Howard PARTNERS
Howard Partners Pty Ltd ACN 090 817 369

Digital Steel

Report of the Steel Industry Research Mapping Project - Attachments

Howard Partners, December 2012

ABSTRACT

This document contains attachments to the Main Report

Table of Contents

Attachment 1: Profile of the Australian Steel Industry

Output indicators

Information drawn from the World Steel Organisation *Statistical Yearbook 2011*, about the Australian Steel industry is reproduced in the following information for information

	Australia	Proportion of Production (Product)	World	Proportion of Production (Aus)
Total crude steel production	**7,296**	100.0%	**1,417,264**	**0.5%**
Ingots	52	0.7%	70,971	0.1%
Continuously cast steel	7,244	99.3%	1,341,273	0.5%
Liquid steel for castings	0	0.0%	3,825	0.0%
Hot Rolled products	**6,327**	**86.7%**	**1,381,218**	**0.5%**
. Hot rolled long products	1,927	26.4%	537,828	0.4%
. Hot rolled flat products	4,399	60.3%	703,399	0.6%
Railway track material	124	1.7%	9,361	1.3%
Heavy sections (>80mm)	0	0.0%	31,684	0.0%
Light sections (<80mm)	266	3.6%	52,526	0.5%
Concrete reinforcing bars	0	0.0%	164,910	0.0%
Hot rolled products (including concrete reinforcing bars)	828	11.3%	115,171	0.7%
Wire rod	709	9.7%	141,493	0.5%
Electrical sheet and strip	0	0.0%	9,879	0.0%
Tinmill products	0	0.0%	9,477	0.0%
Metal coated sheet and strip	1,575	21.6%	76,288	2.1%
Non metallic coated sheet and strip	0	0.0%	12,039	0.0%
Tubes and tube fittings	**251**	3.4%	**92,317**	0.3%
. Seamless tubes	0	0.0%	34,666	0.0%
. Welded tubes	251	3.4%	56,023	0.4%
Trade				
Exports of semi finished and finished steel products	1,659		386,839	0.4%
Imports of semi finished and finished steel products	2,597		377,759	0.7%
Exports of ingots and semis	18		60,619	0.0%
Imports of ingots and semis	53		57,084	0.1%
Exports of long products	79		87,778	0.1%
Imports of long products	856		59,696	1.4%
Exports of flat products	1,481		191,995	0.8%
Imports of flat products	993		156,774	0.6%
Exports of tubular products	40		38,087	0.1%
Imports of tubular products	693		25,849	2.7%
Steel Use				
Apparent steel use (crude steel equivalent)	7,323		1,385,779	0.5%
Apparent steel use (crude steel equivalent) per capita	340		220	
Apparent steel use (finished steel product)	6,612		1,293,538	0.5%
Apparent steel use (finished steel product) per capita	102		206	

Information about Australian steel producing companies, drawn form reports and other publicly available information is provided below.

Company profiles

BlueScope was spun out of the newly formed BHP Billiton in 2000 and listed as a public company in 2002. Since the public listing, BlueScope Steel has expanded further into Asia and North America. The BlueScope Business is summarised below.

The BlueScope Business

BlueScope Steel specialises in the production of flat steel products, including slab, hot rolled coil, cold rolled coil, plate and value-added metallic coated and painted steel solutions. The steelworks at Port Kembla is the largest steel production facility in Australia and one of the world's lowest-cost producers of steel products.

Within Australia, the BlueScope Lysaght business rollforms and supplies a range of steel building products, including roof and wall cladding, steel house framing, rainwater products such as guttering and downpipes, fencing, structural products such as purlins and flooring systems, meshes and walkways, and home improvement products. LYSAGHT® products are sold through distributors and suppliers Australia-wide.

BlueScope Steel operates the only integrated flat products steelworks in New Zealand. In North America, the Company is well known premium quality hot rolled coil from its 50% JV in North Star BlueScope Steel, Steelscape's range of high quality metallic coated and painted steels such as Z-NAL®, TruZinc® and SPECTRASCAPE® steels, Butler Manufacturing and VP Building's range of customised steel pre-engineered buildings for the non-residential market, including self storage warehouses as well as framing and cladding systems, ASC Profiles' range of innovative steel building components and Metl-Span's market leading range of insulated steel panels.

Metallic coating and painting plants are located in Australia, New Zealand, China, Thailand, Malaysia, Vietnam and Indonesia. These facilities are complemented by a network of roll-forming facilities across the Asia Pacific region that are unmatched by any other steel company.

The brands of BlueScope Steel are market leaders in Australia and New Zealand and have a strong presence in Asia. Brands include COLORBOND® steel (known as COLORSTEEL® in New Zealand), ZINCALUME® metallic coated steel, GALVABOND® and GALVASPAN® steel as well as the well-known LYSAGHT® brand.

In Asian markets, BlueScope Steel is continuing to develop branded products tailored to meet specific regional needs, such as Clean COLORBOND® steel which is resistant to tropical discolouration. Other successful brands include PrimaDesa™ steel in Malaysia, and TRUZINC™ galvanised steel in Thailand.

BlueScope Steel is widely recognised for fostering the development of innovative steel solutions through its own research and through strategic alliances with world-leading technical partners. It has led the industry with value-adding technologies such as metallic coating. Solid paint technology is another innovation currently being commercialised. The company is continuing to explore opportunities to break new ground in steel markets.

Over recent years BlueScope Steel has built manufacturing facilities in a number of Asian countries and these are now operating efficiently and growing rapidly in profitability. The company is looking to further develop these established businesses and take advantage of the significant potential for growth in countries such as China and Vietnam.

OneSteel was spun out from BHP in 2000 when it was almost entirely a domestically focussed steel manufacturer and distributor. The company has subsequently focussed on growing its resource based businesses and now has significant mining and mining consumables businesses, as well as its Steel & Recycling business. The company was renamed Arrium in 2012.

OneSteel's manufacturing business is profiled below.

OneSteel Manufacturing Business

Whyalla Steelworks: The Whyalla Steelworks is located in Whyalla, SA, 400km north–west of Adelaide. It is an integrated steelworks producing approximately 1.2 million tonnes of steel per annum using iron ore sourced from OneSteel's iron ore mines in the region.

Rod and Bar: The Rod and Bar sector produces a wide range of products and services for a diverse range of markets including the construction, rural, mining and manufacturing segments. Products include bar and rod for the reinforcing market, merchant bar, and rod feed for the wire industry.

These products are produced from facilities in Sydney, Newcastle and Laverton. The EAF and billet casting facilities at the Laverton and Sydney steel mills have a combined capacity of approximately 1.3 million tonnes per annum.

Wire: The Wire business consists of wire mills in Newcastle and Jindera, NSW and Geelong, VIC. The Wire business predominantly services the rural fencing markets through its Waratah and Cyclone brands, domestic reinforcing and manufacturing segments, as well as OneSteel's Mining Rope business.

Australian Tube Mills: The Australian Tube Mills (ATM) business manufactures structural pipe and tube from manufacturing facilities at Acacia Ridge, QLD, Newcastle, NSW and Somerton, VIC.

The ATM business also manufactures precision tube at manufacturing facilities in Sunshine, VIC and Kwinana in WA. Key market sectors for ATM products include construction, manufacturing and agriculture, while precision tube is supplied to the Australian manufacturing, automotive, fencing and home improvement segments.

LiteSteel Technologies: LiteSteel sells and markets LiteSteel beams primarily in Australia and the United States. LiteSteel beams are a unique cold formed, dual–welded range of steel sections geared to domestic and light commercial construction.

As well as a manufacturing site in Australia, there is also a manufacturing site based in Troutville, Virginia, where the key markets are residential and commercial construction.

OneSteel's Australian Distribution business serves the construction, manufacturing and resources markets with a diverse range of steel and metal products including structural steel sections, steel plate, angles, channels, flat sheet, reinforcing steel and coil in carbon and stainless, and a range of aluminium products, pipe fittings and valves.

The business distributes products sourced from OneSteel, as well as externally purchased products.

OneSteel Distribution

Metaland I Steel & Tube: The Metaland I Steel & Tube business processes and distributes a broad range of structural steel and related steel products and is the leading steel distribution business in Australia. It has 81 outlets, including Midalia in Western Australia, which are supported by an extensive dealer network. The business services mining projects and non-residential and engineering construction, fabrication, manufacturing and agricultural segments.

Reinforcing: Reinforcing steel is used for concrete reinforcement, mining strata control, agriculture and industrial mesh products and reinforcing steel fibres. It is supplied to large and small builders, concreters, form-workers, pre-casters and mining companies.

OneSteel's Reinforcing presence in the construction segments is represented by two separate and competing businesses. OneSteel Reinforcing offers the construction and mining segments, in particular, a solutions focused offer through its range of innovative reinforcing solutions. ARC (the Australian Reinforcing Company) has leading market positions in most segments complemented by strong customer relationships, flexible offers and a "can do" attitude.

Merchandising: The Merchandising portfolio comprises a range of businesses that process and distribute steel and other metal products in Australia. The businesses include OneSteel Sheet and Coil, OneSteel Aluminium, OneSteel Coil Coaters, Building Services, OneSteel Stainless, Fagersta and OneSteel Piping Systems.

Merchandising consists of approximately 30 sites that source metal and related products from a range of domestic and overseas manufacturers. Merchandising also operates Oil & Gas, Fabricated Services and distributes products, primarily to manufacturing and fluid conveyancing segments through its wide portfolio of businesses

Onesteel's vision is to be a leading mining and materials company through a portfolio of mining and materials businesses that are diversified across commodities, geographies and markets. It aims to utilise its unique customer relationships and market positions, capabilities and infrastructure, and investing in opportunities which provide the best return on shareholder funds.

There are several other large steel producers and distributors including Orrcan Steel, a wholly owned subsidiary of Hills Holdings Limited (steel tube and pipe), Southern Steel and Bisalloy Steels. Bisalloy Steels is Australia's only manufacturer of high-tensile and abrasion-resistant quenched and tempered steel plate under the brand name of "Bisplate". The company supplies manufacturers and end-users in a vast array of industries including mining, construction, general fabrication, pressure vessel and defence.

Major steel distributors who import overseas product for the Australian market are listed below.

International Steel Distributors

- Adsteel Brokers
- Amity Pacific Pty Ltd
- Castle International Trading Pty Ltd
- Citi-Steel Pty Ltd
- CMC (Australia) Pty Limited
- Croft Steel Pty Ltd
- Ferropacific Pty Ltd
- G S Global Australia Pty Ltd
- JFE Shoji Trade Australia Pty Ltd
- Marubeni-Itochu Steel Oceania Pty Ltd (MISO)
- Minmetals Australia Pty Ltd
- Mitsui & Co Australia Ltd
- New Zealand Steel (Aust) P/L
- Sanwa Pty Ltd
- Steelforce Aust Pty Ltd
- Stemcor Australia Pty Ltd
- Sumikin Bussan Oceania Pty Ltd
- Tata Steel International
- ThyssenKrupp Mannex Pty Ltd
- Tokyo Boeki (Aust) Pty Ltd
- Toyota Tsusho (Australasia) Pty Ltd
- Wright Steel Sales Pty Ltd

Source: Australian Steel Association

Many distributors are subsidiaries of global steel producers. The volume and categories of steel imported is difficult to ascertain.

Attachment 2: Fields of Research (FORs) Relevant to Steel Fabrication

Code	Field of Research	Research relevant to Steel Fabrication
303	Macromolecular and materials chemistry	Chemical Characterization of Materials Nano chemistry and Supra molecular Chemistry Optical Properties of Materials Physical Chemistry of Materials Polymerisation Mechanisms Synthesis of Materials Theory and Design of Materials Macromolecular and Materials Chemistry not elsewhere classified
`	Artificial intelligence and image 9iiprocessing	Technologies supplementing or supporting information systems or presentation, such as computer graphics, natural language processing, pattern recognition and data mining, virtual and artificial realities and related simulation. Specifically • Agents and Intelligent Robotics • Artificial Life • Computer Graphics • Computer Vision • Expert Systems • Image Processing • Natural Language Processing • Neural, Evolutionary and Fuzzy Computation • Pattern Recognition and Data Mining • Simulation and Modeling • Virtual Reality and Related Simulation Note: Mechatronics for automotive engineering are included in Group 0902 Automotive Engineering; Signal processing and non-manufacturing robotics are included in Group 0906 Electrical and Electronic Engineering; Geospatial information systems are included in Group 0909 Geomatic Engineering; Manufacturing robotics, mechatronics (excluding automotive applications) and CAD/CAM systems are included in Group 0910 Manufacturing Engineering.
803	Computer Software	Technologies related to computer software, software programming, computer languages and software operating systems. This group has ten fields: • Bioinformatics Software • Computer System Architecture • Computer System Security • Concurrent Programming • Multimedia Programming • Open Software • Operating Systems • Programming Languages • Software Engineering Only UNSW was assessed in this category – rating of 4.
806	Information Systems	Covers • computer and information systems organisation, design and management; • interfaces and presentation, including computer-human interaction, and the application of psychology to computer-human interfaces; • web services other than web search; • traditional information and knowledge systems; and • systems theory and conceptual modelling.
904	Chemical engineering	Catalytic Process Engineering Chemical Engineering Design Membrane and Separation Technologies Non-automotive Combustion and Fuel Engineering (incl. Alternative/Renewable Fuels) Powder and Particle Technology Process Control and Simulation
905	Civil engineering	Structural engineering Transport engineering (other than aerospace, automotive and maritime engineering) Water and sanitary engineering Construction engineering.
906	Electrical and Electronic engineering	Circuits and Systems Control Systems, Robotics and Automation Industrial Electronics Microelectronics and Integrated Circuits Photodetectors, Optical Sensors and Solar Cells Photonics and Electro-Optical Engineering (excl. Communications) Power and Energy Systems Engineering (excl. Renewable Power) Renewable Power and Energy Systems Engineering (excl. Solar Cells) Signal Processing
910	Manufacturing engineering	Manufacturing robotics and mechatronics, other than their automotive applications; Flexible manufacturing systems Computer-aided design and computer-aided manufacture, also known as CAD/CAM Precision engineering Packaging, storage and transportation
912	Materials engineering	Ceramics science and ceramics engineering Polymer and textiles engineering Composite and hybrid materials Physical metallurgy and alloy materials Functional materials Semiconductor engineering

Code	Field of Research	Research relevant to Steel Fabrication
913	Mechanical engineering	Acoustics, noise and vibration control; Mechanical aspects of automation and control engineering; Dynamics, Vibration and Vibration Control Energy Generation, Conversion and Storage Engineering Microelectromechanical Systems (MEMS) Numerical Modelling and Mechanical Characterisation Tribology (study of interacting moving surfaces) Energy generation, conversion and storage.
914	Resources engineering and extractive metallurgy	Mining engineering Mineral processing Petroleum and reservoir engineering Geomechanics and geotechnical engineering associated with mining and mineral extraction.
1007	Nanotechnology	Molecular and Organic Electronics Nanoelectromechanical Systems Nanofabrication, Growth and Self Assembly Nanomanufacturing Nanomaterials Nanometrology Nanophotonics Nanoscale Characterisation
1201	Architecture	Architectural Design Architectural Heritage and Conservation Architectural History and Theory Architectural Science and Technology (incl. Acoustics, Lighting, Structure and Ecologically Sustainable Design) Architecture Management Interior Design
1202	Building	Building Construction Management and Project Planning Building Science and Techniques Quantity Surveying Building not elsewhere classified
1203	Design practice and management	Design history and theory; Ergonomics; industrial design; Digital and interaction design; Textile and fashion design; and Visual communication and graphics design.
1204	Engineering design	Engineering Design Empirical Studies Engineering Design Knowledge Engineering Design Methods Engineering Systems Design Models of Engineering Design

Attachment 3: Australian Research Council Grants for steel related research projects

The Australian Research Council does not provide a key word search capability on its website that can provide information about the topic, purpose, researcher involvement in successful grant applications. This information can be gleaned only by searches of each announcement of grants awards. This lack of functionality is in contrast to searchable databases in the United States and Canada.

