strategy was completed and a series of highly successful workshops were conducted with DSTO and DMO staff. The final project report was well received by the Director, Maritime Sustainment Support.

2.5.3 Participants' case studies

Case study 1: AAMCoG

A singular case of CIEAM-driven collaboration was the formation of the Australian Asset Management Collaborative Group (AAMCoG). This group comprises the peak industry bodies associated with various aspects of asset management. Its formation at the initiative of CIEAM, resulted from the recognition that there was no real collaboration across the various industry sectors, each operating in its own 'silo'.

The AAMCoG membership received a positive boost with the Australian Green Infrastructure Council (AGIC) joining as a member. AGIC is a company limited by guarantee formed by a group of industry professionals from engineering, environmental, planning, legal, financial, and construction backgrounds working in both private and public organisations related to infrastructure. It is supported by over 40 companies and government organisations involved in infrastructure as builders, manufacturers and users.

As an example of the spread of the concerns about the need for improved approaches to asset management, the Victorian Auditor General has assumed the chair of AAMCoG.

Case study 2: CIEAM's Asset Health Manager

The development of the Asset Health Manager project provides an outstanding example of the way collaborative linkages developed within the CIEAM framework.

The project began as the development of a system of combining health monitoring data and prognosis analysis into an overall health management system for large pumps operated by SunWater, a CIEAM participant.

As the project developed, other participants became interested, and the application of the technology spread to include pipelines, power transformers and buildings.

In CIEAM II the project is being extended to cover rotating machinery, such as submarine motors, and reciprocating engines, as examples of low speed equipment, for which some acoustic diagnostic technology was also developed in CIEAM.

Case Study 3: Mean Variance Tool (MVT)

The MD107 project produced a stand-alone software decision tool to generate optimal work packages that deliver the maximum possible increase in asset capability at lowest financial risk. The tool is called the Mean Variance Tool (MVT) and is based on portfolio risk optimisation concepts from financial mathematics.

Sponsored by the DMO (Defence Materiel Organization), the MVT will be rolled out across all SPOs (System Project Offices) within the RAN (Royal Australian Navy) during 2011.

The MVT is expected to generate cost savings, boost capability, ensure greater accountability and auditability for Defence funds expenditure, and to contribute to Australia's defence. The tool has commercialisation potential and has already attracted attention from other areas of asset management.

2.5.4 CIEAM communications

From the outset, CIEAM worked quickly to establish a clear profile as the leading, research and development organisation in the field of integrated engineering asset management. This challenge necessitated a level of agility in engaging interest and support within both academic and industry spheres. The result was a wide range of communication materials developed for both internal and external stakeholders. As CIEAM further strengthened and established itself as a leading research and development centre, it consolidated its communication activities to ensure a strong and consistent message was conveyed to all stakeholders.

External communication

CIEAM adopted a range of strategies aimed at expanding CIEAM's linkages with business, and in particular with SMEs. Communication played an integral role in each of these strategies. Additionally, CIEAM took an overall approach through direct liaison with media and publications contacts in order to raise the profile of the CRC and promote the benefits of its research. CIEAM's communication strategies incorporated a range of devices that were constantly being expanded.

Establishing and developing key relationships within CIEAM, including with participants' corporate communications divisions, within the CRC community and with communications staff in other CRCs, allowed CIEAM to better leverage cross-promotional opportunities and outreach activities.

CIEAM's website provided online access to CIEAM news, events and free-to-access publications. As well as presenting information on CIEAM to an external audience, the website also has a number of key deliverables associated with it from a research and an education and training perspective. The website was upgraded to accommodate CIEAM's growth and progress towards these key milestones.

The website provided additional information about CIEAM for outside organisations, including SMEs, and for individuals. New features include an avenue for interested parties to subscribe to news updates, course offerings, scholarship opportunities and featured case studies that focus on the benefits to industry of CIEAM's research.

In April 2006, CIEAM launched a new print-based newsletter entitled *Profile*. This publication targeted key external stakeholders such as government departments, private sector organisations, consultants and members of professional societies and peak bodies. *Profile* is released on a six-monthly basis to an established database and is also distributed with CIEAM promotional information packs at conferences and meetings.

The development of key publications, such as the Publication Policy and Procedure documents, ensured consistent presentation of CIEAM research materials and adequate IP protection practices as specified in the Commonwealth Agreement. CIEAM also developed a suite of corporate communications and marketing materials for use at trade shows, answered ad hoc information requests, and responded to other outreach and promotional opportunities.

CIEAM regularly sponsored and exhibited at key industry events, taking advantage of the opportunity to advertise itself, raise its profile with specific groups and create further networking and marketing opportunities into the future. CIEAM played a principal role in the inaugural World Congress on Engineering Asset Management (WCEAM), held on Queensland's Gold Coast in July 2006, featuring prominently as a joint organiser of the event and exhibiting at the Congress trade show. WCEAM 2007, held in the UK in June 2007, and subsequent annual congresses have also strongly profiled CIEAM as the originator of this significant international event, and featured CIEAM researchers and scholars in technical presentations.

Other large scale events CIEAM was involved with were the Seventh International Tribology Conference hosted in Australia (AusTRIB 2006) held in Brisbane in December 2006, as Bronze Sponsor and exhibitor; the Whole-of-Life Costing Conference in Melbourne, in March 2007 as an Associate Partner; and the International Conference of Maintenance Societies, also in Melbourne, in May 2007, as a trade show exhibitor and technical presenter. CIEAM continued in this tradition and annually supported other events related to engineering asset management both locally and overseas.

CIEAM participated in all CRC Association Annual Conferences. For instance, in Perth in May 2007, the conference included a half-day exhibition of a selection of CRCs, profiling their research and development work. The exhibition was open to conference delegates, as well as the general public, and a number of local primary and secondary schools were invited. Approximately 200 students attended, interacting with the various exhibits. CIEAM featured two interactive displays from the Universities of Newcastle and Western Australia. From the University of Newcastle, a computer-based video allowed students and delegates to navigate their way around a test pipeline and pinpoint key points of wear. The University of Western Australia provided a scale model pipeline with highly sensitive vibration sensors that registered movement and sounds on a terminal screen, giving the audience the chance to see the model 'talk back'.

The level of engagement escalated this year, with CIEAM, in conjunction with other Brisbane based CRCs, organising the 2011 CRCA Annual Conference in Brisbane.

Internal communication

With participants, researchers and students located across the country, CIEAM took steps to ensure every member of the CIEAM community understood the vision and mission of the CRC and recognised the value of their contribution to its outcomes.

A strong organisational community within CIEAM helped create an impression of cohesion and instil confidence not just in the CRC's participants on a daily basis, but with external stakeholders and potential business partners as well.

Internal communication activities undertaken by CIEAM included:

- CIEAM Annual Conference: an ideal opportunity for the CIEAM community to build strong internal working relationships and maximise the impact of the Centre's research, for participants and the industry in general
- CIEAM Matrix: profiling achievements of CIEAM's post graduate students, project successes and case studies, and providing an avenue for promoting news and events within CIEAM
- CIEAM website: provides information on the latest news and events both within CIEAM and from the industry at large
- CIEAM Publications, Policy and Procedure: helping participants protect CIEAM IP and ensuring a high standard of presentation and content in publications released under the CRC's brand.

2.6. Future prospects

CIEAM was granted a three-year extension (CIEAM II) to finalise utilisation and commercialisation of CIEAM project outputs and to transition to a successor body outside of the CRC Program framework at the conclusion of the Commonwealth Agreement in 2013.

2.7. Relationship to new Commonwealth Agreement

At a broad level, the five programs in CIEAM map directly into the four programs in CIEAM II, with the addition of an environmental sustainability project in Program 1.

At the project level, all CIEAM projects were formally closed at 30 June 2010 with final reports prepared and signed off.

About 70% of CIEAM II projects are an extension of the corresponding CIEAM projects, involving further development for commercialisation or utilisation as required in the conditions attached to the grant and in the new Commonwealth Agreement.

All project final reports, as well as the project IP information and data, were logged on the CIEAM confidential portal, and are available for access by registered users.