Grants information can provide rich information about research that is being funded and undertaken across the university sector. Sample data for obtained for 2012 announcements and other searches is provided below.

Discovery awards for funding in 2012

Hybrid stainless-carbon steel composite beam-column joints at ambient and elevated temperatures

Total Funding: $430,000.00
Investigators: Tao, A/Prof Zhong; Han, Prof Lin-Hai
Primary FoR: 0905 CIVIL ENGINEERING
Administering Organisation: University of Western Sydney
Project Summary: This project will consider the behaviour of hybrid stainless-carbon steel composite beam-column joints at ambient and elevated temperatures. By incorporating into potential design codes, the results can promote the application of stainless steel in structures, thereby increasing Australia's maintenance capability of structures.

The behaviour and design of composite columns coupling the benefits of high strength steel and high strength concrete for large scale infrastructure

Investigators: Prof Brian; Tao, A/Prof Zhong; Mashiri, Dr Fidelis R; Liew, Prof Richard J; Han, Prof Lin-Hai
Approved Project Title:
Total Funding: $400,000.00
Primary FoR: 0905 CIVIL ENGINEERING
Administering Organisation: University of Western Sydney
Project Summary: This project will involve the development of a novel structural column system which will be more efficient, robust and require less maintenance than current systems. The outcomes will involve improved design methodologies which will enable large scale infrastructure to be enhanced and will involve the use of materials which improve sustainability.

Durability of carbon fibre reinforced polymer (CFRP) strengthened steel structures against environment-assisted degradation

Investigators: Zhao, Prof Xiao-Ling; Singh, Prof Raman; Bai, Dr Yu; Bandyopadhyay, A/Prof Sri; Rizkalla, Prof Sami H
Total Funding: $380,000.00
Primary FoR: 0905 CIVIL ENGINEERING
Administering Organisation: Monash University
Project Summary: This research project will challenge conventional methods of repairing or strengthening steel structures by using carbon fibre reinforced polymer with advanced epoxy. The outcome of this research is to remove the biggest barrier to the full utilization of such advanced material in civil, offshore and mining industry.

A study of pull-through failures of thin steel battens to improve building safety and resilience during extreme wind events

Investigators: Mahendran, Prof Mahen; Poologanthan, Dr Keerthan

Total Funding: $320,000.00
Primary FoR: 0905 CIVIL ENGINEERING
Administering Organisation: Queensland University of Technology
Project Summary: This project will develop innovative light gauge steel roofing systems with considerably increased wind resistance and reliable design rules for cold-formed steel codes worldwide. It will contribute to the Australian government's goal of increasing building resilience against future extreme and more frequent wind events caused by climate change.

Linkage 2011 awards for funding in July 2012

Reducing the environmental impact of steel making through direct strip casting

Investigators: Ferry, Prof Michael ; Stanford, Dr Nicole ; Hodgson, Prof Peter D; Laws, Dr Kevin J; Quadir, Dr Md Z; Fang, Dr Yuan
Total Funding: $210,000.00
Primary FoR : 0912 MATERIALS ENGINEERING
Partner Organisation(s) Baoshan Iron and Steel Co Ltd
Administering Organisation: The University of New South Wales
Project Summary: This project will investigate direct strip casting of steel, a technology that reduces the environmental footprint of liquid steel processing by up to 90 per cent. With the industry partner Baosteel, the project hopes to expand the application of this process to more steel grades and to also assess possible new steel grades with improved properties.

Recycling lignocellulosic agricultural waste as an iron oxide reductant in ferrous processing

Investigators: Sahajwalla, Prof Veena
Total Funding: $285,000.00
Primary FoR;
Partner Organisation(s): Microbiogen Pty Ltd, OneSteel Sydney Steel Mill
Administering Organisation: The University of New South Wales
Project Summary: This project seeks to recycle agricultural waste as a renewable carbon resource to replace coal-based metallurgical coke as a raw material in ferrous processing. This approach will lead to an innovative recycling of this waste, wherein nothing is wasted and maximum value is extracted from agricultural materials.

Long-span cold-formed steel portal frames

Investigators: Rasmussen, Prof Kim J; Zhang, Dr Hao ; Filonov, Mr Alexander ; Mysore, Mrs Kavitha ; Sharma, Mr Sandeep
Total Funding: $135,000.00
Primary FoR 0905 CIVIL ENGINEERING
Partner Organisation(s) BlueScope Lysaght
Administering Organisation: The University of Sydney
Project Summary: Novel solutions will be developed for building portal frames in cold-formed steel at effectively twice the span currently available. Economies are derived from using cold-formed steel, which will benefit the end consumer and help the Australian steel industry to maintain its position as preeminent provider of innovative cold-formed steel solutions.

New generation high efficiency thermoelectric materials and modules for waste heat recovery

Investigators: Dou, Prof Shi Xue ; Li, A/Prof Sean S; Li, Dr Wenxian ; Zhang, Prof Chao ; Aminorroaya-Yamini, Dr Sima

Total funding: $400,000.00
Primary FoR: 0912 MATERIALS ENGINEERING
Funded Participants: APDI Dr Wenxian Li
Partner Organisation(s) Baosteel Company
Administering Organisation: University of Wollongong
Project Summary: The development of thermoelectric materials and devices, and their subsequent uptake by the steel industry, will bring tremendous socio-economic benefits in terms of decreased operational costs, a

significantly reduced carbon footprint and will set an excellent example for other industries on how to comply with strict environmental regulations.

Bearing capacities of innovative LiteSteel beams and their floor systems

Investigators: Mahendran, Prof Mahen
Total Funding: $195,000.00
Primary FoR: 0905 CIVIL ENGINEERING
Partner Organisation(s): LiteSteel Technologies Pty Ltd
Administering Organisation: Queensland University of Technology
Project Summary: This project will develop accurate bearing capacity design models for the new LiteSteel beams (LSB) to enable innovative and safe applications of LSBs in various flooring systems in buildings. Improved LSB floor systems will also be developed. This will enable expansion of the worldwide market for LSB products and systems by the industry partner.

Linkage 2011 awards for funding in January 2012

Seismic behaviour of drive-in steel storage racks

Investigators: Rasmussen, Prof Kim J; Zhang, Dr Hao; Clarke, Dr Murray J; Yang, Dr Demao; Berry, Dr Paul A
Total Funding: $202,489.00
Primary FoR: 0905 CIVIL ENGINEERING
Partner Organisation(s): Dematic Pty Ltd
Administering Organisation: The University of Sydney
Project Summary:
The purpose of this project is to study the behaviour, analysis and design of drive-in steel storage racks in an earthquake event. The main research outcome is the development of scientifically-based guidelines for the safe design of drive-in racks in seismic regions.

Flexible roll forming of advanced high strength steel sheet

Investigators: Hodgson, Prof Peter D; Barnett, Prof Matthew R; Rolfe, Dr Bernard F; Yang, Dr Chunhui
Total Funding: $270,000.00
Primary FoR: 0913 MECHANICAL ENGINEERING
Partner Organisation(s); Australian Rollforming Manufacturers Pty Ltd, Blue Scope Steel Limited, Research and Development Centre of Wuhan, Iron & Steel (Group) Corporation, data M Sheet Metal Solutions
Administering Organisation: Deakin University
Project Summary: This project will develop light weight automotive components to assist fuel economy and crash worthiness through flexible roll forming. This process has the potential to form complex shapes from very high strength steels in a very cost effective and efficient small scale operation, highly suited to Australian manufacturing.

Other ARC Grants identified through Web search

Establishing In-Depth Understanding of Molecular Degradation Processes in Acrylic Based Polymer Coil-Coatings for Domestic Roofing Applications

Investigators: Prof C Barner-Kowollik; Dr PJ Barker
Funding:
2008 : $ 30,000
2009 : $ 43,500
2010 : $ 31,000
2011 : $ 17,500
Primary RFCD: 2505 MACROMOLECULAR CHEMISTRY
Collaborating/Partner Organisation(s): BlueScope Steel Research
Administering Organisation: The University of New South Wales
Project Summary: The national benefit is multipronged: (i) BlueScope Steel will maintain its technology leadership through continued innovation by taking advantage of the scientific insights that the project delivers for the introduction of next generation long lasting coil coatings for steel, based on an environmentally friendly production processes. (ii) The application of mass spectrometry for the analysis of polymer degradation has been pioneered by the CI and BlueScope Steel. The project will demonstrate the power of this technique and

secure Australia's place at the forefront of molecular polymer degradation research. (iii) The project has a strong educational component, training a PhD student at the interface of application and fundamental research.

Advanced Testing and Structural Analysis for Assessment and Control of Hydrogen Damage in Structural Steels

Investigators: Prof E Pereloma; Dr A Calka; Prof DP Dunne; Dr FJ Barbaro
Funding:
2008 : $ 80,000
2009 : $ 180,000
2010 : $ 160,000
2011 : $ 134,500
2012 : $ 74,500
Primary RFCD 2913 METALLURGY
Collaborating/Partner Organisation(s): BlueScope Steel Limited
Administering Organisation: University of Wollongong
Project Summary: Hydrogen offers the potential for reducing emissions in transport and energy generation industries as it is a low emission energy carrier. However, there remain questions in relation to the effects of hydrogen gas on the structural integrity of large structural steel components, such as gas distribution pipelines. The project aims to provide guidance on the safe use of hydrogen in high pressure vessels manufactured from low alloy ferritic steels.
This project will increase confidence in relevant safety codes and standards, consequently increasing the likelihood of large scale uptake of hydrogen energy technologies.

Strength of two-way steel fibre reinforced composite flooring systems

Investigators: Prof MA Bradford; Prof RI Gilbert; Prof SJ Foster; Mr A Filonov; Mr R Ratcliffe
Funding:
2009 : $ 30,000
2010 : $ 60,000
2011 : $ 30,000
Primary RFCD: 2908 CIVIL ENGINEERING
Collaborating/Partner Organisation(s): BlueScope Lysaght, BOSFA
Administering Organisation: The University of New South Wales
Project Summary: The construction industry in Australia is introducing efficient and economical long-span profiled steel sheeting for composite flooring systems, and Steel Fibre Reinforced Concrete (SFRC) applications are becoming widespread.
Australia is a recognised world leader in the research of both composite structures and SFRC. Using SFRC in composite decks to eliminate conventional reinforcement is very efficient and cost-effective, but surprisingly little relevant research aimed at the Australian industry has been reported. Comprehensive design guidance is much needed to advance this technology. This project will give designers confidence and expertise to advance these technologies, while maintaining Australian research and practice in composite structures at the forefront.

Time-dependent in-service behaviour of composite concrete slabs with profiled steel decking

Investigators: Prof RI Gilbert; Prof MA Bradford; Mrs R Zeuner; Mr GR Brock
Funding:
2009 : $ 45,000
2010 : $ 89,000
2011 : $ 82,500
2012 : $ 38,500
Primary RFCD: 2908 CIVIL ENGINEERING
Collaborating/Partner Organisation(s): Fielders Australia Pty Ltd; Prestressed Concrete Design Consultants Pty Ltd
Administering Organisation: The University of New South Wales
Project Summary: At present, the in-service behaviour of composite floor slabs is incompletely understood, and structural designers have no reliable means to assess the effects on structural behaviour of shrinkage warping, time-dependent cracking, temperature gradients and the influence of prestress on bond-slip at the concrete-deck interface. This project will, through laboratory testing and theoretical analysis, provide the necessary data to develop and calibrate models to simulate structural behaviour and provide rational guidance for design engineers. The project will result in more serviceable and more economical composite floor slabs in Australian buildings, thereby reducing the costs of construction, maintenance and repair.

Attachment 4: Summary of capability in universities and research organisations relating to steel fabrication.

The following material has been drawn from publicly available sources. It has not been validated with the organisations concerned. Additional work is required to bring the material into a consistent format. However, it serves as a base for further development of the research and innovation capability map.

Curtin University

- ***The Corrosion Centre for Education Research and Technology (Corr-CERT***

The Corrosion Centre for Education Research and Technology (Corr-CERT) has been conducting high quality research and providing expert consultancy services to oil and gas industry for more than two decades. The centre's services are diverse and catch the attention of many Australian and foreign companies. The industry will focus on practical problems and continue to encourage research to find out optimal solutions. With this broader perspective in mind, Corr-CERT keeps on exploring opportunities of working with industrial partners on challenging research assignments. It has developed joint projects in collaboration with some of the leading companies like Chevron Australia Pty Ltd and Woodside Energy Ltd.

The generous sponsorship from Chevron and Woodside has established the Chevron-Woodside Chair in Corr-CERT. This has helped the centre to grow multi folds and develop new projects. The centre also provides in-house training to sponsors and to augment research activities, very soon, the Corr-CERT will be relocated to 'Technology Park'. With help from the sponsors, the centre is also seeking to expand industrial collaboration with major oil and gas producers and their suppliers.

The centre has dedicated staff and its research laboratory is well equipped with modern equipment to provide high quality customer service. The laboratory conducts testing as per ASTM, ISO, Australian and NACE standards. At present, Corr-CERT is located at building 500, Resources and Chemistry Precinct.

The Corr-CERT has developed close ties with some of the leading national and international associations. It is a member of the ACA technical group steering committee of petroleum and chemical process industries and also a corporate member of ACA and NACE International.

The Corrosion Centre for Education Research and Technology (Corr-CERT) has been conducting high quality research and providing expert consultancy services to oil and gas industry for more than two decades. The centre's services are diverse and catch the attention of many Australian and foreign companies. The industry will focus on practical problems and continue to encourage research to find out optimal solutions. With this broader perspective in mind, Corr-CERT keeps on exploring opportunities of working with industrial partners on challenging research assignments. It has developed joint projects in collaboration with some of the leading companies like Chevron Australia Pty Ltd and Woodside Energy Ltd.

The generous sponsorship from Chevron and Woodside has established the Chevron-Woodside Chair in Corr-CERT. This has helped the centre to grow multi folds and develop new projects. The centre also provides in-house training to sponsors and to augment research activities, very soon, the Corr-CERT will be relocated to 'Technology Park'. With help from the sponsors, the centre is also seeking to expand industrial collaboration with major oil and gas producers and their suppliers.

The centre has dedicated staff and its research laboratory is well equipped with modern equipment to provide high quality customer service. The laboratory conducts testing as per ASTM, ISO, Australian and NACE standards. At present, Corr-CERT is located at building 500, Resources and Chemistry Precinct.

The Corr-CERT has developed close ties with some of the leading national and international associations. It is a member of the ACA technical group steering committee of petroleum and chemical process industries and also a corporate member of ACA and NACE International.

Contact
Prof. Rolf Gubner
Chevron-Woodside Chair in Corrosion Engineering Director,
Corrosion Centre for Education Research and Technology (Corr-CERT)
School of Chemical and Petroleum Engineering
Curtin University Bentley, Western Australia 6102
Phone: +61 8 9266 7272 Fax: +61 8 9266 2300 Email: R.Gubner@curtin.edu.au
Mr. Sarang Behere
Centre Manager, Corrosion Centre for Education Research and Technology (Corr-CERT)
School of Chemical and Petroleum Engineering Curtin University Bentley, Western Australia 6102
Phone: +61 8 9266 9684 Fax: +61 8 9266 2300 Email: Sarang.Behere@curtin.edu.au

Deakin University

- ***Research Institute for Frontier Materials***

Society is facing major challenges that are increasingly requiring step changes in materials design and performance. At the same time the impact of the production of new materials and issues such as recycling are also becoming more important. So we now face an exciting new frontier in the development of materials to meet key challenges facing us into the future.

As a response to this the materials research at Deakin University is embracing a new structure that will allow it to tackle more complex problems of national and international importance, in the areas of energy, health, environment, as well as manufacturing. Our aim is to develop new materials and structures that are not only affordable, but also have a low societal cost of manufacture, usage and recycling.

The Institute for Frontier Materials has the ability to process and characterise materials across all scale lengths, from the atomistic level in the manipulation of interfaces and surfaces through to entire structures. It will also bring together engineering, chemistry, materials science, physics, biology, mathematics and other disciplines to inform the development of these new material discoveries and engineering solutions.

- ***Advanced High Strength Steels for the Automotive Industry***

This is a very broad research program that considers both the steel industry as well as the automotive industry aspects. Current topics include:

- Formability of dual phase, TRIP and other steels, including the fracture behaviour, FLD construction, finite element modelling of the forming strains and springback and advanced microstructure-FEA models examining strain partitioning.
- Fatigue behaviour of TRIP and DP steels using our strain controlled 30Hz fatigue tester that can do both tension and compression cycles. This has included examining the effect of prestrain and an understanding of the evolution of the dislocation substructure.
- Crash Behaviour of AHSS. This work has led to the development of improved models to represent the constitutive behaviour of a wide range of steels under crash conditions. We will be extending this work later this year when the 25m/s tensile frame is commissioned. The objective is to develop a microstructure based constitutive model.
- Bake Hardening of AHSS. The bake hardening response of these steels is very variable and we have been looking at why this is the case for TRIP and DP steels. By using atom probe tomography (APT) we have been able to link the level of solute C in the ferrite and the nature of the dislocation structure to the bake hardening response.
- Thermomechanically produced TRIP steels. This is an ongoing project to understand the microstructure evolution and the alloy partitioning and TRIP effect. Again we have recently used APT to examine the details of alloy partitioning.

- ***Ultrafine Grained and Nanostructured Steels***

Our work on the ultrafine grained steels through strain induced transformation is widely known. We still maintain a small program on this, largely in collaboration with NIMS in Japan. Our real focus at present is to understand the fundamentals better and in particular the deformation structure evolution in the austenite prior to or during the transformation.

We are considering a range of in-situ techniques for this at present. We have also a program related to the new nanostructured bainites developed by Bhadeshia and co-workers. We have produced a range of structures and are considering their dynamic properties as well as undertaking detailed microstructural characterization including APT. Another project is considering the strength ductility balance of ultrafine structured steels produced by a range of methods. This is linked to a more general program on nanostructured metals.

- ***Deformation***

We have had a number of projects examining the deformation and dynamic and post deformation softening behaviour of steels. This has largely involved advanced use of our EBSD equipment to identify the key features of the microstructure evolution.

We have also examined a range of model alloys and recently commenced new work related to strain induced precipitation in Nb microalloyed steels, particularly under multi-pass and strip mill conditions - areas that have not received much attention to date. We are also interested in the potential loss of Nb for latter precipitation strengthening in the production of thick plate.

- ***Texture Development***

Most of this work has previously been related to warm rolling. However, with our new thrust into strip casting this research will consider a much broader range of conditions and microstructures.

- ***Phase Transformations***

This is largely linked to the TMCP of AHSS and will in the future focus on the potential to develop advanced steels through the strip casting or other near net shaped casting and TMCP routes. We are extending the TMCP TRIP steel work to consider other much higher strength microstructures. Also once we have the ability to make our own melts we will be pursuing other ideas related to standard TRIP compositions.

Another thrust for this year will be TWIP steels and in particular designing the compositions for the balance between forming and crash conditions. We would also be interested in pursuing research related to the transformation of more basic TMCP plate and strip steels and using new modelling techniques combined with our excellent experimental capabilities.

Griffith University

- ***Centre for Infrastructure Engineering and Management***

The Centre for Infrastructure Engineering and Management aims to optimise the life cycle performance of civil infrastructure systems through product innovation and process integration. The primary aim of the Centre is to capitalise on the collective expertise of a highly qualified group of engineers so as to provide practical solutions and answers to the diverse challenges associated with the creation and operation of civil infrastructure systems such as:

- buildings
- roads
- bridges
- marine facilities

The Centre has two Research Programs: Infrastructure Engineering and Infrastructure Management. The Infrastructure Engineering program focuses on the technical aspects of infrastructure systems, whereas the Infrastructure Management program focuses attention on the more managerial and strategic issues concerning the operation of such systems. Both programs are strongly inter-related with a number of apparent and critical synergies existing between them.

Research focus has the following three major objectives:

- improved engineering design methods;
- advanced construction techniques and technologies; and
- enhanced decision-making managerial processes.

The structural engineering group has expertise in the design and analysis of reinforced and pre-stressed concrete and steel structures. Serviceability and strength of concrete structures has been the main focus of the group's research.

James Cook University

- ***Civil and Environmental Engineering Discipline***

Research activities in structural engineering are analytical, numerical and experimental in nature and are directed at investigations into:

- Rehabilitation and retrofitting of timber, steel and concrete structural members using advanced composite jacketing techniques
- Strength of concrete-filled steel tubular beams and columns
- Bending, buckling and dynamic behaviour of fibre-reinforced composite plates
- Non-destructive characterization of flaws in composite structures
- Time-invariant and time-variant reliability analysis of structural elements and systems
- Reliability assessment of existing structures subject to deterioration
- Analysis and assessment of concrete bridges
- Soil-pile/structure interaction
- Computer modelling of structural behaviour of houses

The structural engineering research group has access to latest microcomputers and high performance central computing facilities of JCU. Experimental and testing work is carried out in well-established and well equipped structural, concrete and material testing laboratories.

Structures Laboratory

The structures laboratory is designed to provide facilities for testing structural components and assemblies under applied load. One of the main features of the laboratory is the reaction floor consisting of a 1.2m thick prestressed concrete slab to which the testing rigs can be attached. The floor is designed to allow structural assemblies ranging in size up to 25m prestressed concrete bridge girders to be tested to failure.

The laboratory is equipped with an assortment of manual and servo-controlled jacks ranging in capacity up to 1000 tonnes, together with associated measuring devices such as load cells and deflection gauges, and loading frames. During the recent years, the major emphasis in the laboratory has been on structural testing in relation to resistance to cyclonic wind loads for which a number of special purpose testing rigs have been developed.

Materials Testing Laboratory

The materials testing laboratory houses the major items of equipment used for determining the mechanical properties of building materials - concrete, steel, aluminium, timber, composite materials, etc. The laboratory occupies a floor area of 130 m2 and is located adjacent to the structures laboratory. The major items of equipment include :

- M.T.S. universal servo-controlled testing machine - 1 MN capacity
- Avery universal testing machine - 500 kN capacity, 5 ranges
- Avery compression testing machine - 1800 kN capacity, 3 ranges
- Avery universal impact tester - 300 J capacity, 2 ranges
- Izod impact tester - 120 lbf/ft capacity
- Instron universal servo-controlled testing machine - 100 kN capacity
- Instron testing machine - 10 kN capacity

Cyclone Testing Station

The Cyclone Testing Station (CTS) is the pre-eminent independent authority on the performance of buildings in severe wind events. It works with other industry groups to assess the vulnerability of houses in cyclonic and non-cyclonic parts of Australia. Existing houses and houses under construction have been surveyed. Full-scale houses and components have been tested and analysed.

Using wind tunnel tests based on scale models and full scale wind load data, vulnerability models that estimate damage to a range of house types are being produced. These models incorporate engineering theory and reliability analysis of housing performance. They are validated from post windstorm damage investigations.

The outcomes from these studies are being expanded to align with the work at the National Climate Change Adaptation Research Facility.

Macquarie University

- ***OptoFab***

OptoFab is one of the 8 nationwide nodes that form ANFF which provides researchers and industry with access to state-of-the-art fabrication facilities across Australia.

OptoFab consists of four centres of facilities and expertise based at Macquarie University, Bandwidth Foundry International, University of Sydney and the University of Adelaide with the headquarters at Macquarie University.

The list below represents the key facilities offered by the node.

- Nanosecond laser microfabrication facility
- Femtosecond laser microfabrication facility (on a limited basis)
- Full characterisation suite
- Functionalised nanoparticle fab system (Diamond CVD)
- Glass Fibre Surface Functionalisation

Monash University

- ***Department of Materials Engineering***

The ability to understand and manipulate materials and their properties is a key factor in any industrial process or technology, new or old. Increasingly nanotechnology, sustainable materials and biomaterials are becoming important areas of our endeavour.

Because of the enabling aspect of Materials Engineering, and the multidisciplinary nature of the skills learned, our graduates are much in demand in many industrial organisations. Many also go into research, be it in academia, industrial laboratories or government research organisations

Materials Engineering has an active well-funded research program with extensive, modern facilities, and a large number of postgraduates and research fellows. The projects range from fundamental topics to many which involve collaboration and funding from industry and government.

Our areas of research strength include:

- nanomaterials, nanoparticulates and nanocomposites,
- solar energy and photovoltaic materials,
- biomaterials, tissue engineering,
- functional materials (magnetic and electronic) and devices,
- metals and alloys (particularly light alloys),
- diffraction studies,
- polymer science and engineering,
- ceramic engineering,
- corrosion,
- fracture of materials,
- production and properties of composites,

- mechanical properties,
- mathematical and computer modelling of materials and processes.

Underpinning all of these strengths is a wide range of techniques to probe material structures at all size scales.

- ***Research Facilities***

The Department has wide range of excellent facilities itself and access to an even wider variety of sophisticated research facilities, including an Atom Probe Field Ion Microscope and some of the worlds most advanced electron microscope facilities at its Monash Centre for Electron Microscopy.

The Australian Synchrotron is 10 minutes walk away across the road from Monash, and access to major synchrotron facilities in Japan, the US and Europe is also facilitated via the Australian Synchrotron Research Program. Academics also use the OPAL Nuclear Reactor at Lucas Heights in New South Wales.

The Melbourne Centre for Nanofabrication is located near to Monash University (next door to the synchrotron) and is providing scientists with the tools to build miniature devices and have a range of high end characterisation tools (including e-beam, various lithographies, CVD systems etc.)

Research capabilities include:

- Advanced Polymer Science and Engineering
- Biomaterials and Tissue Engineering
- Electronic and Magnetic Materials
- Engineering Alloys
- Advanced Light Alloys
- Thermomechanical Processing
- Corrosion
- Materials Characterisation
- Modelling and Simulation of Materials and Processes
- Structural and Functional Ceramics
- Solar Cells

Queensland University of Technology

- ***Institute for Future Environments – a focus for science and engineering***

QUT is developing a new $230 million Science and Engineering Centre and Community Hub on its Gardens Point campus, which is due for completion in 2012.

The Institute for Future Environments (IFE), located in the new Science and Engineering Centre at QUT Gardens Point and a number of distributed sites, will play a key role in delivering the key Blueprint3 priority - “to build QUT’s reputation as a selectively intensive research university”.

The Institute will deliver interdisciplinary collaborative research at scale with focus. The Institute is dedicated to transformation and improvement of interdisciplinary research performance in the fields of Science, Technology, Engineering and Mathematics. The establishment of IFE coincides with a major capital investment in physical infrastructure in the new Science and Engineering Centre (SEC). The Centre will house the Institute, complex analytical research facilities, new teaching and learning spaces, and community facilities.

QUT’s aim is to establish an internationally significant hub for the integration of science, technology, engineering, and mathematics disciplines.

RMIT University

- ***The School of Aerospace, Mechanical and Manufacturing Engineering***

The School is recognised by industry and general community for its work-relevant education programs, supreme research facilities, creative real-world project work and robust relations with local and international industry leaders.

The School has achieved significant successes in advanced design and manufacturing across different application areas and industry sectors. Capabilities include:

- sophisticated design of high performance racing cars including alternative racing technologies (solar, hydrogen, electric)
- bold steps and impressive progression in energy conservation and renewable energy technologies
- collaboration with the US on designing and building a military fighter jet engine
- leading in virtual engineering technologies capable of simulating complex systems and processes
- developing novel automotive technologies in collaboration with leading vehicle manufacturers and suppliers in Australia and overseas
- advancing the capabilities of heavy-lift helicopter with a design that enables it to lift battle tanks for the Australian Defence Force
- innovation in sports engineering resulting in cutting-edge sports technologies for able-bodied and disabled athletes

The School has developed extensive and advanced research facilities to support its research efforts. Research facilities, located at RMIT's Bundoora East and City campuses, include:

- Advanced Manufacturing Laboratories
- Aerodynamics Laboratories
- Automotive Laboratories
- CAD / CFD/ CAE Engineering Laboratory
- Composite and Polymer Laboratory
- Dynamics Laboratories
- Material Testing Laboratory
- Measurements Laboratory
- Mechatronics Laboratory
- Rapid Prototyping Facility
- Thermodynamics and Renewable Energy Laboratories

- ***The Material and Manufacturing Processes Group (MMPG)***

MMPG is currently represented by four academic staff and ten postgraduate students. At the hub of the research activities of the MMPG are the laboratories for Materials, Manufacturing Processes, Metrology and Laser-based Measurement, Polymer processing and access to the workshop and latest computer software.

Major research areas

- Metal sheet forming
- Multi-diameter drilling performance
- Application of low power laser in manufacturing industry
- EDM performance
- Composite and smart material properties
- Polymer processing and testing
- Stress analysis of engineering products
- Design and application of expert system in manufacturing technology
- Flexible Manufacturing System (FMS)
- Services available to industry

Some of the areas in which the MMPG is able to assist Manufacturing-based companies are:

- Scrap reduction or materials failures during manufacturing
- Improving surface quality of a products in process
- Monitoring and in-process measurement by laser with customised software capability
- Independent feasibility study for manufacturing industry
- Training and providing short courses to all level of staff either on site or at RMIT Faculty of Engineering
- Destructive and non-destructive product testing and evaluation

- ***Materials modelling and simulation***

MMS aims to develop fundamental relationships between the atomic structure and properties of molecules and bulk materials as well as their surfaces and interfaces, so that advanced materials with enhanced and new properties can be designed.