Finalised project reports with their IP are currently being assessed for potential commercialisation or utilisation.

The work program of CIEAM II includes some additional components necessary to fully utilise existing CIEAM work.

Focus of commercialisation efforts over the next three years

Many CIEAM research projects produced outputs with potential for commercialisation and utilisation. Several were identified as requiring further work to complete their full commercialisation phase. These projects continue to maintain close links with their industry participants to ensure relevance and value to participants. Some projects are progressing to the stage of patent registration to protect the resulting IP.

The direct marketing of systems and services by CIEAM II is a medium- to long-term prospect, and would require a project champion with significant on-going time commitment to the commercialisation activity. It is likely that considerable financial, physical and human resources would be required to extend the core competency of CIEAM II from industry-linked research to sale and support of a commercial product in order for this route to be pursued.

In light of the support for CIEAM II, and in particular the commercialisation requirements, all these outputs are embedded into the CIEAM II revised program of work. The plan is to work toward completion of commercial-ready prototypes within the next 24 months for those projects which have commercialisation potential. Doing so would maximise the chances of producing mature, robust technologies with adequate IP protection in place, and which could be commercialised with time for commercial negotiations to be completed during the life of the Centre.

Transition of CIEAM outside the CRC program

A feasibility study of options for the structure of a stand-alone entity capable of continuing the CIEAM agenda will be undertaken as part of the work program in CIEAM II. Ease of transition to a new entity will be facilitated by extending the vehicles already set up under CIEAM, including expansion of the International Society for Engineering Asset Management (ISEAM), the future development of the World Congress in Engineering Asset Management, and the advancement of the national body for public good research and collaboration in asset management, the Australian Asset Management Collaborative Group (AAMCoG).

Outputs from the CIEAM II program that are likely to encourage new participants to continue an association, and contribute to a new entity will be encouraged.

The CIEAM II PhD program, with an additional 12 new scholars, will focus on work seen as important for the new entity. These students are expected to complete their work after the end of the three-year CIEAM II program, and will be fully funded from the CIEAM II budget.

2.7.1 Future arrangements and prospects

N/A

2.7.2 Additional work to develop or commercialise outputs of the CRC that are not being further pursued in the extension CRC

N/A

2.7.3 Expected future economic, environmental and social benefits from any activities completed but not being further pursued.

N/A

2.8. Contact details

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Attachment 1: Outcomes, outputs and milestones

Outcome/ output/ milestone/ number	Description	Contracted achievement date	Achieved (yes or no)
Outcome 1	More effective decision support systems for the management of engineering assets in place throughout industry, with resultant savings in the cost of maintenance, and the total cost of ownership of engineering assets.		
Output 1.1	<p><i>Description:</i> A framework for integrated lifetime asset management.</p> <p><i>Delivery targets:</i> Systematic analysis to establish the most effective research to achieve integrated engineering asset management objectives. Research outputs from Program 1 are central to this process.</p>		
Milestone 1.1.1	<p>Conducting a facilitated scoping study that involves:</p> <p>1.1.1a Establishing industry challenges issues and opportunities</p> <p>1.1.1b Developing a vision of industry futures and applications in asset management</p> <p>1.1.1c Providing ways for industry and researchers to match and review requirements and drivers (that is, expansion of ideas and opportunities in asset management).</p>	December 2005	Yes
Milestone 1.1.2	<p>Reviewing coverage of requirements and enablers for Program 1 against Programs 2 to 5.</p> <p>Developing strategies to close gaps in asset management requirements.</p>	June 2006	Yes
Milestone 1.1.3	<p>Providing guidance for Programs 1 to 5 based on the above work; providing documentation to CRC Centre Board for consideration.</p>	December 2005	Yes
Output 1.2	<p><i>Description:</i> Integrated frameworks, models and software that enable holistic management of assets within the corporate business environment.</p> <p><i>Delivery targets:</i> Development of the concept of the strategic asset management framework.</p>		
Milestone 1.2.1	<p>Commencing the development of an industry-focused methodology for describing the asset management process.</p>	December 2007	Yes
Milestone 1.2.2	<p>Completing methodology for describing asset management processes.</p>	March 2010	Yes

Outcome/ output/ milestone/ number	Description	Contracted achievement date	Achieved (yes or no)
Milestone 1.2.3	Validation of the methodology for describing asset management across several (for example, three) industry participants.	March 2010	Yes
Milestone 1.2.4	Developing integrated risk management models and decision software linking maintenance strategies with corporate objectives and business needs.	November 2007	Yes
Output 1.3	<i>Description:</i> Development and validation of advanced maintenance decision models and tools for industry. <i>Delivery targets:</i> Development and validation of advanced maintenance decision models and tools on an ongoing basis throughout the life of the Centre.		
Milestone 1.3.1	Developing asset management decision-making algorithms and models that use expert systems and other advanced AI (artificial intelligence) that incorporate, for example, costs, operational level, asset health, failure modes, redundancy, criticality and reliability histories.	March 2010	Yes
Milestone 1.3.2	Designing AM data warehouse using case-based reasoning for maintenance management decision systems.	March 2010	Yes
Milestone 1.3.3	Developing smart asset maintenance decision-support systems incorporating intelligence and self-learning ability for different industry sectors.	March 2010	Yes
Output 1.4	<i>Description:</i> Models and analysis tools to assess condition, analyse reliability and cleanse data. <i>Delivery target:</i> Regular testing of models and tools in industry.		
Milestone 1.4.1	Developing new reliability models that simultaneously take into account multiple condition variables, usage rate, degradation speed and reliability/failure histories.	March 2010	Yes
Milestone 1.4.2	Developing links between condition and reliability data using statistical models for whole of life prediction.	June 2009	Yes

Outcome/ output/ milestone/ number	Description	Contracted achievement date	Achieved (yes or no)
Outcome 2	New sensor and prognosis technologies relating to degradation and structural damage for use in intelligent management of air and sea platforms		
Output 2.1	<i>Description:</i> Sensors and predictive models for corrosion and coating degradation on structural components. <i>Delivery targets:</i> Development of new corrosion sensors and predictive models.		
Milestone 2.1.1	Developing and deploying novel corrosion and environment sensors.	June 2009	Yes
Milestone 2.1.2	Developing corrosion prediction models.	June 2009	Yes
Output 2.2	<i>Description:</i> Tools for assessing the effects of corrosion damage on life of structures. <i>Delivery targets:</i> Development of tools for assessing the effects of corrosion damage on life of structures.		
Milestone 2.2.1	Reviewing literature on environmental effects on crack growth from near micron defects and extending the generalised Frost-Dugdale Model to account for these effects and link with the US Navy Unigro formulation.	March 2010	Yes
Milestone 2.2.2	Validating the analysis methodology by comparison with full-scale tests performed at DSTO and transitioning the prognosis technology into fleet management tools.	March 2010	Yes
Output 2.3	<i>Description:</i> Cost-effective thickness measurement in large-scale structures. <i>Delivery targets:</i> Methodology for assessing the structural integrity of composite repairs on aircraft structure.		
Milestone 2.3.1	Evaluating durability of in-situ sensors and actuators.	December 2009	Yes
Milestone 2.3.2	Laboratory preparation of test specimens. Undertaking laboratory assessment of structural monitoring techniques under various conditions.	December 2009	Yes
Milestone 2.3.3	Refining, and experimentally validating and structurally detailing the dynamic finite element models of F-111 aircraft lower wing skin stiffener depression zones.	December 2009	Yes

Outcome/ output/ milestone/ number	Description	Contracted achievement date	Achieved (yes or no)
Outcome 3	New technologies operational in industry that both streamline and automate the tasks of fault diagnosis and prognosis in intelligent maintenance systems		
Output 3.1	<i>Description:</i> Signal processing methods to analyse multi-parameter data using an integrated approach incorporating vibration data, reliability history, and operational data. <i>Delivery targets:</i> New techniques and processes for enabling multi-parameter assessment of machinery condition information.		
Milestone 3.1.1	Developing innovative strategies for the design of integrated advanced machine condition monitoring and diagnostic/prognostic systems.	March 2010	Yes
Milestone 3.1.2	Developing a systematic technique for handling data from multiple sources within a condition monitoring and diagnostics system which leads to improved diagnostics and prognostics.	March 2010	Yes
Milestone 3.1.3	Developing a robust strategy for monitoring the condition of large and low speed machines readily available for industry implementation.	December 2007	Yes
Output 3.2	<i>Description:</i> Automated diagnostics techniques, including pattern recognition algorithms for specific application to identify and classify faults in machinery and distribution infrastructure. <i>Delivery targets:</i> New techniques and algorithms for the implementation of automated diagnostics of machines and machine systems.		
Milestone 3.2.1	Developing models, algorithms and strategies for implementing automated diagnostics in condition monitoring.	June 2010	Yes
Milestone 3.2.2	Developing cost-effective, non-intrusive techniques and methodologies to assist in the management and minimisation of wear and scale build-up in pneumatic conveying pipeline systems.	June 2010	Yes
Output 3.3	<i>Description:</i> Cutting edge tools and techniques for accurately assessing the remaining life of machinery and equipment <i>Delivery targets:</i> Methods and technologies to enable the assessment of remaining life in machine and machine systems.		
Milestone 3.3.1	Developing residual and service life prediction algorithms and strategies with particular applications to tribological systems and power transformers.	June 2009	Yes

Outcome/ output/ milestone/ number	Description	Contracted achievement date	Achieved (yes or no)
Milestone 3.3.2	Developing a predictor of the wear rate (model) from associated wear mechanisms which will aid in the prediction of the remnant life of a machine component.	December 2009	Yes
Milestone 3.3.3	Developing a methodology to monitor the condition of low-speed machinery with the view to predicting residual/service life.	July 2007	Yes
Outcome 4	New standards, tools and methodologies for data exchange and integration between the management information systems and the asset-based technical systems to provide strategic management decision tools in the maintenance and operations environment; and asset management approaches and technologies in electronic business paradigm.		
Output 4.1	<i>Description:</i> A standardised data format protocol for data exchange. <i>Delivery targets:</i> New protocol for addressing the issue of representation of data held in engineering assets with the aim of standardizing exchange of this data.		
Milestone 4.1.1	Initiating a two industry based project to develop standardised data format protocols.	December 2007	Yes
Milestone 4.1.2	Developing a framework for standardising data acquisition from multiple technologies.	March 2010	Yes
Milestone 4.1.3	Developing standardised communication techniques and methods for system engineering data and model representations.	June 2007	In progress
Milestone 4.1.4	Developing a vigorous methodology for data exchange based on XML.	December 2006	Yes
Output 4.2	<i>Description:</i> Integrated information open systems architecture. <i>Delivery targets:</i> New forward-looking open systems information architecture for realising adaptive integrated engineering assets maintenance and management.		
Milestone 4.2.1	Modelling of enterprise information requirements for asset monitoring, inspection and the utilisation of information thus obtained to design a feedback loop from production to design.	March 2010	Yes

Outcome/ output/ milestone/ number	Description	Contracted achievement date	Achieved (yes or no)
Milestone 4.2.2	Developing a set of interoperability techniques and methodologies for managing, monitoring and maintaining systems, operating concurrently on distributed networks and without any centralised control.	March 2010	Yes
Milestone 4.2.3	Utilising object-oriented technology in production systems by way of which an ability to manage heterogeneous views and propagation of changes between views could be achieved.	March 2010	Yes
Output 4.3	<i>Description:</i> Asset information Quality Management. <i>Delivery targets:</i> A suite of frameworks, methodologies, and applications aimed at enhancing quality of information in asset management information systems.		
Milestone 4.3.1	Developing a data quality framework for asset management.	March 2010	Yes
Milestone 4.3.2	Developing a data quality assessment framework.	June 2007	Yes
Milestone 4.3.3	Developing data cleansing methodologies that address organisational, as well as cultural, issues.	June 2008	Yes
Milestone 4.3.4	Developing a data cleansing software prototype.	June 2008	Yes
Milestone 4.3.5	Developing metadata based enrichment of asset management data.	June 2008	Partially
Milestone 4.3.6	Developing data analysis and profiling methodologies.	June 2008	Yes
Outcome 5	Adoption of best practice, effective transfer and integration of research outcomes into asset management business practice to improve the industry capacity and organisational capability.		
Output 5.1	<i>Description:</i> Practical models, protocols and tools for asset management systems in industry. <i>Delivery targets:</i> Models, protocols and support materials through pilot demonstrator projects.		
Milestone 5.1.1	Developing performance and capability support materials for asset management and maintenance management systems.	December 2007	Yes

Outcome/ output/ milestone/ number	Description	Contracted achievement date	Achieved (yes or no)
Output 5.2	<i>Description:</i> A rigorous evaluation of the effectiveness of professional development programs and redesign of industry-led research-based programs. <i>Delivery targets:</i> Review of existing programs, and restructure and redesign of them for engineering asset management organisations.		
Milestone 5.2.1	Developing industry and service provider supported materials.	December 2007	Yes.
Milestone 5.2.2	Developing industry and provider information linked to the CIEAM Education and Training program and presented at an industry symposium.	September 2006	Yes
Output 5.3	<i>Description:</i> Policy guidelines and practical tools for the integration of newly developed knowledge of OHS&E issues with the commercial practice of asset management. <i>Delivery targets:</i> Support tools policy guidelines.		
Milestone 5.3.1	Developing draft policy guidelines for the integration of OH&S issues.	January 2008	Yes
Output 5.4	<i>Description:</i> A culture change model based around the data quality and data packaging requirements of engineering asset intensive organisations. <i>Delivery targets:</i> Identification of key antecedents of data quality; development and deployment of an engineering asset data packaging process; development and deployment of a broader culture change model for CIEAM members.		
Milestone 5.4.1	Developing data packaging methodologies, and collecting and analysing this data from CIEAM industry participants.	July 2008	Yes
Milestone 5.4.2	Developing a data quality framework, and a model to understand the issues of human error in data collection.	November 2007	Yes
Milestone 5.4.3	Using a demonstration project to develop strategies from data quality analysis results.	July 2009	Yes.
Milestone 5.4.4	Developing and validating an engineering asset management culture change model.	July 2008	Yes
Output 5.5	<i>Description:</i> A contingency model for structuring asset governance and contractual arrangements. <i>Delivery targets:</i> Model development, and deployment of this into asset management organisations.		

Outcome/ output/ milestone/ number	Description	Contracted achievement date	Achieved (yes or no)
Milestone 5.5.1	Piloting the development of an asset management governance model and case selection testing.	August 2007	Yes.
Output 5.6	<p><i>Description:</i> Analysis of the organisational and human dimensions of regulatory and policy frameworks that facilitate optimal infrastructure management and maintenance regimes.</p> <p><i>Delivery targets:</i> A framework to assess the current regulatory and policy environment relating to the human dimensions of infrastructure management and maintenance.</p>		
Milestone 5.6.1	Mapping the existing policy and regulatory framework which relates to infrastructure management and availability.	January 2008	Yes
Milestone 5.6.2	Determining the desired performance of this policy and regulatory framework, and identify ways of measuring and improving organisational human resource performance in the current policy and regulatory framework.	November 2009	In progress
Outcome 6	Development of CIEAM as the national research and education centre meeting the industry requirements for Australia's research base in asset management, and the needs of Australian industry generally.		
Output 6.1	<p><i>Description:</i> Quality PhD and Masters graduates to meet the industry requirements of the national research base, and the needs of Australian industry for quality graduates.</p> <p><i>Delivery targets:</i> Up to 100 PhD and research Masters students graduating during the life of CIEAM.</p>		
Milestone 6.1.1	Implementing scholarship funding arrangements.	December 2003	Yes
Milestone 6.1.2	Awarding and managing full and top-up scholarships.	February 2003/07	Yes
Output 6.2	<p><i>Description:</i> Quality education and training courses for industry professionals and technical staff.</p> <p><i>Delivery targets:</i> An education and training needs survey, defined and enhanced education pathways and programs, and an ISO accredited education for asset maintenance professionals.</p>		