Current applications include projects in both life and material sciences. Our projects involve simulations of industrial materials, such as metals, minerals, organic coatings, carbonaceous and nanomaterials, as well as biological materials, such as peptides, proteins and biological membranes. We are also interested in modelling interactions of engineered nanoparticles with biological environment which is relevant to new technologies for drug delivery, tissue engineering, biosensors as well as nanosafety and nanotoxicology.

Electronic structure calculations, classical molecular mechanics and dynamics, Monte Carlo and other methods are being used in the group.

Our research is supported by the Australian Research Council and industry, including BHP Billiton, BlueScope Steel and Cytopia. We work with RMIT’s Health Innovations Research Institute and Platform Technologies Research Institute.

For further information, please contact Professor Irene Yarovsky

- ***Advanced Manufacturing Precinct***

RMIT University’s Advanced Manufacturing Precinct brings together RMIT’s expertise and strengths in innovative technology and design.

We house the latest in industrial platform technologies focusing on additive and subtractive technologies, and develop and realise conceptual design and its many iterations, across many disciplines of product and industrial design.

We provide companies with access to a range of specialised equipment that can enhance product development and design, drawing on our international reputation for excellence in work-relevant education and high-quality research that is engaged with the needs of industry and community.

Our specialised equipment provides access to cutting-edge technology that can enable companies to develop new conceptual products, perform multiple design iterations, or develop existing products.

Additive manufacturing

We can build final products direct from a computer model in both polymers and high-tech metal alloy powders. Our state-of-the-art additive manufacturing technologies include:

- selective laser melting (metal-based technology)
- fused deposition modelling (polymer-based technology)
- objet machines (polymer-based technology)
- U Print machines (polymer-based technology).

Subtractive manufacturing

The Advanced Manufacturing Precinct houses internationally recognised multi-axis CNC machines (Okuma, Haas and BIESSE) for machining high-performance alloys and composites for engineering and furniture applications.

Industrial automation

Robotic technology gives our subtractive manufacturing capability greater diversity and flexibility of applications. We use a range of automation robotics to simulate manufacturing production lines used in the furniture, textile and design industries. We have the latest in CAD software, allowing students and researchers to design components and models.

Partnerships with industry may involve collaborative and contractual agreements, with RMIT's capabilities complemented with appropriate industry contribution.

Testing and analysis

The Advanced Manufacturing Precinct allows access to RMIT's full capabilities. Prototypes can be tested to determine limitations and specifications. Testing can include:

- mechanical analysis
- material analysis
- system power
- acoustics testing
- fatigue testing
- tensile testing.

Highly accurate digital coordinate measuring machines allow detailed verification for quality assurance and reverse engineering.

Swinburne University of Technology

- ***Australian Advanced Manufacturing Research Centre***

The Australian Advanced Manufacturing Research Centre (AusAMRC) is an initiative led by Swinburne University of Technology and the Boeing Company to research and develop new aerospace and other industry sector component materials and manufacturing technologies.

Located at Swinburne's Hawthorn campus, AusAMRC is an open and collaborative industry alliance seeking to develop technology-driven solutions to ensure Australian supplier organisations are amongst the most innovative, competitive and capable in the world.

Research projects are funded by membership fees and through partnerships with State and Federal Governments, as well as other leading research organisations.

Coordinated by Boeing Research & Technology Australia, AusAMRC has been established to research and develop projects that will help Boeing Australia and Australian suppliers improve their capability to deliver globally competitive and high-quality Boeing products.

Based on the supply chain model for new technology research AusAMRC will initially focus on:

- High performance machining of titanium and aluminium alloys;
- Hybrid metal-composite components; and
- Advanced tooling for integrated composite structures.

AusAMRC works closely with the internationally acclaimed Advanced Manufacturing Research Centre (AMRC) in the United Kingdom. It will l join AMRC's network of world-leading aerospace supply chain companies and key government and international academic institutions to bring high performance machining technologies to Australian industry.

In 2011 AusAMRC will move into a new Advanced Technology Centre at Swinburne until construction of the proposed Advanced Manufacturing Centre Factory of the Future is complete.

Membership to AusAMRC provides a number of benefits including the opportunity to have a seat on the Board and influence the direction of future research projects. All members can participate in and obtain the results of generic research projects.

AusAMRC is part of "GlobalNet", a group of Boeing-engaged research centres around the world. The group collaborates and coordinates its research efforts, including through an annual conference (2009 in the UK and 2010 in Italy).

AusAMRC is based on and closely allied to the highly successful AMRC (Advanced Manufacturing Research Centre) at Sheffield University in the UK. The UK's AMRC is a £60 million collaboration among more than 40 partner organisations, comprising world leaders in the aerospace supply chain, key government offices and international academic institutions.

- ***Smart Structures Research Laboratory***

AusAMRC houses iconic research equipment related to the University's areas of research strength, including a new Smart Structures Laboratory.

The $15 million laboratory is a major three-dimensional testing facility developed for large scale testing of civil, mechanical, aerospace and mining engineering components and systems and the only one of its type available in Australia. The 1.0m thick strong floor measures some 20m x 8m in plan with two 5m tall reaction strong walls meeting at one corner.

The 3D strong cell have a grid of tie down points 0.5m apart over the whole floor and walls to secure the test specimens, as well as a suite of hydraulic actuators and universal testing machines varying in capacity from 10 tonnes to 500 tonnes. The laboratory is serviced by adjacent workshops and a hydraulic pump system located in the basement. The facility is housed in a large architecturally designed test hall about 8m tall, located prominently at the front of the ATC building.

The facility provides support to Swinburne's Centre for Sustainable Infrastructure and provides a regional and national focus for large 3D static and dynamic testing with a wide range of applications including; civil, mining, railway, aerospace and automotive components, systems and infrastructure.

The facility allows testing of existing and new systems and facilitate investigations of new materials under full-scale real loading conditions.

The research outcomes from these tests allow for the verification and calibration of computer models and simulations in three dimensions and provide significant benefits to both industry and government in developing sustainable and innovative solutions to complex problems.

The Australian National University

- ***Materials & Manufacturing Group***

The Materials and Manufacturing group is a research and teaching unit within the Research School of Engineering in the ANU College of Engineering and Computer Science. Our research spans the fields of mechanics, advanced materials, and manufacturing technology. A key theme for all research topics is to view the process as a system and understand the interactions within the systems and the effect of variability on the system output.

Important to the work of the group is its relevance and applicability to industry. Strong collaborations have been established with industrial organisations with many projects being partially undertaken within company premises.

The Materials and Manufacturing group has access to a number of laboratory facilities at ANU which include:

- Advanced systems laboratory
- Advanced manufacturing laboratory
- Manufacturing workshop
- Materials processing laboratory
- Computational mechanics laboratory
- Advanced materials laboratory
- Materials teaching laboratory

Materials & Manufacturing links

- ANU College of Engineering & Computer Science
- National ICT Australia Ltd
- Automotive Technology CRC
- Cambridge University, Institute for Manufacturing
- Canon Australia
- CSIRO, Division of Materials Science and Engineering
- Deakin University, Centre for Material and Fibre Innovation
- Ford Australia
- Liverpool University, Department of Engineering
- Nanyang Technological University, School of Materials Science and Engineering, Singapore

- Tsinghua University, Department of Engineering Mechanics
- Queens University, Department of Mechanical Engineering, Ontario
- Tianjin University, Department of Mechanics
- Curtin University, Department of Computer Science
- National Database for Research Capabilities & Expertises
- National University of Singapore
- Quickstep Pty. Ltd.
- Simile Systems
- Specialty Group Pty. Ltd.
- Telstra
- Victorian Centre for Advanced Materials Manufacturing

The University of NSW (UNSW) -

- ***School of Materials Science & Engineering***

The field of Materials Science and Engineering offers unlimited possibilities for innovation and development. Attention is being focused on developing and processing metals, ceramics, polymers and composites with improved properties.

The School has strong research interest ranging from materials production, including their extraction from ores and their refining, to the design, development, processing and recycling of materials for use in aerospace, transportation, electronics, energy conversion, and biomedical systems. Advanced materials can provide a major competitive advantage in virtually every part of a country's manufacturing industry.

Because Australia is a country rich in minerals, materials science has been designated as a priority area for research and development. Examples of recent and significant developments include the emergence of environmentally friendly and economical metal processing methods; advanced surface coatings; electrical ceramics; engineering polymers, and advanced composites.

Need to summarise the extensive laboratory capability.

- ***Centre for Sustainable Materials Research and Technology***

The Centre for Sustainable Materials Research and Technology (SMaRT@UNSW) brings together researchers from the Faculties of Science, Engineering, Built Environment and ADFA to work with industry on the development of innovative, sustainable materials and manufacturing processes.

Achieving sustainability targets set by industry has created a need for commercially relevant and globally significant R&D. The SMaRT Centre works with industry partners to develop the fundamental and applied science underlying sustainable materials and technologies.

SMaRT brings together the distinctive research capabilities of UNSW's academics and a track record of delivering research and technology suitable for rapid implementation.

The overall aim of the Centre is to develop innovative, sustainable materials and processes through world-class research, with strong emphasis on environmental and economic benefits.

- Lead scientific and engineering advances in sustainability of materials and associated technologies
- Strengthen links with local and international institutions and industries for research into developing sustainable materials and associated technologies through ARC Linkage Grants, ARC Discovery Grants, Industry Funds, and visiting researchers
- Facilitate rapid transfer of technology by addressing the scientific & engineering barriers.

SMaRT has strong relationships with Industry and Research partners from the metallurgical, materials, building, construction and mining sectors across the globe. The Centre has 20 academic staff and postdoctoral researchers.

The Centre also has state-of-the-art Research Infrastructure funded through the Vice- Chancellor's strategic priorities funding, along with well-equipped sustainable materials laboratories.

The University of Queensland

- ***Centre for Advanced Materials Processing and Manufacturing (AMPAM)***

AMPAM provides a focus for UQ's materials engineering and manufacturing activities, and those of its partners in major successful national collaborative ventures.

UQ's current capabilities and the new facilities to be located in the Advanced Engineering Building at UQ allow Queensland industry to capitalise on emerging trends in manufacturing research where innovations in material developments are driving new combinations of metals, polymers, ceramics and composites that have not before been economically possible.

With AMPAM's industry and research members working together within AMPAM the blending of technologies and processes will create new unique opportunities for materials development, processing and manufacturing.

AMPAM is comprised of seven core partnerships with extensive experience in a multitude of research sectors from defence to consumer products. Our wealth of experience means AMPAM's footprint is large and far reaching. Our formal and informal partnerships extend beyond the core centres to the many national and international industry and research members. The following links are to the web sites of the AMPAM participants where you can gain an appreciation of the breadth and depth of their research and industry linkages selection of case studies are provided below. This work was performed at UQ or within AMPAM's participants.

- Improved aluminium production for Australian smelters [494 KB]
- Titanium technology for Australian aerospace SME [297 KB]
- New biodegradable plastics for Australian company [305 KB]
- New composites for aerospace [294 KB]
- Increased productivity for regional QLD SME [181 KB]
- Collaborating on corrosion [288 KB]
- Value Stream Mapping with QLD SME [171 KB]
- Fire-retardant composite developed in Australia [307 KB]
- Advanced process monitoring and SME technology transfer [3.2MB]

See www.uq.edu.au/ampam

The University of Sydney

- ***Centre for Advanced Materials Technology, University of Sydney***

The aims of CAMT are to conduct high quality fundamental research in materials science and technology and to promote collaboration with industry in the design, engineering, development and manufacturing technology of advanced materials, which can give a competitive edge to new products and processes.

It has a widely recognised international and national reputation for high quality research, equipped with state-of-the-art facilities of computing, material characterisation, mechanical testing and processing.

The CAMT conducts both fundamental studies, aiming at new discoveries, and applied research, focusing on the direct solutions to industrial problems.

- ***Biomaterials and functionally graded materials***

New research activities initiated to develop fibre-polymer functionally graded materials and hydroxyapatite biomimetic coatings, ceramic matrix nanocomposites and metal-ceramic functionally graded materials for the Aerospace industry and Biomaterials industry.

- ***Composites science and technology***

Include structure-property relationships, manufacturing techniques for thermoplastic composites, thermoforming, interface characterisation and durability analysis.

- ***Nanomaterials***

A new class of engineering materials consisting of nano-metre scale particles or fillers. The current research focuses on processing and characterisation of structure-property relationship of several typical polymer-based, metal-based and ceramic-based nano-composites to understand the deformation and failure mechanisms.

- ***Nanomechanics and Nanotribology***

With the rapid development in applications of high-density information storage devices, micro-electro-mechanical systems, biomedical devices and wireless and fibre optic communication systems, nanomechanics and nanotribology have become increasingly important. The current research activities are on the mechanical analysis of nanomaterials including carbon nanotubes, mechanisms nanowear and the effect of nano-cracks and shear bands.

- ***Smart materials and structures***

Effort has been made to build "smart" structures using active materials such as shape memory alloys/polymers, piezoelectric ceramics and polymers, and magnetostrictive composites. The research includes development and characterisation of novel active materials with improved performance, development of active structures with surface mounted/embedded sensors/actuators for vibration and damping control and on-line health monitoring or non-destructive evaluation.

- ***Theoretical and applied fracture mechanics***

Covers interface fracture of fibre/matrix system, damage of polymer alloys and blends, microstructure-toughness relationships of polymers, constitutive modelling, micro-damage and micro-crack propagation, failure mechanisms of piezoelectric materials, fatigue, effects of crack tip constraint and mismatch of adhesive joint's geometry.

University of Technology Sydney (UTS)

- ***The Centre for Built Infrastructure Research (CBIR)***

CBIR is a multidisciplinary team of researchers from the faculties of Engineering, Science and Design, Architecture and Building. CBIR's nationally and internationally renowned work focuses on finding solutions to important global problems in building structures, materials, design, management, improvement, safety and conservation.

- ***The Centre for Intelligent Mechatronic Systems (CIMS)***

CIMS integrates the disciplines of mechanical, electrical and electronics engineering and computer systems. Its four main research directions are: autonomous robots (operating in unstructured environments and for infrastructure maintenance, search and rescue, health care and road vehicles); electrical machines (new materials and topologies, system optimisation, variable speed control and compact, low temperature fuel cells); automotive systems (performance, comfort, fuel efficiency, road safety and emission control); and Human Factors (physiological and psychological aspects of human-machine and human-environment interaction).

University of Western Sydney

- ***Institute for Infrastructure Engineering, UWS***

The Institute is currently involved in 13 national grants funded through the Australian Research Council Discovery and Linkage Grants Scheme which have formed the basis for the majority of honours projects in Engineering. Industry partners contributing to the Linkage Projects include a plethora of leading National and International Companies, namely Ajax Fasteners, Arup, BlueScope Lysaght, Coffey Geotechnics, Lincoln Electric, One Steel, Penrith Lakes Development Corporation, Roads and Maritime Services and Stramit Industries.

University of Wollongong

- ***BlueScope Steel Metallurgy Centre***

The BlueScope Steel Metallurgy Centre (BSMC) was established in 2004, evolving out of the previous BHP Institute for Steel Processing and Products, which had been operating since 1995. The centre provides opportunities for academic staff to play a greater role in assisting industry in enhancing its business. It also enhances the opportunities for industry staff to make a contribution to fundamental research and education.