Output/ milestone/ number	Description	Contracted achievement date	Achieved (yes or no)
Milestone 6.2.1	Conducting the first survey of unmet needs from Australian industry in asset management education and devising programs to address the need.	December 2003	Yes
Milestone 6.2.2	Enhancing existing education programs in engineering asset management across participant tertiary education sectors on the basis of industry need.	September 2004	Yes
Milestone 6.2.3	Defining education and project pathways from vocation and undergraduate courses to research and R&D projects.	July 2005	Yes
Milestone 6.2.4	Devising an offshore e-based professional education program for service to selected countries in the Asia Pacific region.	December 2005	Yes
Milestone 6.2.5	Setting up an accreditation program for maintenance professionals in accordance with ISO standards.	September 2004	No
Output 6.3	<i>Description:</i> The development of CIEAM as a national information resource centre for asset management. <i>Delivery targets:</i> Website, online discussion forums, bulletin board and policy papers.		
Milestone 6.3.1	Establishing and maintaining a comprehensive website.	December 2003 and ongoing	Yes
Milestone 6.3.2	Setting up and maintaining a discussion forum for practitioners.	2004 and ongoing	Yes
Milestone 6.3.3	Setting up and maintaining a bulletin board for new developments in technology, standards and government regulations concerning asset management.	2004 and ongoing	Yes
Milestone 6.3.4	Developing policies and position papers to define and disseminate world's best practice in asset management for Australian industry.	2004 and ongoing	Yes
Output 6.4	<i>Description:</i> CIEAM annual conferences and innovation forums for researchers, research students, and university and industry partners. <i>Delivery targets:</i> Conference and innovation forum program organisation.		

Outcome/ output/ milestone/ number	Description	Contracted achievement date	Achieved (yes or no)
Milestone 6.4.1	Establishing the conference format and paper submission criteria.	July 2004	Yes
Milestone 6.4.2	Devising a program to showcase student and staff projects.	December 2004	Yes
Output 6.5	<i>Description:</i> Regular seminars, workshops and conferences on issues related to asset management. <i>Delivery targets:</i> Up to three seminars, workshops and/or conferences a year.		
Milestone 6.5.1	Facilitating up to three seminars dealing with issues in engineering asset management.	2004 and onwards	Yes
Milestone 6.5.2	Hosting the biennial Asia-Pacific Conference for System Integrity and Maintenance (ACSIM).	2004, 2006, 2008	2004 only
Outcome 7	Adoption of CIEAM-generated asset management systems and technologies by industry participants and the packaging of these for commercialisation and diffusion into industry generally. Consultancy services will develop into a key tool for CRC integration with industry.		
Output 7.1	<i>Description:</i> Review and redesign industry asset management data collection, data processing and integrated decision-support systems. <i>Delivery targets:</i> A strategy for industry asset management data collection, data processing and integrated decision-support systems.		
Milestone 7.1.1	Developing a data collection and evaluation framework for implementation directly into industry business processes through the development of an appropriate and robust architecture. The process of developing this strategy would be considered for commercialisation and application more widely through the SME community.	June 2005 and ongoing for various industries	Yes
Milestone 7.1.2	Developing an appropriate engineering asset management modelling framework by integrating technical and costing parameters into the asset management models.	June 2006	Yes

Outcome/ output/ milestone/ number	Description	Contracted achievement date	Achieved (yes or no)
Milestone 7.1.3	Assessing the need for various data capture technologies (sensors and IT strategies) and integrating these progressively into industry data capture processes to support demonstrator projects which will allow for application across several industry sectors.	December 2007	No
Output 7.2	<i>Description:</i> Commercialisation of specific CIEAM developed technologies. <i>Delivery targets:</i> Exploration of all possible avenues for IP commercialisation and revenue generation.		
Milestone 7.2.1	Developing a series of specific industry-related sensors and technologies for application to a wide range of industry sectors.	December 2005	Yes
Milestone 7.2.2	Developing integrated engineering asset management IT solutions for direct application into industry.	December 2005 and ongoing	No
Milestone 7.2.3	Promoting the human factor program outcomes into industry progressively as the new integrated asset management models are adopted.	April 2006	No
Output 7.3	<i>Description:</i> A Commercialisation Plan. <i>Delivery targets:</i> Development of a commercialisation and utilisation plan in the first two years.		
Milestone 7.3.1	Undertaking a workshop to develop the strategic focus on issues relating to the CRC achieving all its research goals.	December 2003	Yes
Milestone 7.3.2	Developing and achieving Centre Board approval for a commercialisation and utilisation plan as required under the Commonwealth Agreement. The plan will incorporate both formal and informal methods of IP protection and various methods of commercialisation, such as licensing assignment and sale.	June 2004	Yes
Milestone 7.3.3	Promoting a research structure that encourages all participants to become involved in the commercial application of research projects and their application into the business activities of industry partners.	December 2003	Yes
Milestone 7.3.4	Pursuing a close relationship with the International Standards Organisation and encouraging Centre projects to contribute to the formulation of international standards.	June 2004 and Ongoing	Yes and Ongoing

Outcome/ output/ milestone/ number r	Description	Contracted achievement date	Achieved (yes or no)
Milestone 7.3.5	Establishing a participant researcher reward scheme.	December 2004	No
Output 7.4	<i>Description:</i> Formation of an IP commercialisation company. <i>Delivery targets:</i> A strategy for and implementation of an IP commercialisation company.		
Milestone 7.4.1	Auditing the range of specific IP issues and the mechanisms for application and commercialisation, utilising SMEs where possible for technology diffusion.	December 2004 and ongoing	Yes
Milestone 7.4.2	Completing the formalities of corporate formation and establish a funding source for IP protection and marketing.	June 2005 and ongoing	Yes
Milestone 7.4.3	The application of Centre IP to providing consulting services and training courses into the business activities of the industry partners and industry generally through formal postgraduate courses and specialised training programs, incorporating outputs from all programs. Accreditation will occur through all university partners.	December 2005 and ongoing	Yes
Output 7.5	<i>Description:</i> An IP register. <i>Delivery targets:</i> Development of an IP register at commencement of CRC operations.		
Milestone 7.5.1	Developing a register of background IP, ascertain which of this IP can be commercialised through the CRC, with the approval of the contributing participant.	December 2004	Yes.
Milestone 7.5.2	Developing a second register of third party IP that may be of value to CIEAM projects and if this IP can be accessed for centre projects and jointly commercialised.	December 2005 and ongoing	Yes
Milestone 7.5.3	Where appropriate working collaboratively with third parties (including other CRC's, TAFE and industry) to create commercial products for the benefit of improving integrated engineering asset management.	December 2005 and ongoing	In progress
Milestone 7.5.4	Maintaining the IP registry.	Annually	Yes

Attachment 2: IP Register

Reference	Title	Type	Date	Related project	Status
AS101-B1	Joint corrosion: strain sensor using metal coated fibre Bragg grating	Background	22/07/2004	AS101 Sensors for Corrosion Detection & Thickness Measurement, AS301 Sensors for Crack and Disbond/Delamination Detection and Monitoring	Active
AS101-B2	Joint strain: temperature sensor using combined fibre BRAGG gratings and fluorescence from rare earth-doped fibre	Background	22/07/2004	AS101 Sensors for Corrosion Detection & Thickness Measurement, AS301 Sensors for Crack and Disbond/Delamination Detection and Monitoring	Active
AS101-B3	Corrosion fuse sensor using metal coated optical fibres	Background	22/07/2004	AS101 Sensors for Corrosion Detection & Thickness Measurement, AS301 Sensors for Crack and Disbond/Delamination Detection and Monitoring	Active
AS101-P1	Utilisation of optical fibre corrosion sensor technology for simultaneous strain and temperature measurements in a range of corrosive environments	Centre	03/03/2008	AS101 Sensors for Corrosion Detection & Thickness Measurement, AS301 Sensors for Crack and Disbond/Delamination Detection and Monitoring	Active
AS102-P1	Assessment of the crack growth mechanism of typical military aircraft skin materials	Centre	25/06/2010	AS102 Integrated Prognosis Tools for Assessing the Effect of Corrosion on Structural Integrity and Fleet Management	Active

Reference	Title	Type	Date	Related project	Status
AS301-P1	In situ crack and disbond monitoring of composite bonded repaired metallic structures of military aircrafts using stress wave based techniques (Experimental result- no protectable IP)	Prospective	24/09/2009	AS301 Sensors for Crack and Disbond/Delamination Detection and Monitoring	Active
AS302-B1	Environmental sensor suite	Background	05/02/2007	AS302 Industrial Applications of Corrosion Sensing	Active
AS302-B2	Models to determine the corrosion state of steel structures	Background	05/02/2007	AS302 Industrial Applications of Corrosion Sensing	Active
AS302-B3	Electrical resistance corrosion sensor prototype (for steel structures)	Background	05/02/2007	AS301 Sensors for Crack and Disbond/Delamination Detection and Monitoring, AS302 Industrial Applications of Corrosion Sensing	Active
AS302-P1	Software and hardware interfaces for low-cost automated remote corrosion sensing technology (Experimental result - no protectable IP)	Prospective	19/05/2010	AS302 Industrial Applications of Corrosion Sensing	Active
AS302-P2	Development and testing of piezoelectric sensors using a novel electron-mechanical impedance technique for paint breakdown and structural damage detection	Centre	19/05/2010	AS302 Industrial Applications of Corrosion Sensing	Active
AS303-P1	Effects of CPCs on fatigue crack growth of aviation aircraft structural components (Experimental result - no protectable IP)	Prospective	17/06/2010	AS303 The effect of CPCs on fatigue crack propagation in aluminium alloy type 2024-T3 aircraft structural skin	Active
HD102-B1	Tool for agility measure in an enterprise	Background	30/06/2006	HD102 CIEAM Toolbox	Active
HD102-B2	Teamworking in the Australian Automotive Industry	Background	28/06/2006	HD102 CIEAM Toolbox	Active

Reference	Title	Type	Date	Related project	Status
HD102-B3	CIEAM Toolbox content	Background	28/06/2004	HD102 CIEAM Toolbox	Active
HD102-P1	Guidelines on agility, team working, data quality and human factors in integrated engineering asset management (Information is in public domain)	Centre	03/03/2008	HD102 CIEAM Toolbox	Active
HD103-P1	A strategic work design to improve the quality of engineering data and knowledge transfer for maintenance and asset management	Centre	03/03/2008	HD103 Strategic Work Design in Engineering Asset Environments	Active
HD203-B1	Interview Questionnaire to identify engineering roles and work activities	Background	22/09/2006	HD203 Engineering work in Asset Management	Active
HD203-P1	Maintenance and its support activities in an industrial processing plant and identification of areas of improvement for effective engineering asset management in an organization (Experimental result- no protectable IP)	Prospective	08/05/2009	HD203 Engineering work in Asset Management	Active
HD204-P1	Contingency model for the management of assets in asset intensive multi-division organizations (Experimental result- no protectable IP)	Prospective	14/04/2009	HD204 Asset performance: impact of stewardship and governance strategies	Active
HD301-B1	Fatigue Management Planning	Background	28/06/2004	HD301 Third Party OHS Projects	Active
HD301-P1	Risk assessment of driver fatigue in both short and long distance driving and the driving patterns of shift workers on days off (Experimental result- no protectable IP)	Prospective	15/09/2009	HD301 Third Party OHS Projects	Active
HD302-B1	Risk assessment of nuclear facilities	Background	01/01/2009	HD302 Improving the integration of safety, business and asset management systems: a demonstrator project.	Active

Reference	Title	Type	Date	Related project	Status
HD302-P1	OHSE guideline for nuclear industry (Experimental result- no protectable IP)	Prospective	25/05/2010	HD302 Improving the integration of safety, business and asset management systems: a demonstrator project.	Active
HD505 - B1	Australian Defence Organisation/ Defence Material Organisation, material logistics/ asset management, data, usage, know-how, and documentation	Background	17/06/2008	HD505 Maritime Systems Division Materiel Logistics Strategy Development	Active
ID201-B1	RMS Software Package Project	Background	28/06/2004	ID201 Integrated Decision Support System for Asset Management in the Water Utility Industry	Active
ID201-B2	Condition and risk assessments of water and waste pipelines	Background	28/06/2004	ID201 Integrated Decision Support System for Asset Management in the Water Utility Industry	Active
ID201-P1	Integrated condition-based health prediction schema	Centre	03/03/2008	ID201 Integrated Decision Support System for Asset Management in the Water Utility Industry	Active
ID201-P2	A software prototype for asset health assessment and integrated health based asset decision support	Centre	03/04/2008	ID201 Integrated Decision Support System for Asset Management in the Water Utility Industry	Active
ID201-P3	Modified MIMOSA OSA-EAI data model	Centre	03/04/2008	ID201 Integrated Decision Support System for Asset Management in the Water Utility Industry	Active
ID201-P4	Layered structure for integrated asset management decision support system	Centre	03/04/2008	ID201 Integrated Decision Support System for Asset Management in the Water Utility Industry	Active
ID202-P1	Techniques for condition monitoring and diagnosis (CM/D) of low speed bearings	Centre	03/03/2008	ID202 Condition Monitoring of Low Speed Machinery	Active

Reference	Title	Type	Date	Related project	Status
ID202-P2	Experimental results from laboratory test using seeded low speed bearings	Centre	03/03/2008	ID202 Condition Monitoring of Low Speed Machinery	Active
ID202-P3	Demonstrative software for condition monitoring of low speed bearings (COMOLOS)	Centre	03/03/2008	ID202 Condition Monitoring of Low Speed Machinery	Active
ID202-P4	Low Speed Test Rig (LSTR)	Centre	03/03/2008	ID202 Condition Monitoring of Low Speed Machinery	Active
ID204-P1	Vibration-based asset health assessment web service	Centre	02/05/2008	ID204 Integration of MIMOSA Compliant Condition Monitoring Information with the Mainet™ Asset Management System	Active
ID204-P2	Asset registration and data management system	Centre	02/05/2008	ID204 Integration of MIMOSA compliant condition monitoring information with the Mainet™ asset management system	Active
ID205-B1	Bulk solids and particulate technologies	Background	03/10/2006	ID205 Pneumatic Conveying Pipeline Management System for Wear Minimisation	Active
ID205-P1	Automated algorithm software based on a pipeline wear model for predicting the service life of pneumatic conveying pipelines	Centre	30/10/2006	ID205 Pneumatic Conveying Pipeline Management System for Wear Minimisation, ID303 Wear in conveying pipelines	Active
ID206-B1	Awoonga Callide pipeline; base data from Sunwater's asset management system	Background	28/03/2007	HD201 Developing Maturity Measurement for Engineering Asset Management, ID206 Integrated Asset Health Manager (AHM)	Active

Reference	Title	Type	Date	Related project	Status
ID206-B2	Methods and techniques for condition monitoring and reliability analysis	Background	28/03/2007	ID201 Integrated Decision Support System for Asset Management in the Water Utility Industry, ID206 Integrated Asset Health Manager (AHM)	Active
ID206-B3	Integrated condition-based health prediction schema	Background	28/03/2007	ID201 Integrated Decision Support System for Asset Management in the Water Utility Industry, ID206 Integrated Asset Health Manager (AHM)	Active
ID206-B4	MIMOSA compliant data models for integrating condition monitoring, reliability analysis and health based asset decision support	Background	28/03/2007	ID201 Integrated Decision Support System for Asset Management in the Water Utility Industry, ID206 Integrated Asset Health Manager (AHM)	Active
ID206-B5	High level Asset Management Process Models with multiple views	Background	28/03/2007	ID201 Integrated Decision Support System for Asset Management in the Water Utility Industry, ID206 Integrated Asset Health Manager (AHM)	Active
ID206-B6	Software prototype for asset health assessment and integrated health based asset decision support	Background	28/03/2007	ID201 Integrated Decision Support System for Asset Management in the Water Utility Industry, ID206 Integrated Asset Health Manager (AHM)	Active
ID206-P1	Integrated Asset Management Decision Support System (IAMDS) framework	Centre	21/06/2010	ID206 Integrated Asset Health Manager (AHM), MD301 Multi-criteria Asset Decision Support Tool (MAD)	Active