It has built up specialized equipment infrastructure that is shared by the University and company employees in a unique arrangement. Since 1997 the Centre has conducted research on 42 competitive grant projects with a total budget of $8.92 million.

Research activities have been conducted in several key areas focussing on the changing needs of BlueScope Steel as the company has responded to changes in its commercial environment. The Primary Processing Program has focussed on iron and steel making processes as well as associated process technologies. The Casting and Rolling Program has concentrated on thin strip continuous casting technology, thermo-mechanical processing, and steel product development.

The casting part of this program contributed to the development of the recently commercialised thin strip casting process and will now focus on the physical metallurgy of thin strip cast steel. The Coatings Technology Program investigates the basic scientific and technological issues underpinning future advances in metal and polymer coating of steel.

The Centre is multidisciplinary, encompassing physical and process metallurgy, mechanical engineering, polymer science, chemistry, and mathematical modelling. It has established strong and focussed research groups and has attracted a talented staff not only to the Centre, but also to the associated teaching disciplines.

Two major applications of flat rolled steel are building materials (galvanised steel and pre-painted steel) and packaging products (tinplate). In these applications, polymer coatings - paints and lacquers - are used for decorative purposes and to protect the metal substrate from corrosion. Reliable adhesion of the organic coating to the substrate is therefore very important.

The Bluescope Steel Metallurgy Centre is conducting a research program on polymer coatings, which is focused on improving our understanding of the mechanical properties of the coatings, with particular emphasis on adhesion. The research team is concerned not only with the question of adhesion to the metal substrate, but also with the adhesion of contaminant particles to a painted surface. Such contamination tends to discolour buildings very rapidly, particularly in tropical areas, so contamination-resistant paint formulations are an important feature of their research.

- ***The Advanced Structural Engineering and Construction Materials Group***

The Group couples the existing research strengths of structural engineering and construction materials within the School of Civil, Mining and Environmental Engineering at the University of Wollongong. The focus of this group is to undertake advanced structural analysis and evaluate high performance materials used in civil engineering construction.

Much of the research undertaken by this group has been funded through the Australian Research Council and associated industry partners. The group consists of six full time academic staff members and two visiting staff members. In addition there are numerous BE (Hons), Masters and PhD students associated with the group's activities. The group also has approximately five technical staff associated with its two structural engineering laboratories.

ASEACM was established in January 2005. The members of the group have a very strong research record with a total of $5 million in National Competitive Grants attracted since 2000. Furthermore, the members of the group have produced over 300 publications and supervised over 150 theses in the last five years.

Four primary strands of research of this group include:

- Advanced analysis and design of structures: Here, we consider the non-linear analysis of concrete, steel and composite steel-concrete structures and the behaviour of structures under extreme loading. We are also developing novel techniques for optimising structural design
- High performance concrete: This research considers the constitutive behaviour and application of high strength concrete, self-compacting concrete, fibre reinforced concrete and FRP wrapped concrete members.
- High performance steels: High performance steel research and applications in civil engineering construction is being conducted using high strength steels, stainless steels and titanium based alloys.
- Soil-structure interaction investigating the interaction between foundations with soil under variable loading.

- ***Sustainable Buildings Research Centre***

Buildings have major economic, environmental and social impacts on our community and the planet. Between a quarter and a half of all greenhouse emissions result from the use of buildings.

The Sustainable Buildings Research Centre (SBRC) will be a multi-disciplinary facility that brings together a wide range of researchers to holistically address the challenges of making our buildings sustainable and effective places in which to live and work.

Our mission is to assist in the rapid decarbonization of our built environment. Thus, a major focus of the SBRC is the retrofitting of existing buildings, since replacement of existing building stock occurs at between only 1 or 2% p.a. The SBRC brings together researchers, students and industry to:

- Develop, prototype and test sustainable building technologies and designs for residential and commercial applications;
- Perform in-depth experimental and theoretical analysis of the thermal design of buildings;
- Develop architectural and structural design tools to facilitate the inclusion of ecological costing throughout the design phase of buildings (e.g. water, embodied energy, carbon);
- Investigate day-to-day behaviour of building occupants to improve our effectiveness of building use and design and improve the uptake of environmentally sustainable technologies;
- Develop novel control systems and sensor technology for improving building performance; and
- Develop novel modelling tools to aid sustainable design.

The development of the SBRC has been made possible through generous grants from the Australian Commonwealth Government under the Education Investment Fund (EIF) and NSW Trade & Investment under the Science Leveraging Fund (SLF).

As a Living Laboratory, the SBRC will provide a demonstration space for display of sustainable building technologies and components that will be of benefit to the sustainable buildings industry.

SBRC facilities include:

- Large Scale Integrated Component Testing Lab
- Electrical Power Quality, Renewable Generation and Storage Lab
- Water Sustainability Lab
- Thermal Analysis and Simulation Lab
- Roof Top Testing Lab
- Building Performance and Monitoring Lab
- Sustainability Training Hall
- Collaborative Partner Space

- ***Intelligent Polymer Research Institute***

The Intelligent Polymer Research Institute (IPRI) is a key research strength at the University of Wollongong and is the lead node of the Australian Research Council (ARC) Centre of Excellence for Electromaterials Science (ACES). Professor Gordon Wallace and his team at IPRI are recognised internationally as world leaders in the development of 'intelligent' materials and nanotechnology

Researchers work with materials in the nano-domain (that is, with particles as small as one billionth of a millimetre) where electronic conductivity is vastly higher than in larger structures. Their challenge is to make materials at these nanodimensions and assemble them into larger structures (micro or macro) that retain the special characteristics of the nanocomponents, resulting in improved functionality.

IPRI is renowned for expertise in the electrochemistry of organic conductors; especially when those conductors are used in the applications of artificial muscles, photovoltaics, batteries, and biomedical applications.

New developments in nanoscale materials offer the potential for groundbreaking improvements in charge generation and transfer, which can be used to tackle some of the biggest challenges facing society. Challenges such as renewable energy (plastic solar cells, lightweight batteries and electronic textiles), sustainable industries (which would benefit from advances in the recovery of precious metals and new corrosion protection technologies) and medical science (nerve and muscle regeneration and cell communications).

The high quality of research in nanotechnology and materials science at IPRI was recognised, strengthened and rewarded with the establishment in 2005 of an ARC Centre of Excellence for Electromaterials Science (ACES), with partners from Monash University, the Bionic Ear Institute, St Vincents Health and the NSW Department of State and Regional Development. $12 million funding was provided to form ACES with the aim to concentrate expertise and encourage collaboration among high quality researchers to maintain and develop Australia's international standing in research areas of high priority.

IPRI is situated at the state-of-the-art Australian Institute for Innovative Materials (AIIM) Facility at the University of Wollongong's Innovation Campus and draws together researchers from a range of disciplines, including biologists, clinicians, chemists, physicists and engineers. Professor Gordon Wallace is the Executive Research Director of this ARC Centre of Excellence. The Centre recently received an additional $7.7 million in funding from the ARC from July 2010 to December 2013 to continue to build on the progress achieved since 2005 in developing electromaterials for use in relevant applications.

In addition to the ACES core projects of synthesis, characterisation and modelling of new electromaterials, energy conversion, energy storage, ethics and bionics, IPRI has related research activities supported by CRC Polymers, DSTO, University of South Australia, and several Commercial Partners. IPRI has developed global linkages with research institutions in the USA, Japan, Korea, China, Ireland and the United Kingdom, with a growing international reputation and important industry partnerships.

Key Competencies

- Intelligent polymers and nanostructures
- New electrode materials and functional electrolytes
- Spinning nanostructured fibres
- Electromechanical actuators
- Chemical and mechanical sensing networks
- Nanodimensional electrocatalysts
- Organic and inorganic batteries
- Nano biotechnology and biomaterials
- Cellular interactions
- Medical devices for diagnostic and therapeutic use

ANSTO

- ***Institute of Materials Engineering***

The Institute of Materials Engineering (IME) is a major centre of materials engineering and expertise in Australia with a multidisciplinary team of scientists and engineers.

The Institute plays a significant role in maintaining Australia's international profile in the field of nuclear science and technology and enhancing the sustainability and international competitiveness of Australian industry.

The Institute's core mission is to: develop, manufacture, characterise, model and ultimately, utilise materials in support of the Advanced Nuclear Fuel cycle and next generation power generation systems.

It also undertakes a number of other research activities, both sponsored and collaborative, and undertakes related projects including National Security Research with a wide range of national and international stakeholders.

IME has a strong nuclear focus to most of its activities. It also uses the skills and experience that is generated by such activity to undertake sponsored collaborative research and commercial consultancy in both the Australian and international arenas.

Current research

- Nuclear materials modelling & characterisation
- Nuclear materials science
- Structural integrity
- National security research
- Facilities support

CSIRO

- ***Future Manufacturing Flagship***

The Future Manufacturing Flagship draws on the expertise of over 300 scientists and engineers with world-class capabilities in materials and process sciences, ICT, mathematical and social sciences, economics & design, and is building new capability through clusters and consortiums.

One of 11 National Research Flagships, FMF was established in 2008 with an initial focus on niche manufacturing. Since then the Flagship has grown significantly and evolved to increase its relevance to a broader cross-section of manufacturers recognising the common challenges they face. The evolution of the Flagship also recognised the role that CSIRO can play in both helping existing firms make transitions to the future and to help create opportunities for establishing new businesses. The evolution of the Flagship coincided with a significant realignment and coordination of manufacturing research within CSIRO, starting in May 2010. The strategy of the Flagship was approved by CSIRO's Executive in May 2011 and the FMF has continued to evolve and grow to cover a broad base of manufacturing research, with a focus on:

- Sustainable Materials – helping manufacturers achieve a more sustainable use of resources
- Factories of the Future – helping manufacturers build flexibility, agility and lift productivity
- Transformative Industries – supporting the creation of new business opportunities through disruptive technology platforms

The Flagship 'Focus Areas' were developed to meet the challenges arising from an increasingly resource constrained, competitive environment and support manufacturers capture opportunities presented by an increasing demand for sustainable products. They look to support manufacturers develop new, scalable, low cost, efficient manufacturing technologies that leverage information sciences and the digital economy (for example, Australia's new National Broadband Network) to lift productivity and worker safety. And, to support manufacturers capture opportunities through new industry supply chains that leverage Australia's significant natural mineral resource advantages.

The Flagship delivers its research through five industry-facing Themes, namely:-

- Sustainable High Performance Materials
- Agile Manufacturing Technologies
- Manufacturing Technologies for Transport and Mining
- Flexible Electronics and

- Titanium Technologies.

The multi-disciplinary program of research conducted through these Themes enables the Flagship to fulfil its four primary roles in the Australian National Innovation System. These roles being to:

- Help existing firms make transition to become more sustainable and remain competitive in an increasingly competitive, resource constrained world
- Support the development of new businesses and industry supply chains
- Help position CSIRO as a global R&D provider by applying Australian science and technological capabilities in international markets
- Play a Trusted Advisor role to government, industry and community.

The Flagship operates on an annual budget of $70m, of which $30m is externally sourced. External funding is secured primarily through commercially contracted research with industry, with varying levels of co-investment. About 80% of the Flagship's resources are directed towards research projects with industry partners. The remaining is invested in early stage strategic research.

The Flagship draws scientific and engineering expertise from 340 CSIRO researchers and through various collaborative arrangements, such as Flagship Collaboration Clusters over 150 more researchers from Australian universities participate in Flagship programs.

ANFF

The Australian National Fabrication Facility (ANFF) links eight university-based nodes to provide researchers and industry with access to state-of-the-art fabrication facilities. The capability provided by ANFF enables users to process hard materials (metals, composites and ceramics) and soft materials (polymers and polymer-biological moieties) and transform these into structures that have application in sensors, medical devices, nanophotonics and nanoelectronics.

The nodes, which are located across Australia, draw on existing infrastructure and expertise. Each offers a specific area of expertise including advanced materials, nanoelectronics & photonics and bio nano applications. Our commitment to providing a world-class user facility is underpinned by the sharing of best practice in service provision across the nodes.

ANFF has undertaken some work with SMEs in relation to powders and coatings, but details are commercial in confidence.

Defence Materials Technology Centre (DMTC)

DMTC is a collaborative venture that brings together defence industry, universities and government research agencies to develop new materials and manufacturing technologies that will enhance Australia's defence capability. It is Australia's first Defence Future Capability Technology Centre – a Federal Government initiative based on the successful Co-operative Research Centre (CRC) model.

Operational funding of approximately $86 million is drawn from several sources including a $30 million contribution from the Federal Government and a combined $9 million from the state governments of Victoria, Queensland and New South Wales. Collaborative industry and research sector partners provide the balance.

DMTC develops and delivers new materials technologies and manufacturing processes to enhance Australia's defence capability through a by collaborative partnership approach between Defence, defence industries and research agencies.

Projects deliver real solutions to Defence across program areas including Air Platforms, Maritime Platforms, Armour Applications, Propulsion Systems and the recently announced Personnel Survivability. These programs provide a governance framework and context for each research project involving industry and academic partners, and provide the mechanism for delivering practical, measurable results with a strong technical underpinning.

Attachment 5: Research Models from Other Sectors and Internationally

Australian Minerals Industry Research Association

AMIRA International Ltd is an independent association of minerals companies that develops, brokers and facilitates collaborative research projects.

Through this process a number of companies can jointly fund research and jointly share the benefits. This combined funding enables AMIRA to recruit the world's leading researchers to address industry problems and opportunities and to conduct sustained research which leads to the development of a stronger industry research base.

The Australian Rural Research and Development Corporation (RDC) Funding Model

RDCs commission agricultural R&D on a competitive basis amongst public and private providers using funds from levies on production and matching Commonwealth grants. They target research and foster uptake and adoption based on the identified needs and priorities of both industry and the Australian Government.

The model has given rural industry the vehicle to negotiate new standards for investment, focussed on triple bottom line outcomes. There are currently 15 RDCs

The Australian Government provides dollar for dollar matching of industry expenditure on R&D up to a limit of 0.5 percent of each industry's Gross Value of Production (GVP).

The RDC model today is a mix of statutory and industry-owned companies. The industry-owned R&D companies are independent corporate entities with expertise-based boards. They were formed in response to an industry desire to have more control over their affairs and increased flexibility, industry representation and to foster market driven R&D that will be widely adopted by industry.

RDCs can fund R&D into either production (on-farm) or processing (off-farm) issues and are expected to fund portfolios of projects that have a mix of both public good and industry good components given the taxpayer contributions. The RDCs engage with a diversity of stakeholders in a shared vision of what the future can be, which is updated in 5 year plans and reinforced with each of the annual operating plans.

The RDC model allows for a targeted approach to R&D fund allocation by industry, where those funds are a mixture of government and industry contributions. Further, the model encourages accountability, allowing levy payers to contribute to RDC strategies including the amount of the levy collected.

See http://www.ruralrdc.com.au/Page/Home.aspx

New Zealand Heavy Engineering Research Association (HERA)

HERA was established in 1978 as an industry owned, non-profit research organisation dedicated to serving the needs of metal-based industries in New Zealand. While the emphasis of its activities is on heavy engineering, HERA also services wider metals industry interests such as light-gauge steel, stainless steels, light alloys and metals-based composites.