Reference	Title	Type	Date	Related project	Status
ID206-P2	Software prototype for integrated Asset Health Manager (AHM)	Centre	21/06/2010	ID206 Integrated Asset Health Manager (AHM)	Active
ID206-P3	Preventive maintenance decision optimisation methodology	Centre	21/06/2010	ID206 Integrated Asset Health Manager (AHM), MD301 Multi-criteria Asset Decision Support Tool (MAD)	Active
ID207-P1	Integrated health monitoring technique using combined vibration and acoustic emission data for structural damage identification of civil engineering structures	Centre	16/04/2010	ID207 Integrated Health Monitoring System for Civil Infrastructure in Operational Environments	Active
ID208-B1	Techniques for condition monitoring and diagnosis (CM/D) of low speed bearings	Background	05/11/2007	ID202 Condition Monitoring of Low Speed Machinery, ID208 Utilisation of Condition Monitoring/Diagnostics Software for Low Speed Machinery	Active
ID208-B2	Low Speed Test Rig (LSTR) for simulation of various faults in low speed machinery	Background	05/11/2007	ID202 Condition Monitoring of Low Speed Machinery, ID208 Utilisation of Condition Monitoring/Diagnostics Software for Low Speed Machinery	Active
ID208-B3	Experimental results from Low Speed Test Rig (LSTR)	Background	05/11/2007	ID202 Condition Monitoring of Low Speed Machinery, ID208 Utilisation of Condition Monitoring/Diagnostics Software for Low Speed Machinery	Active
ID208-B4	A demonstrative software for CM/D of Low Speed Machinery	Background	05/11/2007	ID202 Condition Monitoring of Low Speed Machinery, ID208 Utilisation of Condition Monitoring/Diagnostics Software for Low Speed Machinery	Active

Reference	Title	Type	Date	Related project	Status
ID208-P1	Hardware for on-line condition monitoring system for low speed machinery	Centre	11/05/2010	ID208 Utilisation of Condition Monitoring/Diagnostics Software for Low Speed Machinery	Active
ID208-P2	Condition monitoring and diagnostics (CM/D) software for low speed machinery	Centre	11/05/2010	ID208 Utilisation of Condition Monitoring/Diagnostics Software for Low Speed Machinery	Active
ID301-B1	MPT's proprietary RMS software package	Background	28/06/2004	ID301 Gas Turbine Asset Management	Active
ID301-B2	Techniques for condition assessment and risk assessment of water and waste pipelines	Background	28/06/2004	ID301 Gas Turbine Asset Management	Active
ID301-B3	Gas turbine material life assessment methodology for GT blades, vanes and discs	Background	28/06/2004	ID301 Gas Turbine Asset Management	Active
ID301-B4	Finite Element Modelling input data for life assessment of GT discs, vanes and blades	Background	28/06/2004	ID301 Gas Turbine Asset Management	Active
ID301-B5	Blade, vane and disc material aging characteristics for use in temperature quantification	Background	28/06/2004	ID301 Gas Turbine Asset Management	Active
ID301-B6	Generic life assessment methodology for predicting spallation of thermal barrier coatings	Background	28/06/2004	ID301 Gas Turbine Asset Management	Active
ID301-P1	Life prediction methodologies for the remnant life assessment of hot gas path turbine components and turbine discs (Information is in public domain)	Centre	28/06/2010	ID301 Gas Turbine Asset Management	Active
ID302-B1	Power Transformer Remnant Life Estimation Model	Background	15/11/2007	ID302 Transformer Remnant Life Estimation	Active
ID302-P1	An alternative of FURAN measurement technique for power transformers	Centre	26/08/2009	ID302 Transformer Remnant Life Estimation	Active

Reference	Title	Type	Date	Related project	Status
ID302-P2	The Transformer Remnant Life Estimation Software based on fuzzy logic models	Centre	26/08/2009	ID302 Transformer Remnant Life Estimation	Active
ID302-P3	An Electrical-Mechanical-Acoustical model for predicting the remnant useful life of a transformer	Centre	17/05/2010	ID302 Transformer Remnant Life Estimation	Active
ID303-P1	Development of a wear model to predict the service life of pneumatic conveying pipelines	Centre	21/05/2009	ID303 Wear in conveying pipelines	Active
ID304-B1	Rail track simulation software and data	Background	24/06/2004	ID304 Development of integrated wear-fatigue-lubrication model for assessment of rail-wheel degradation & operational risks	Active
ID304-B2	Field and test curve data from QR	Background	17/01/2006	ID304 Development of integrated wear-fatigue-lubrication model for assessment of rail-wheel degradation & operational risks	Active
ID304-B3	Test and simulation data and DECO track software	Background	20/01/2006	ID304 Development of integrated wear-fatigue-lubrication model for assessment of rail-wheel degradation & operational risks	Active
ID304-P1	Final report outstanding	Prospective	03/03/2008	ID304 Development of integrated wear-fatigue-lubrication model for assessment of rail-wheel degradation & operational risks	Active
ID305-P1	Vibration measurement method for damage detection of subsea pipelines	Centre	02/06/2008	ID305 Offshore structure condition-monitoring using vibration measurement	Active
MD101-P1	A high level generic framework for optimising management of physical assets in an organisation (Information is in public domain)	Centre	18/06/2010	MD101 Engineering Asset Management Frameworks	Active

Reference	Title	Type	Date	Related project	Status
MD102-B1	Framework development and process modelling	Background	19/02/2004	MD102 Asset Management Framework and process modelling for specific industries	Active
MD102-P1	Asset management process modelling method and models	Centre	03/03/2008	MD102 Asset Management Framework and process modelling for specific industries	Active
MD102-P2	Control and Constraint Tree (CCT) technology and its programming code	Centre	03/03/2008	MD102 Asset Management Framework and process modelling for specific industries	Active
MD102-P3	Pipeline renewal decision support tool	Centre	03/03/2008	MD102 Asset Management Framework and process modelling for specific industries	Active
MD103-B1	Strategic and asset management framework	Background	30/06/2005	MD103 Strategic Directions	Active
MD103-P1	CIEAM Asset Management Body of Knowledge	Centre	03/03/2008	MD103 Strategic Directions	Active
MD105-B1	General information of SACA team working through QUT	Background	19/12/2005	MD105 Engineering and asset management frameworks (Economic/Econometric component of LCOO framework to represent navy logistics management)	Active
MD105-P1	Software demonstrators showing different aspects of SACA in a defence context	Centre	04/10/2008	MD105 Engineering and asset management frameworks (Economic/Econometric component of LCOO framework to represent navy logistics management)	Active

Reference	Title	Type	Date	Related project	Status
MD106-B1	Defence (Navy) asset data, asset management and usage documentation	Background	27/02/2006	MD106 Data collection research services associated with defence asset management research programs	Active
MD106-P1	Final report outstanding	Prospective	03/03/2008	MD106 Data collection research services associated with defence asset management research programs	Active
MD107-B1	Australian Defence Organisation - asset data, asset management and usage, know-how and documentation	Background	13/12/2006	MD107 MSD LCOO and RAN SACA Applications	Active
MD107-B2	General know-how of the SACA team working through QUT	Background	10/01/2007	MD107 MSD LCOO and RAN SACA Applications	Active
MD107-P1	A SACA naval configuration management tool and a SACA business process simulator	Centre	20/04/2010	MD107 MSD LCOO and RAN SACA Applications	Active
MD121-B1	Software demonstrators showing different aspects of SACA in a defence context	Background	31/08/2006	MD121 SACA Commercialisation Project – Stage 1	Active
MD121-P1	Translated to MD107	Centre	30/06/2006	MD121 SACA Commercialisation Project – Stage 1	Active
MD122-B1	Australian Defence Organisation- asset data, asset management and usage, know-How and documentation	Background	04/01/2007	MD122 MSD Financial and Management Constructs for Defence Asset Management	Active
MD122-B2	Know-how of Monash research team	Background	05/02/2007	MD122 MSD Financial and Management Constructs for Defence Asset Management	Active
MD122-B3	Background know-how of the QUT research team.	Background	21/12/2006	MD122 MSD Financial and Management Constructs for Defence Asset Management	Active