HERA obtains its income from an industry contribution in the form of a levy on steel and welding consumables, Public Good Science funding for contract research programmes, direct funding from industry for specific programs, consultancy work, seminar and course fees, subscriptions from members and sales of publications.

The major types of business represented are:

- Metal Fabricators: Structural, Pressure Equipment, Stainless Steel, Aluminium, General Engineers, Site Fabricators and Erectors.
- Designers: Civil, Mechanical, Chemical Engineers, Architects, and Quantity Surveyors.

- Suppliers: Steel, Special Steel, Stainless Steel, Aluminium and Copper Alloys, Welding Consumables, Engineering Component Suppliers, Steel Manufacturers, Metal Forming and Pre-fabrication.
- Supporting Companies: Construction, Metal Coating/Preparation and Inspection Companies.
- Manufacturing Companies: Engineering products

Research is selected on the advice of subject-specific industry advisory panels and is usually of applied nature with short- to medium-term implementation. HERA's research activities encompass the areas of structural steel, light gauge steel and composite action, welding/joining, industry capability and marketing.

HERA incorporates the New Zealand Welding Centre (NZWC), Inspection & Quality Control Centre (I&QC Centre), Structural Systems Division including the Composite Structural Assembly (CSA) joint-venture & Bridge Development Group (BDG), Metal Forming Group and the HERA Information Centre (HIC).

HERA's research capabilities

Steel construction research through its Structural Systems Division

- General structural steel systems research for design of hot-rolled and cold-formed steel including multi-storey building and bridge construction
- Composite research for structures having metals as a key material (such as steel-concrete composite floors and composite structural assemblies)
- Seismic design of steel and steel-based composites
- Fire engineering design
- Design for occupant-induced floor vibrations
- Structural reliability and design assisted by testing
- Sustainability and environmental performance of steel-framed buildings
- Durability research for metals-based structures (coating systems, corrosion)
- Specialist Finite Element based research capability

- Welding fabrication technology related R&D through the New Zealand Welding Centre
  - Productivity research of standard and emerging welding processes
  - Welding engineering design including welding fatigue
  - Materials performance and failure evaluation
- Metals forming (in conjunction with AUT University Centre for Metal Forming)
  - Characterisation of metals for forming processes
  - Metal forming technology research
- Inspection and quality control
  - Non destructive testing technologies in metals engineering
  - Metals engineering productivity and Quality Assurance
- Industry development research
  - NZ metals engineering capability and capacity
  - Heavy engineering business opportunity research

HERA staff has additional expertise across a range of metals engineering disciplines including machining, casting, metal forming and NZ metals industry capability. HERA also maintains active links to related overseas research institutions and is therefore able to extend its research coverage via those organisations if needed.

German Fraunhofer institutes

Fraunhofer-Gesellschaft is Europe's largest application-oriented research organization. Its research is oriented toward concrete applications and results. Pure basic research, as practiced at universities, is funded to almost 100 per cent by public grants. Industrial R&D, up to prototype level, is largely financed by private enterprise. The Fraunhofer-Gesellschaft operates in a dynamic equilibrium between application-oriented fundamental research and innovative development projects.

There are more than 80 research units, including 60 Fraunhofer Institutes, at different locations in Germany. The majority of more than 20,000 staff are qualified scientists and engineers. It has an €1.8 billion annual research budget. Of this, €1.5 billion is generated through contract research. More than 70 per cent of this is derived from contracts with industry and from publicly financed research projects. Almost 30 per cent is contributed by the German federal and Länder governments in the form of base funding.

One Institute that has particular relevance to the steel fabrication sector in an Australian context is the Fraunhofer Institute for Production Technology

Fraunhofer Institute for Production Technology
On behalf of our clients, we develop and optimize solutions for modern production facilities. Rather than considering production activities as individual operations, our work involves looking at all production processes and the links between all the elements of the overall process in their entirety. **Applied Research and Consulting** The task of the Fraunhofer IPT is to transfer research findings into economically viable and unique innovations in the field of production. It promotes and conducts applied research, implements research results in an industrial context, and provides relevant and effective consulting services for the direct benefit of industry, thereby contributing significantly to the competitiveness of companies. **Excellent and Exceptional** The Fraunhofer IPT offers research and consulting services of excellent quality on the basis of scientifically recognized procedures and using state-of-the-art facilities. It is the goal of the Fraunhofer IPT to achieve technological and opinion leadership in its key focus areas with respect to contract research at both a national and international level. **Research and development** Right at the early phases of product emergence - the research and development phase - we can use our expertise to help you identify new technologies, create concepts and develop prototypes. We place a great deal of importance on getting your equipment, material and processes to perform optimally, giving your products the best chances of competing in the market. **Purchasing** Whatever you cannot make yourself, you buy in from your suppliers. You need to be able to rely on suppliers to provide top quality goods and services at reasonable prices, so we take a close look at your supply base and the services it provides. We structure the purchasing market for you, help you to choose the right partners and develop individual courses of action using tried-and-tested methods in order to optimize your purchasing costs. **Production** The Fraunhofer IPT is seen by its clients as an experienced partner for all issues related to production - and not without good reason. Whether we are determining your status quo, analyzing your production concept, selecting technology, designing a system, or developing, optimizing and implementing processes, you can rely on our motivated team of experts representing different disciplines and many years of expertise. We never look at concepts, technologies and systems in isolation, but see them within the context of your industrial practice. **Management** In some situations, it becomes necessary to critically review one's fundamental management processes, the technology strategy or the strategic and operative management as a whole. We analyze your structures and processes at all phases of research and development, purchasing and production and help you to develop a new, more promising approach without abandoning best practices. We consider it particularly important that your employees stand firmly behind any changes, especially in sensitive areas. The Fraunhofer IPT develops systems solutions for production. We focus on the topics of process technology, production machines, mechatronics, production quality and metrology as well as technology management. Our clients and cooperation partners represent all fields of industry: from aerospace technology to the automotive industry and its suppliers as well as tool and die making companies and the precision mechanics, optics and machine tool industries in particular. The institute currently employs around 380 people who are dedicated to applying their creativity to a range of projects. http://www.ipt.fraunhofer.de/en/Profile.html

US National Network for Manufacturing Innovation (NNMI)

President Obama proposed the establishment of a National Network for Manufacturing Innovation (NNMI) in his FY2013 budget, and formally introduced the concept on March 9, 2012. The following text contains extracts from a briefing prepared by the Congressional Research Service in August 2012 (John R Sargent 2012).

- ***Administration Proposal***

According to the proposal, the purpose of the NNMI is to bring together industry, universities and community colleges, federal agencies, and regional and state organizations to accelerate innovation by investing in industrially relevant manufacturing technologies with broad applications, and to support manufacturing technology commercialization by bridging the gap between the laboratory and the market.

In particular, the NNMI seeks to "advance technological innovation at a pace much faster than any one company could on its own," integrate innovation resources, improve the competitiveness of U.S. manufacturing, and encourage investment in the United States.

The NNMI would consist of a network of institutes where researchers, companies, and entrepreneurs can come together to develop new manufacturing technologies with broad applications. Each institute would have a unique technology focus. These institutes will help support an ecosystem of manufacturing activity in local areas. The Manufacturing Innovation Institutes would support manufacturing technology commercialization by helping to bridge the gap from the laboratory to the market and address core gaps in scaling manufacturing process technologies.

The NNMI would be managed collaboratively by the Department of Commerce's (DOC's) National Institute of Standards and Technology (NIST), the Department of Defense (DOD), the Department of Energy (DOE), the National Science Foundation (NSF) and other agencies.

- ***Funding***

As proposed in the President's FY2013 budget, NIST would receive a one-time infusion of $1 billion in mandatory funding in FY2013 to be spent over 10 years (FY2013-FY2022). Federal funds would be used to help establish and support up to 15 Institutes for Manufacturing Innovation (IMIs, which collectively would form the NNMI) on a cost-shared basis with industrial, academic, and state and local organization partners.

Each IMI is expected to become financially sustainable within seven years. Funding for the program would be frontloaded with $206 million in spending projected for FY2013, and a total of $839 million in spending in the first five years.[15]

- ***Structure and Guiding Principles***

The National Network for Manufacturing Innovation would be composed of competitively selected, independently managed Institutes for Manufacturing Innovation. Each IMI would have a specific focus area and serve as a regional innovation hub. Focus areas could include an advanced material (e.g., carbon nanotubes), manufacturing process (e.g., additive manufacturing), enabling technology (e.g., nanotechnology), or industry sector (e.g., medical devices).

The institutes would bring together large companies, small and medium-sized enterprises, academia, federal agencies, and state governments to accelerate innovation through co-investment in industrially relevant manufacturing technologies with broad applications. The institutes would be focused on helping to bridge the gap between basic research and product development, provide companies with access to cutting edge capabilities and equipment, and an environment for educating students and training workers in advanced manufacturing skills.

The institutes would seek to reduce the costs and risks of commercializing new technologies and to address relevant manufacturing challenges on a production-level scale.[16] While the IMIs are intended to serve as regional hubs for manufacturing innovation in specific focus areas, collectively the institutes would also function as a network for the sharing of knowledge and best practices.

The key principles that will guide the governance and work of the NNMI are:

- An interagency program management team would define the NNMI's and IMIs' organizational design, manage an open and competitive selection process, and execute the awards process. The team would also define the selection criteria to be used, incorporating public input.
- Each IMI would integrate capabilities and facilities needed to address crosscutting manufacturing challenges that, if met, have the potential to retain or expand domestic manufacturing on an economically sound basis.
- IMIs would conduct applied R&D and development projects to reduce the cost and risk of commercializing new technologies or solve generic industrial problems, conduct education and training efforts at all levels, develop methodologies and practices for supply chain integration, and engage with small and medium-sized enterprises.
- Each IMI would have a core of two or more companies, incorporate industry in agenda development, and have direct involvement of industry scientists and engineers in institute projects.
- IMI awards would be made in the form of grants, contracts, and cooperative agreements, possibly over multiple rounds of competitions.
- IMI proposers would be expected to show how federal investments would stimulate investments by the organizations comprising the partnership and/or from other non-federal sources.
- Subsequent federal support for an IMI would be contingent on demonstration of this additional investment, on progress to self-sustainability, and on progress toward meeting the goals of the NNMI

The NNMI is said to be modelled after the German Fraunhofer Institutes, which some consider to be a key facet of Germany's high-tech manufacturing success.

The Council on Competitiveness, Information Technology and Innovation Foundation, and President's Council of Advisors on Science and Technology and other organizations have endorsed the NNMI concept or proposed a network of U.S.-based public-private manufacturing centers similar to the NNMI.

UK ESRC Collaboration Programs

Collaboration Awards in Science and Engineering (CASE)

- **Introduction to industrial CASE**

Industrial CASE provides funding for PhD studentships where businesses take the lead in arranging projects with an academic partner of their choice.

These aim of these awards is to provide PhD students with a first-rate, challenging research training experience, within the context of a mutually beneficial research collaboration between academic and partner organisations e.g. industry and policy making bodies.

Benefits to the student - Industrial CASE provides outstanding students access to training, facilities and expertise not available in an academic setting alone. Students benefit from a diversity of experimental approaches with an applied/translational dimension. Students have an opportunity to develop a range of valuable skills and significantly enhance their future employability; many will become research leaders of the future.

Benefits to the academic / partner organisations - Industrial CASE studentships encourage productive engagement between partners who benefit from a motivated, high-quality PhD student undertaking cutting-edge research relevant to the organisations' priorities and objectives. The studentship provides opportunities to explore novel research collaborations and strengthen current partnerships.

Defining an excellent CASE Studentship:

High-quality project - A challenging, feasible and realistically achievable PhD project which stimulates excellent discovery-oriented research. Through a truly collaborative approach, it provides tangible benefits to all partners.

High-quality training environment - Through access to distinctive but complementary environments, partners provide a stimulating framework for research training in the proposed field. Joint supervision gives a unique and broadening perspective on the impact of collaborative research.

High-quality student experience - An enriched integrated training experience allows the student to acquire novel skills and expertise. The student gains a wider understanding of, for example, applied research or policy development that will enhance their future career prospects

Industrial CASE studentships

Students receive funding for a full EPSRC studentship for 3.5 years (currently ~£67,443). Companies provide additional top up to the project of a minimum of a third of the EPSRC funding. This top-up is £22,481 over the course of the project. The student must spend at least three months at the company, and the company pays any travel and subsistence costs. Projects should be in the area of engineering and the physical sciences.

- **How it works**

A company allocated an award defines a research project and picks an academic partner. Once the arrangements for the project have been agreed between the company and research organisation, they can recruit a student. For 2012/13 awards, the earliest start date for students is 01 October 2012 and the latest 01 October 2013.

Companies may place these studentships with any Research Organisation that also receives Doctoral Training Grant funding from EPSRC. The rationale for this is twofold:

- to provide a potentially better student experience (via the student being part of a larger cohort of individuals working in leading research teams for example) and
- to facilitate the strategic use of all ESPRC's students via EPSRC working with a smaller group of companies and research organisations, to target training at areas of particular strategic importance.

How industrial CASE awards are allocated

We allocate awards directly to businesses, primarily using an algorithm based on financial contributions on EPSRC-funded research. Following a review of the allocation process, all other routes to CASE awards have been discontinued in order to target support more strategically and efficiently.

- **Eligibility**

To be an Industrial CASE sponsor, companies must have an established UK-based research and/or commercial production capability.

Student eligibility requirements for EPSRC Industrial CASE funding are the same as for our other studentship awards, namely:

- A relevant connection with the UK, usually established by residence
- An upper second class honours degree, or a combination of qualifications and/or experience equivalent to that level

EU students may be eligible for a fees-only award (no maintenance grant). Please see student eligibility for details and contact your university postgraduate admissions office for advice.

- **EPSRC funding**

Historically, Industrial CASEs were (and in some cases still are) funded through our collaborative training accounts. Awards from 2009 onwards are funded through Industrial CASE accounts. Further information on this can be found in the Industrial CASE accounts terms and conditions document which is available to download on the Industrial CASE landing page.

Information on individual university Industrial CASE accounts can be found on the List Schemes page on the Grants on the Web website.

Industrial CASE is not our only scheme where industry can get involved with PhD projects. Companies can sponsor students and projects supported through EPSRC doctoral training accounts (DTA). If you are interested in sponsoring a student through this route, please contact the research organisation you would like to work with.

Note: To actively support and encourage collaboration through the doctoral training account route, EPSRC has, since 2009, set the research organisation the target of converting 10% of its (DTA) funds into CASE awards.

For queries about the Industrial CASE scheme, please email IndustrialCASE@epsrc.ac.uk

Industrial Doctorate Centres

Industrial Doctorate Centres (IDCs) are a subset of EPSRC' Centres for Doctoral Training (CDTs). These user-oriented Centres provide the same training environment and features as CDTs whilst also incorporating a strong industrial focus.

IDCs are an evolution of the Engineering Doctorates Centres (EngD) scheme operated by EPSRC since 1992. As part of substantial expansion of the CDT scheme, in 2009 EPSRC decided to both expand the scope of the previous EngD scheme (to cover the entire remit of EPSRC) and to seek to refresh the portfolio of Centres being supported (to allow new priority areas to be identified and supported - in energy for example). Thus, the cohort of 19 IDCs represents a mixture of new Centres and continuations (albeit in an evolved form) of a number of EngD Centres.