Reference	Title	Type	Date	Related project	Status
MD122-P1	Decision support software tool to link the logistic of operations to cost modelling	Centre	21/06/2010	MD122 MSD Financial and Management Constructs for Defence Asset Management	Active
MD201-P1	Software integration tool between MIMOSA OSA-EAI and ISO 15926 and its application to certain asset registry scenarios	Centre	21/06/2010	ID205 Pneumatic Conveying Pipeline Management System for Wear Minimisation, ID206 Integrated Asset Health Manager (AHM), ID208 Utilisation of Condition Monitoring/Diagnostics Software for Low Speed Machinery, MD102 Asset Management Framework and process modelling for specific industries, MD201 CIEAM Integration Project, MD302 Asset Management of road surfacing: Optimizing skid resistance	Active
MD301-B1	Awoonga Callide Pipeline: Base data from Sunwater's asset management system	Background	28/03/2007	ID201 Integrated Decision Support System for Asset Management in the Water Utility Industry, ID206 Integrated Asset Health Manager (AHM), MD102 Asset Management Framework and process modelling for specific industries, MD301 Multi-criteria Asset Decision Support Tool (MAD)	Active

Reference	Title	Type	Date	Related project	Status
MD301-B2	Delta Electricity maintenance report	Background	25/07/2007	ID201 Integrated Decision Support System for Asset Management in the Water Utility Industry, ID206 Integrated Asset Health Manager (AHM), MD102 Asset Management Framework and process modelling for specific industries, MD301 Multi-criteria Asset Decision Support Tool (MAD)	Active
MD301-B3	Delta Electricity market price report	Background	05/03/2008	ID201 Integrated Decision Support System for Asset Management in the Water Utility Industry, ID206 Integrated Asset Health Manager (AHM), MD102 Asset Management Framework and process modelling for specific industries, MD301 Multi-criteria Asset Decision Support Tool (MAD)	Active
MD301-B4	Fast Asset Management Process Modelling (FAMPM) technology	Background	04/08/2006	ID201 Integrated Decision Support System for Asset Management in the Water Utility Industry, ID206 Integrated Asset Health Manager (AHM), MD102 Asset Management Framework and process modelling for specific industries, MD301 Multi-criteria Asset Decision Support Tool (MAD)	Active

Reference	Title	Type	Date	Related project	Status
MD301-B5	Control and Constraint Tree (CCT) Technology	Background	04/08/2006	ID201 Integrated Decision Support System for Asset Management in the Water Utility Industry, ID206 Integrated Asset Health Manager (AHM), MD102 Asset Management Framework and process modelling for specific industries, MD301 Multi-criteria Asset Decision Support Tool (MAD)	Active
MD301-B6	Flexible Asset Maintenance Management Framework (FAMMF)	Background	04/08/2006	ID201 Integrated Decision Support System for Asset Management in the Water Utility Industry, ID206 Integrated Asset Health Manager (AHM), MD102 Asset Management Framework and process modelling for specific industries, MD301 Multi-criteria Asset Decision Support ToolAD)	Active
MD301-B7	Pattern/ knowledge-based reference library for CCT and FAMPM	Background	04/08/2006	ID201 Integrated Decision Support System for Asset Management in the Water Utility Industry, ID206 Integrated Asset Health Manager (AHM), MD102 Asset Management Framework and process modelling for specific industries, MD301 Multi-criteria Asset Decision Support Tool (MAD)	Active
MD301-P1	Fast Asset Management Process Modelling (FAMPM)	Centre	30/06/2004	MD301 Multi-criteria Asset Decision Support Tool (MAD)	Active

Reference	Title	Type	Date	Related project	Status
MD302-P1	Data mining analysis of road crashes and the development of a risk-based model and software tool for risk assessment of road crash in relation to skid resistance	Centre	03/03/2008	MD302 Asset management of road surfacing: Optimizing skid resistance	Active
SI101-P1	Asset management data quality framework	Centre	03/03/2008	SI101 Data Quality for Asset Management	Active
SI101-P2	Data cleansing methodology for EAM data	Centre	03/03/2008	SI101 Data Quality for Asset Management	Active
SI101-P3	Data cleansing software prototype	Centre	03/03/2008	SI101 Data Quality for Asset Management	Active
SI101-P4	Data quality handbook	Centre	03/03/2008	SI101 Data Quality for Asset Management	Active
SI101-P5	Information Quality Management Capability Maturity Model (IQM-CMM)	Centre	03/03/2008	SI101 Data Quality for Asset Management	Active
SI101-P6	Taxonomy of data quality problems	Centre	03/03/2008	SI101 Data Quality for Asset Management	Active
SI102-P1	Usage of Radio frequency identification (RFID) for engineering asset management.(Experimental result- no protectable IP)	Prospective	03/03/2008	SI102 Automated Configuration Management	Active
SI103-P1	GPS-based remote work event management system to support the operations of the SA Water Asset Maintenance Division (Experimental result - no protectable IP)	Prospective	03/03/2008	SI103 GPS-based work event management systems for wireless hand held devices.	Active
SI104-B1	AMPS, MSD/RAN asset management information	Background	24/07/2006	MD106 Data collection research services associated with defence asset management research programs, SI104 DSTO configuration and transactional data	Active

Reference	Title	Type	Date	Related project	Status
SI104-P1	Data quality assessment methodology and associated software tools & techniques	Centre	03/03/2008	SI104 DSTO configuration and transactional data	Active
SI104-P2	PIP (restricted to DMO)	Prospective	03/03/2008	SI104 DSTO configuration and transactional data	Active
SI203-P1	Wireless sensor controller	Centre	20/05/2010	SI203 Wireless Prognostics – Wireless capture of condition and operational environment data for real time fault detection and maintenance management	Active
SI203-P1	Software for wireless sensor monitoring	Centre	06/03/2009	SI203 Wireless Prognostics – Wireless capture of condition and operational environment data for real time fault detection and maintenance management	Active
SI203-P2	Serial downloader software	Centre	06/03/2009	SI203 Wireless Prognostics – Wireless capture of condition and operational environment data for real time fault detection and maintenance management	Active
SI203-P3	PC configuration software for slave nodes	Centre	06/03/2009	SI203 Wireless Prognostics – Wireless capture of condition and operational environment data for real time fault detection and maintenance management	Active
SI203-P4	Hardware and software details for wireless sensor nodes	Centre	06/03/2009	SI203 Wireless Prognostics – Wireless capture of condition and operational environment data for real time fault detection and maintenance management	Active

Reference	Title	Type	Date	Related project	Status
SI204-P1	Asset management data profiling and cleansing software	Centre	07/06/2010	SI204 Asset Management Data Analysis, Verification and Enrichment System	Active
SI205-P1	Integrated information framework to support the exchange of community based data	Centre	28/06/2010	SI205 Integrated Information Model for Community Infrastructure and Asset Management	Active
SI301-B1	RMS software package project	Background	28/06/2004	SI301 Technologies For Integrating Multiple IT Systems Relating to Plant Reliability	Active
SI301-B2	UniSA general know-how from prior projects	Background	29/06/2004	SI301 Technologies For Integrating Multiple IT Systems Relating to Plant Reliability	Active
SI301-B3	ANSTO risk assessment methods and corporate procedures	Background	14/07/2004	SI301 Technologies For Integrating Multiple IT Systems Relating to Plant Reliability	Active
SI301-P1	Prototype “data-bridge” product	Centre	07/05/2010	SI301 Technologies For Integrating Multiple IT Systems Relating to Plant Reliability	Active
SI302-P1	Asset Management Integration Service (AMIS) for bridging syntactical and structural differences between data sources	Centre	18/06/2010	SI302 Improved OPAL Monitoring and Management System	Active

Attachment 3: Completed and current scholars

A3.1 Completed scholars (26)

Institution	Scholar	Research project	Program	Study mode	Completion year
Curtin	LAI, Sin Pin (David)	Analysis on the conductivity and furan “content of the transformer oil due to aging using spectral response	ID	Masters	2009
CQU	CHOWDHURY, Ashfaque	Management and control strategies of building assets	MD	Masters	2005
Monash	NOORI, Soudabeh	Study of the American Petroleum Institute methodology applied to furnace tubes and boiler tubes undergoing loss of thickness	ID	PhD	2005
Monash	TAM, Allen	Asset management framework for optimisation of maintenance investment	MD	PhD	2007
Monash	WONG, Wilson	Modelling of composite bonded repair systems as applied to structures. Note: This title is different from Application Form and Agreement	AS	Masters	2007
Monash	TAHERA, Khadiza	Process adjustment to improve process quality using a genetic algorithm fuzzy logic approach	MD	PhD	2008
Monash	KRISHNAPILLAI, Kumanan	Designing for durable structures subjected to isolated and widespread damage	AS	PhD	2009
QUT	KARIMI, Mahdi	Intelligent machinery fault diagnostics based on blind deconvolution	ID	PhD	2007
QUT	LIU, Xiaofeng	Multi-parameter data fusion based on fault diagnosis and prognosis	ID	PhD	2007

Institution	Scholar	Research project	Program	Study mode	Completion year
QUT	RAHMAN, Anisur	Modelling and analysis of reliability and costs for service contract and lifetime warranty policies	MD	PhD	2007
QUT	REDDY, Venkatarani	Development of an integrated model for assessment of operational risks in rail tracks to enhance rail and wheel life	MD	PhD	2007
QUT	SUN, Yong	Reliability prediction of complex repairable systems	ID	PhD	2007
QUT	TRUSCOTT, Rachael	Socially responsible asset management: a case study of Delta Electricity	HD	Honours	2007
QUT	WILSON, Lance	Optimisation of rail/wheel lubrication	ID	PhD	2007
QUT	MATHEW, Avin	Data architecting and knowledge discovery for asset management in the water utility industry	MD	PhD	2008
QUT	WILIEM, Leonard	Online quality condition monitoring system for the water facility industry	MD	PhD	2009
QUT	HENG, Aiwina Soong Yin	Intelligent fault prognostics of rotating machines	ID	PhD	2009
QUT	TOO, Eric	Developing capabilities for infrastructure asset management	HD	PhD	2010
QUT	SAMTANI, Laxman	Technology Transfer Evaluation in the High Technology Industry	HD	PhD	2010
QUT	LINGAMENAI, Srimanth	Executable asset management process modelling and simulation	MD	Masters	2010
UniSA	CARAPIET, Saadia	Role of self organisation in implementing adaptive organisation structures	HD	PhD	2006
UniSA	HAIDER, Abrar	IT-enabled strategic asset management: a comparative study of infrastructure and industrial assets	SI	PhD	2007

Institution	Scholar	Research project	Program	Study mode	Completion year
UniSA	MARTIN, Chris	Examination of technology implementation within small and medium sized enterprises	HD	PhD	2007
UniSA	BASKARADA, Sasa	Asset management data quality maturity model	SI	PhD	2008
UniSA	LIN, Shien	Data quality for asset management	SI	PhD	2008
UniSA	YEOH, Ging-Sun	Asset maintenance knowledge management model: an information quality driven approach	SI	PhD	2009

A3.2 Current scholars (36)

Institution	Scholar	Research project	Program	Study mode	Expected completion year
Monash	TENGGU-RASYDAN, Tengku-Adnan (Dan)	Models and decision systems	MD	PhD	2010
Monash	TIONG, Ung Hing	Development of an integrated analytical capability for the through-life support of aircraft structural components	AS	PhD	2010
QUT	FROLOV, Vladimir	Asset management process modelling: methodology and application	MD	PhD	2010
QUT	FURNEAUX, Craig	Optimal regulatory frameworks for infrastructure management and maintenance	HD	PhD	2010
QUT	GORJIAN JOLFAEI, Nima	Reliability prediction of engineering assets using multiple condition data	MD	PhD	2010
QUT	IKHINMWIN, Cletus	A decision-support process for selecting the most cost effective contract strategies in operations and capital expenditure projects	HD	PhD	2010
QUT	KAM, Shui-cheong	Developing diagnostic and prognostic algorithms for power system equipment from transient waveforms	ID	PhD	2010
QUT	KIM, Hack-Eun	Machine prognostics based on condition monitoring data	ID	PhD	2010
QUT	MARDIASMO, Diaswati (Asti)	Asset governance and performance: The case of government-owned firms	HD	PhD	2010
QUT	NGUYEN, Lynda	Organisational culture change in engineering asset management environments	HD	PhD	2010
QUT	PUDNEY, Steven	Asset management decision framework for the water utility industry	MD	PhD	2010
QUT	YU, Yi	Uncertainty measurement and control in asset health production	MD	PhD	2010

Institution	Scholar	Research project	Program	Study mode	Expected completion year
QUT	ZHOU, Yifan	Assessing and predicting asset health condition using multi-scale techniques and the hidden Markov model	MD	PhD	2010
QUT	BEACH, Sandra	Do stakeholders influence the sustainability of network governance in public organisations, and how?	HD	PhD	2011
QUT	MILLS, David	Governance of major engineering assets to meet stewardship expectations	HD	PhD	2011
QUT	WIEWIORA, Anna	Strategic work design in the engineering environment	HD	PhD	2011
QUT	COWLED, Craig	An innovative approach to the incorporation of global and local sensors in structural health monitoring of bridges	ID	PhD	2012
QUT	KAPHLE, Manindra Raj	Development and use of acoustic emission (AE) sensors for global and local monitoring of bridge structures	ID	PhD	2012
QUT	LOWE, David	Intelligent diagnostics/prognostics system for rotating machine condition monitoring	ID	PhD	2012
QUT	WANG, Ruizi	Prognosis and decision making in considering future condition changes and maintenance intervention	ID	PhD	2012
QUT	WU, William	Optimising blind deconvolution technique for intelligent bearing fault diagnosis/prognosis	ID	PhD	2012
QUT	Fengfeng Li (Kevin)	Multi-criteria maintenance decision optimization for distributed pipeline assets	MD	PhD	2013
Uni of Newcastle	PANG, Kim-Sung	Pneumatic conveying pipeline management system for wear minimisation	ID	Masters	2010

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UniSA	MASAYNA, Veerawat	A framework for linking data quality efforts to organisational key performance indicators	SI	PhD	2011
UniSA	NASTASIE, Daniela	Integrated information framework for community infrastructure and asset management	SI	PhD	2010
UniSA	NATARAJAN, Kalaivany	Data quality mining techniques engineering asset manager	SI	PhD	2010
UniSA	VNOK, Lubos	Toward the development of tools for automating the metadata management process for asset management	SI	PhD	2012
UWA	FILLERY, Brent Pierson	An investigation of weight function methodologies for thermal shock stress intensity factor evaluation	ID	PhD	2010
UWA	GOUWS, Leonie	Maintenance management effectiveness	HD	PhD	2010
UWA	JING, Min	Transformer remnant life estimation	ID	Masters	2010
UWA	NAIR, Sule	Effects of computer based maintenance management systems on maintenance work identity	HD	PhD	2010
UWA	SALASI, Mobin	Synergistic effect of abrasion and corrosion on development of localised attack in gas lines	ID	PhD	2010
UWA	ZHU, Li	Develop deterioration models to support objective asset decisions	ID	Masters	2010
UWA	STEPHAN, Adrian	Understanding maintenance work practices on aging equipment	HD	PhD	2010
UWA	SIDDHPURA, Artiben	Development of a method for machine condition monitoring of equipment with stick-slip	ID	PhD	2012
UWA	SIDDHPURA, Milind	Health monitoring of precision machine tools using vibration analysis	ID	PhD	2012