Examples –

- **Industrial Doctorate Centre in Advanced Forming and Manufacture, University of Strathclyde**

Our programme will provide EngD students with the opportunity to make a significant impact on the UK forming and forging industry and the UK manufacturing industry as a whole. This will be achieved predominantly through access to knowledge and expertise within the Advanced Forming Research Centre (AFRC), and its connections with leading global manufacturers. The major programme themes include; Forging Technology, Advanced Materials, Automation, Process Improvement, Micro-system Manufacture, Information Management, Operations Management and Process Design.

- **Industrial Doctorate Centre in Machining Science, University of Sheffield**

The IDC focuses on the development of skills and expertise in machining science. In recent years significant developments have taken place in engineering science that can produce a step-change in machining performance. The IDC is a collaboration between the Faculty of Engineering, the AMRC with Boeing and the Nuclear AMRC and applies high level engineering science to the solution of industrially relevant machining problems.

- **Engineering Doctoral Centre in High Value, Low Environmental Impact Manufacturing, University of Warwick**

Our new WMG International Doctorate Centre will deliver a revolutionary new doctorate for the 21st century. It will address industrially challenging issues that will enable companies to develop and implement innovative and world leading sustainable research solutions.

Our International Doctorate is a four year programme that combines industry relevant research, taught courses, international visits, entrepreneurial flair and networking.

Driven by research teams that combine industrial and academic experience, we work with entrepreneurial leaders who understand and appreciate that global environments are constantly changing. Our vision is to create a future generation of manufacturing leaders with the high-level know-how and research experience that is essential to compete in a global environment defined by high impact and low carbon.

- **Innovative and Collaborative Construction Engineering, Loughborough University**

The centre's research is focused on these themes: Innovative construction technologies (materials and construction techniques); Construction business processes (improving value and efficiency in design and construction, collaborative engineering, knowledge management); Advanced information and communications technologies (mobile technologies, ICT enabled information management and collaborative working); Sustainable design and construction (building performance, energy efficiency, climate change impact on the built environment); and Transport and infrastructure (transport operations and management, sustainable travel, infrastructure engineering, water and waste management).

SWECAST

http://www.swerea.se/en/Start24/

Working in close co-operation with the Swedish Foundry Association, Swerea SWECAST conducts extensive research and consulting in foundry-related matters, including materials technology, casting simulation, process technology, energy use and environmental concerns.

- **Research on foundry technology**

During 2010 – 2015 our foundry technology research is focused on four areas:

- Lightweight, multifunctional cast components
- Efficient product development
- Efficient production
- Environmentally sustainable manufacturing

- **Strategic development projects**

During 2010 – 2011, in collaboration with other Swerea institutes, we are also conducting five strategic development projects:

- Swerea WINDMILL. The objective of this project is to develop leading-edge competence on the construction, manufacture and maintenance of wind generators especially in cold climate.
- Swerea SME. A combined resource for the support of the product-, process- and business development of small and medium enterprises.
- Swerea Pure Steel. Research on process development to minimize internal defects in steel and thereby increase its performance capabilities.
- Swerea EcoDesign. This project is intended to help small and medium enterprises to develop products and processes with minimal environmental impacts.
- Swerea Future Car. A preliminary study to determine future needs for research related to the automotive industry of the future.

- **Casting Innovation Centre, CIC**

A national centre for research, development and education concerning cast materials and components for the Swedish automotive and machine industries.

Lightweight components

Swerea Lättvikt is a Swerea programme to help our customers take the leap into lightweight components. During 2009 - 2010, a special investment of SEK 20 million has been made to develop workable solutions in collaboration with selected companies.

Partners

The most important partners of Swerea SWECAST are foundries, suppliers and buyers of cast components. To the larger companies, many of them multi-nationals, we can supply research results that are of high scientific quality and often border on basic research. To smaller companies we often supply practical assistance with everyday tasks.

Other important partners within Sweden are institutions of higher learning, including:

- Royal Institute of Technology
- Linköping University Institute of Technology
- Chalmers University of Technology
- University of Skövde
- Halmstad University
- Jönköping University School of Engineering

At the international level we are currently collaborating with several foundry institutes within the European Union, including: IfG in Germany, ÖGI in Austria, CTIF in France, and FRI in Poland

Attachment 6: Relevant Literature

Policy Documents

Prime Minister's Manufacturing Taskforce, Report of the Non-Government Members, August 2012

NSW. NSW Manufacturing Industry Taskforce, NSW Manufacturing Industry Action Plan – Draft for Consultation

Victoria. A More Competitive Manufacturing Industry: New Directions for Industry Policy and Manufacturing

Sweden. Invest in Sweden Agency, Innovation Hotbeds, 2006

Commissioned Research Reports

Howard Partners, Study of the Role of Intermediaries in Support of Innovation, March 2007, A Report for DITR

Howard Partners, The Emerging Business of Knowledge Transfer, DEST, 2005

Herman Hauser, The Current and Future Role of Technology and Innovation Centres in the UK: Report for Lord Mandelson, Secretary of State for Business, Innovation and Skills

ACCIC, Howard Parners, Carisgold, Best Practice Processes for University Research Commercialisation, DEST, 2002

Deloitte, The Business Case for Knowledge Transfer: Prepared for the Business Industry Higher Education Collaboration Council, March 2007

Research Papers

ATSE. Using Our Research – Strengthening the Uptake Links, ATSE Focus, August 2011

ATSE. Innovation: Taking Australia's Technology to the Marketplace, ATSE Focus, August 2011

COHE, Absorbing Research: The Role of University Research in business and market innovation, April 2010

CIHE, CBR, Universities, Business and Knowledge Exchange, 2008

EIRMA, EUA, EARTO, Proton Europe, Responsible Partnering: Joining Forces if a World of Open Innovation – Guidelines for Collaborative Research and Knowledge Transfer Between Science and Industry, October, 2009

Group of Eight. The University-Innovation Nexus in Singapore. June 2012

Group of Eight. The University-Innovation Nexus in Finland. August 2012

Group of Eight. The University-Innovation Nexus in Australia. February 2012

National Academy of Engineering and National Research Council, Partnerships for Emerging Research Institutions – Report of a Workshop, Washington 2009

National Council of University Research administrators and the Industrial Research Institute, Guiding Principles for University-Industry Endeavours, April 2006

National Council of University Research administrators and the Industrial Research Institute, Living Studies in University-Industry Negotiations, April 2006

The Warren Centre. Steel – Framing the Future, 2007.

Journal Articles

Marcus Perkmaann and Ammon Salter, How to Create Productive Partnerships with Universities, MIT Sloan Management Review, Summer 2012

Randall Wright, How to Get the Most From University Relationships, MIT Sloan Management Review, Spring 2008.

John H Howard, Great Expectations: Developing Instruments for Engagement in University Business Relationships, September 2011

Jeremy Howells, Intermediation and the Role of Intermediaries in Innovation, Research Policy, 35, 2006

Industry Documents

Australian Steel Institute. NSW Manufacturing Industry Action Plan: Submission to the New South Wales Government

Australian Steel Institute, Capabilities of the Australian Steel Industry to Supply Major Projects in Australia, March 2010

Steel Supplier Advocate (Dennis O'Neill) Steel Supplier Advocate's Report for Australian Participation in Large Resource and Infrastructure Projects, December 2011

Press Releases

Group of Eight. Go8 Launches Research Gateway, 25 May 2011

Attachment 7: Extracts from Key Policy Documents

1. ASI: Capabilities of the Australian Steel Industry to Supply Major Projects in Australia - Extracts

The Australian steel industry consists of two main producers – BlueScope Steel Ltd and OneSteel Ltd, supported by over 200 steel distribution outlets throughout the country and numerous fabrication and engineering companies.

According to the Australian Bureau of Statistics, the entire Australian steel industry chain, from basic iron and steel production though to downstream users such as fabricators, employed over 91,000 Australians and generated almost $29 billion in turnover in 2005-061.

The value of iron and steel exports was $1.6 billion for the same period (see figure 1). Steel production is performed by BlueScope Steel and OneSteel and concentrated in NSW, Victoria and South Australia

Both steel companies have a combined production capacity of over nine million tonnes annually, compared to domestic consumption some s

even million tonnes (these figures do not include imports or exports of finished or semi-finished steel products).

Not all grades of steel are produced in Australia - Australia no longer produces stainless steel. The bulk of steel use is in the construction sector.

Fabrication

- ***Fabrication Overview***

The Australian structural steel sector is about equivalent in capacity to the highly regarded UK fabrication industry at between 1.6 and 2.0 million tonnes per annum but with a focus on the engineering projects sector.

One of the largest the steel industry sectors, Australian structural steel fabricators have committed heavily to new technology in recent times to meet the demands of new resources and infrastructure investments head on.

There has been a real increase in capability, capacity and competitiveness to take on major projects. A recent Australian Steel Institute survey, confirmed with ABS statistics shows $400million having been spent on new technology capital equipment since 2007.

This investment takes in the latest technology in new overhead cranes, plate rolling equipment, CNC beam lines, angle lines and plasma cutting lines.

The fabricators are increasing their capability and capacity and investing in Australia's future not only by installing new plant but also by keeping skills in Australia to build and maintain a sustainable steel manufacturing sector.

This investment has seen the fabrication steel processing capacity increase by close to 30 percent. The sector has ample capacity in reserve and is more cost competitive due to this recent investment in automation.

- ***General Fabrication***

The Australian fabrication industry is characterised by a very large number of fabricators with a total output of approximately 1.6million tonnes/annum including some product used in repetition manufacturing like lintels, truck body and trailer fabrication.

The medium and larger fabricators (2000–20,000 tonnes per annum) process approximately 1.1million tonnes with a large shift from labour-based fabrication to CNC, beam lining, angle lines and plasma and gas profile cutting. A trend is for fabricators to invest in detailing or to have close liaison with detailers to enable the benefits of computer files to drive their CNC equipment. Automotive processing is progressively being applied to plate profiling, line marking, identification marking, drilling and tapping and where required, weld preparation.

A characteristic of steel fabrication in recent years has been the move to introduce technology throughout the steel value chain, including processing facilities at distribution level.

New and innovative business models are being developed with better interface in the technology areas between engineers and detailers and the fabricator, flowing from the UK we are seeing an emergence of the Design and Construct Steel Contractor assuming an increased share of design and erection for the entire steel component.

Australian steel's market share for the industrial buildings market is worth approximately 120,000 tonnes a year, whilst its percentage of the multi-storey buildings market segment has grown over the past decade from three to about 13 per cent.

This market segment includes portal frame buildings like factories and warehouses and commercial buildings such as offices, shops, schools, health and civic facilities. Steel brings advantages in speed of construction, lightweight and reduced foundation costs and a smaller manufacturing footprint to the construction site as most fabrication is off-site in more secure and safer manufacturing environments.

The Australian fabrication industry capacity is extended by the outsourcing of some functions to specialist processors and coaters. A community of specialist subcontractors augment the fabrication capacity in:

- Steel detailing.
- Blast cleaning.
- Painting.
- Galvanising.
- Non-destructive testing.
- Grating and handrail manufacture.
- Bending.
- Transportation.

Fabricators will often specialise in structural steel, pipe fabrication, plate fabrication or mechanical fabrication. This has served the industry well, maintaining capability, cost effectiveness and flexibility. In fact, fabricators often specialise in certain market segments which makes them more competitive and profitable in these segments.

This paper assumes that reference to 'fabricators' covers all these disciplines.

The leading fabrication firms are equipped with state-of-the-art CNC automated fabrication equipment and are adept at utilising electronic information direct from the Engineer or Detailer to run fabrication machines. This improves cost and quality and enables 'just in time' processing and erection.

- ***Fabricator Quality***

The Australian steel industry is based around the integrated nature of Australian Standards.

For example the material specifications of Pipe and Tube (AS1163) and the structural sections Specification (AS3678) feed into the design requirements of AS4100 and AS3600 which are called up in the Building Code of Australia.

Significant to this structure is the welding code, AS1554. For special purpose welds, the welder needs to be qualified and tested and the equipment used calibrated and approved through the production of tested samples.

Australian fabricators maintain a system of apprenticeships to renew and update the skill levels in this country and to ensure training so that the skill sets to the relevant standards are maintained.

Similarly, the importance of a steel structure is dependent on the coating scheme which must be applied onsite or handled well to the site. These requirements defray significant on-costs from avoiding not getting the specification requirements right the first time.

Detailing

Australian detailers are widely sought and internationally recognised for application of advanced technologies and tight management with established relationships build from work in the US, Canada, East Asia, the UK and Africa.

For one, they have led the charge in Building Information Management (BIM), the process of generating and managing building data across its life cycle.

BIM uses three-dimensional, real-time, dynamic building modeling software to increase productivity in building design and construction, taking account of building geometry, spatial relationships, geography as well as quantities and properties of building materials.

Australian detailers have come to the fore on resource projects such the early stages on Woodside's LNG Train 4 and Pluto Project, Worsley's Alumina Expansion, and more extensively on various iron ore projects for BHP Billiton and Rio Tinto.

Benefits that have been realised from Australian detailers contributing to those iron ore projects encompass:

- ***Project schedule and cost savings***

Australian-based detailers keep projects on-time and on-budget through:

- Parallel managing of design and modeling stages.
- Delay mitigation during modeling ahead of construction.
- Project efficiencies through use of advanced BIM systems.
- Construction efficiencies by developing designs that avoid extra rework.
- Applying powerful multidiscipline inspection and clash detection tools.
- Achieving efficiencies through optimising use of datacentric information.
- Maximising workloads offsite.
- Using BIM tools to mitigate construction issues like RFI management.

- ***Improved safety***

Australian detailers enhance safety during project developments by:

- Employing visualisations for training, inductions, construction sequencing and project scope to anticipate potential site hazards.
- Minimising onsite work commotion by maximising offsite preassembly.
- Deploying powerful intelligent multi-disciplined clash detection to ensure better design for more responsible construction and operating plant.

- ***Environmental care***

Steel detailers in Australia help to safeguard the environment through:

- Better planning that reduces site needs for lay-down areas.
- Facilitating improved site handling and less material wastage.

- ***Experience and quality***

Australian detailers are typically independent dedicated specialists who bring a higher level of expertise than a typical detailer associated with a fabricator. They generally have a higher level of industry experience due to the high portion of resource projects than commercial type work and this experience provides resource clients with risk mitigation by providing a more professional design verification process.

With close familiarity with advanced 3D systems, Australian detailers mitigate delays and site rectification costs. Leading Australian detailers are on record for very low rates of rework averaging just 0.01 per cent.

With modularisation becoming more popular, steel supply and fabrication is typically falling on the critical path and owners are therefore engaging detailers that have high productivity rates, efficiencies and quality to mitigate typical engineering delays and maintain schedule.

Australian detailers boast a proven track record on a number of large resource projects with productivity rates of two to three times that of low-cost Asian workshops.

- ***Technology***

One of the reasons why Australian detailers lead the implementation of BIM technologies is due to their advanced knowledge of various 3D modeling technologies as required to maintain a competitive edge against low-cost centres.

They have systems and personnel that understand the complexity of providing accurate data to achieve the benefits of the BIM concept. In addition to the industry standard detailing packages such as Bocad, ProSteel, StruCad and Tekla Structures, specialised proprietary systems are also embraced.

Hot Dip Galvanising

Hot dip galvanizing with a history of 170 years, commands an unrivalled reputation as a cost effective and efficient system of corrosion protection for steel assets. In Australia, there are examples of hot dip galvanising that have managed to survive in the harshest conditions for 130 years. Galvanising is prepared off-site in controlled conditions to reduce labour costs, minimise maintenance and ensure environmental cleanliness.

This is of critical importance in meeting the environmental demands of many Australian projects. In most cases, this gives hot dip galvanising a competitive first cost and life cycle cost in comparison to other high performance corrosion protection systems.

The hot dip galvanising industry in Australia is experienced in the delivery of large infrastructure and resources projects and most of the plants offer large galvanising baths and state-of-the-art processes by global standards. Hot dip galvanising of steel structures for large infrastructure and process plant has become more common in recent years and this gives Australian galvanisers proven expertise in the delivery of such projects.

The industry is active in global innovation and technology exchange through the Galvanizers Association of Australia (GAA). Members of the GAA have access to technical expertise on corrosion issues, case studies and are part of an international network.

All of this backup can be utilised by project managers and asset owners in the delivery of their projects. The services provided by the Australian galvanising industry include assistance in the design of steelwork and detailing to meet the requirements of superior corrosion protection (eg; meeting Australian standards or others as required), chamfering/rounding of sharp edges, using the most effective methods of venting and draining work, and designing for maximum corrosion protection through initial product design.

Due to the large distances often encountered in Australia, the galvanising industry has developed proficiency in overcoming logistical challenges. Experience in transport coupled with the geographical distribution of galvanising plants (some in regional areas) gives the industry outstanding coverage and capability in meeting the requirements of all major projects.

The selection of materials for use in all industries and applications requires innovative design and selection. Infrastructure assets not only need to withstand the rigours of everyday use, but these days they need to reduce their economic and environmental impact by reducing maintenance and also their environmental footprint. Designers are beginning to appreciate the fact that galvanised steel is a material with superior corrosion resistance, abrasion and mechanical resistance and environmentally friendly qualities.

Hot dip galvanising provides a robust protective finish and minimises site work and ongoing maintenance. Its robustness and ability to withstand 'rough' handling also provides security during transport that reduces or eliminates the requirement for final dressing and touch up on site to maintain corrosion protection integrity prior to erection and installation – a significant factor when dealing with the remoteness of many Australian locations.

Galvanising and steel combine to produce a cost effective sustainable building material that is totally recyclable and which is proven through a long list of successful local case studies.

Protective Coatings

The use of coatings in the protection of steel substrates from the natural process of corrosion formation is required to minimise the cost and risk associated with corrosion on major oil and gas projects.

Annual corrosion costs in Australia are generally accepted to be between two to five per cent of Australia's GDP.i According to the Australian Corrosion Association (ACA), that cost was estimated to be $28 billion in 2006.

- ***What is Corrosion?***

There are many definitions of corrosion, however, two common ones are:

- Corrosion is the deterioration of a material, (usually steel), because of a reaction with its environment.
- The destruction of steel by an electrochemical process that is recognised by the formation of rust or pits.

These two definitions bring together the idea of an environment and the electrochemical process which are fundamental in understanding corrosion in terms of why it occurs and how it can be prevented.

- ***Consequences of corrosion***

As steel corrodes, it deteriorates as more iron oxide is produced. This causes a reduction in the steel's structural integrity in terms of its fundamental properties which make it such an ideal cost effective and reliable construction material (ie: tensile strength, toughness and flexibility).

Consider steel constructions such as offshore structures, stadiums and bridges that must support the weight of extreme loadings and provide a safe working environment and the catastrophe of potential structural failure due to corrosion. What price has the loss of life?

This simple, very natural, electrochemical process can be very costly! The latest figures for the USA suggest that corrosion costs approx $276 Billion per year!

- ***Specifications for Major Projects***

The onset of corrosion can be effectively controlled by a protective coating specification that outlines a paint system being a product or combination of products as well as appropriate surface preparation methodologies.

Consideration of the specifications at the early stages of a major project will assist in determining the most cost effective coatings solutions for the life of the asset.

In selecting a coating system it is important to understand the:

- Construction of a structure.
- Environment and location.
- Profile of the project and aesthetic requirements.
- Expected lifetime of the structure prior to first major maintenance.

To ensure correct specification and advice is received, certain Australian paint manufacturers can offer NACE (National Association of Corrosion Engineers) qualified personnel to minimise risk and costs associated with the potential onset of corrosion.

Grating and Handrails

ASI members, Webforge and The Graham Group manufacture grating in numerous combinations of load bar depth and thickness, load bar pitch and cross rod pitch.

Steel grating is suited to many applications, from light-duty applications (maintenance floors, occasion usage), though light/medium duty applications (residential, light industrial occasional public usage), medium duty applications (mining and commercial, regular or medium industrial usage), heavy duty applications (heavy industrial, mining and trolleys and industrial equipment), and extra heavy duty applications (frequent impact from trolleys).

Both companies supply a complete range of mild steel grates in compliance with the load and permanent set requirements specified in AS3996-1992. Conformance certificates can be supplied upon request. They are also capable of custom manufacturing Mild Steel Grates and Frames to suit specific client applications and load test according to AS3996-1992 if required.

Quality and Standards

Australia's two fully integrated steel manufacturers OneSteel and BlueScope Steel have a long and proud history of manufacturing structural steel in Australia. Both steel companies manufacture product to Australian and International Standards, providing a known level of quality with full traceability.

Over the years, the Australian Standards used for structural steel design have developed, reflecting improved understanding of material performance, structural behaviour and design processes.

Sites producing steel in Australia have a quality policy to guide process control to ensure product quality. All manufacturing facilities have quality management systems accredited to ISO 9001:2008. This accreditation is actively maintained and audited, ensuring a mature and fully functional system.

Manufacturers are committed to the principles of quality assurance, thereby increasing the customers' confidence of the project being delivered to the required quality standards. Steel manufacturers are active in the development of improved product, fabrication and steel design standards.

Welding and Testing

Welding is an economical method of joining materials, enabling transmission of large critical loads that may be static and/or dynamic under various conditions (high/low temperature, etc). The welding and related testing industry in Australia is highly sophisticated and is on par, if not exceeds the service requirements and outputs of many similar industries around the world.

Industrial applications in Australia are well serviced by specialist and general welding and testing contractors including experienced and qualified structural steel fabricators, boilermakers, pressure piping and mechanical contractors. Such contractors have been successfully engaged in many and various complex and high-profile welding applications both in Australia and abroad.

Complex and economical welded fabrication has been readily achieved with Australian welding contractors. Such positive outcomes have been due to rigorous welding, certification, testing and inspection as embraced by the local industry via Standards Australia, International Institute of Welding (IIW), International Standards Organisation (ISO) and other national standards (ASME, etc). The development and utilisation of such standards has taken place for many years.

Steel Reinforcing

The Steel Reinforcement Institute of Australia (SRIA) is a national non-profit organisation providing a high quality technical support and information service to the Australian building industry on the use of reinforcing steel in concrete, primarily reinforcing bar (Rebar) and reinforcing mesh (Reomesh). SRIA is funded and supported by the vast majority of the manufacturers and suppliers of steel reinforcing used in Australian construction.

The SRIA offers practical solutions to meet the diverse and ever changing needs of the Australian building industry. The organisation actively supports and encourages the use of Australian capability and quality in the processing and use of reinforcing steel in concrete in an increasingly competitive global market.

Whole of Industry Cooperation

- ***Working together***

The steel value chain has a very long and proud history of cooperation and banding together to get the job done in the most efficient way. The value chain is very strongly linked from manufacturer to distributor to fabricator as customers and suppliers, each of whom works seamlessly with the various other associated links including, engineers, architects, design detailers, painters, galvanisers, erectors and others to ensure that a solution is delivered to the end-users' satisfaction.

The Australian Steel Institute (ASI) also has long established links with a number of key industry bodies that supports the steel industry including; Engineers Australia, the Architects Institute of Australia, the Australian Industry Group, the Building Products Innovation Council, and other key associations who interact with the steel industry.

The ASI and the industry in general also work closely with the trade union movement and the specific relevant unions that work within the steel sector including the Australian Workers Union, Australian Metal Workers Union, National Union of Workers and the Construction Forestry Mining and Energy Union.

- ***Steel Industry Innovation Council***

Recently the Australian Federal Government's Minister for Innovation, Industry, Science and Research, Senator the Hon. Kim Carr established the Steel Industry innovation Council, under the guidance of his own Government Department. The Council includes senior representatives from the steel manufacturers, the ASI, trade unions and the academic and research community.

The Council supports the long term sustainability and competiveness of the Australian steel value chain. This includes boosting demand for Australian steel and looking at innovation to support international competitiveness.

The Council is a forum for steel industry stakeholders to form a whole-of-industry perspective on key issues and as a collective, presents its advice to the Minister. The Council operates at a high strategic level to identify and address impediments in achieving the goal of maintaining a competitive and sustainable industry in an increasingly global marketplace.

To achieve the goal of maintaining our international competitiveness into the next decade, the Council promotes innovation for the Australian steel industry. This includes promotion of improvements in the steel value chain, from the raw steel production stage; right through to fabrication of the many forms of end-user steel products.

Another key resource and appointment by the Minister is the Steel Supplier Advocate (the Advocate) to provide leadership and act as a champion for the Australian steel industry in the market for major steel consuming projects. The Advocate also works along the Australian steel value chain with those from the major producers to fabrication by small and medium sized enterprises (SMEs) to improve their competitiveness and coordinate support from the Industry Capability Network, Enterprise Connect, Austrade and other Government agencies.

Safety

The Australian steel industry ensures the safety of its employees is its Number One priority.

All Australian steel manufacturers conform to the Australian Standard AS 4801 which sets out requirements for implementing, auditing and certifying Occupational Health and Safety Management systems.

Whilst all the industry companies work diligently on safety individually, the ASI also convenes a National Industry Safety Committee that is represented by all sectors of its membership.

This is underpinned by State safety committees consisting of all industry sectors such as fabrication, coatings, transport, distribution, manufacturing and industry suppliers. The vision of these committees is simple - A Safer Steel Industry.

These committees aim to cultivate a healthier and safer steel industry through promotion safety leadership, educational support and sharing initiatives. Their core principles are that

- All injuries and work-related illnesses can and must be prevented.
- Management is responsible and accountable for health and safety performance.
- Employee engagement and training is essential.
- Working safely is a right of employment.
- Excellent health and safety performance at work supports excellent business results and health and safety must be integrated in all business management processes to bolster that.

Environment and sustainability

The Australian steel industry takes its environmental and sustainability responsibilities very seriously. The two Australian steel manufacturers BlueScope Steel and OneSteel have environmental management systems to ISO14001 and are party to a convention on sustainable development established through World Steel, the international steel institute representing the major steel manufacturers and steel associations globally.

That policy lists the commitments made by its member companies to address the economic, environmental and social sustainability of their businesses and to engage in constructive and open dialogue with their stakeholders.

Eleven indicators have been developed to measure economic, environmental and social performance to systematically measure progress in steel's sustainable development. These measurements now form the basis of The Sustainability Report of the World Steel Industry –Steel: the Foundation of a Sustainable Future and are acting as benchmarks in the drive for world steel industry improvement.

These steel manufacturers are also members of the Climate Action Group which seeks to provide carbon breakthroughs by the sharing of data and technologies.

The ASI is also a member of World Steel and is working to provide a global approach to sustainability.

World Steel has joined the United Nations Environmental Program (UNEP), is a member of the International Life Cycle Board and has released global life cycle data to enable the impact of steel in a global sense to be included into Life Cycle Analysis (LCA) models so that preliminary estimates of steel in carbon impact studies can be made.

Locally, the ASI has been working through the venue of the Building Products Innovation Council (BPIC) to understand and agree on processes and measures for LCA to determine the environmental impacts of all building system materials. This three-year project will be concluded in approximately 12 months (early 2011).

The aim is to provide universally agreed information upon which the Australian construction industry can produce the lowest long-term environmental impacts.

Australian steel's environmental movement is given industry-wide thrust through the work of the ASI's dedicated Sustainability Committee which comprises sustainability experts, including those from the major Australian steel producers, who meet regularly on initiatives supporting steel's improving environmental performance and to promote adoption of the latest sustainability advances to members.

A cleaner industry

Australian steel manufacturers and supply chain are taking sustainability seriously and are devoting considerable resources to understanding and minimising environmental impacts from operations and design and operation of their products.

Currently in Australia, it is estimated that 82 percent of all steel products are recovered from building demolition ranging from 95 percent for structural steel (world class recovery) to 70-80 percent for reinforcing steel.

An estimated 2.6 to 2.8 million tonnes of steel is available for recycling in Australia each year. This is improving as the scrap value increases. In a report recently commissioned by Hyder for the 2007-2008 financial year, only 299,681 tonnes of 2.6 million total tonnes was disposed of in landfill, while a massive 2.54 million tonnes was recovered for recycling.

In Australia about 2.7 million tonnes are recycled annually, a substantial part of the eight million tonnes produced. Continuous improvement in eco-efficiency during production, world class recycling rates and product development combined with design flexibility and innovation ensure that steel will continue to make a positive contribution to the life cycle performance of the built environment in Australia.

Australia's rigorous environmental standards and industry strides are matched by the steel mills' widespread use of cleaner technologies to save precious resources like water and energy.

AIP Plans and EPBS guidelines

- ***Australian Industry Participation Plans***

Major infrastructure and resource projects in Australia source a significant proportion of manufactured components and capital equipment from overseas even though local capability exists. Government wants to encourage the maximum level of local content in goods, services and labour for major projects where these are competitive in price, quality, and delivery requirements.

To address this issue, Federal and State Governments have developed Industry Participation Plans (IPPs). The purpose of these plans is to encourage major project proponents to provide fair and equal opportunity to local business to supply. It must be emphasised that IPPs do not mandate that Australian business tenders will be selected.

The policy intent of IPPs is to:

- Promote Australian capability.
- Maximise opportunities for Australian industry, especially small to medium enterprises (SMEs) to participate in major projects in Australia and overseas.
- To adopt a national approach to major projects.

- ***AIP Framework is FTA and WTO compliant***

State and Territory Industry Participation schemes have been developed to be consistent with Australia's national and international obligations, including the Australian Industry Participation Framework (AIPF) and the Australia New Zealand Government Procurement Agreement (ANZGPA). Further details are available at www.apcc.gov.au.

Other factors influencing the policy development of these schemes include:

- The World Trade Organisation (WTO).
- Australian National Competition Policy and other Commonwealth Legislation.
- Other treaties and Free trade Agreements.

- ***Australian Industry Participation Framework***

The Australian Industry Participation Framework (AIPF) has been signed by Australia's Industry Ministers and gives effect to their commitment to provide Australian industry will full, fair and reasonable opportunity to actively participate in investment projects. The framework encourages all spheres of government to adopt a coordinated approach to maximising Australian industry participation in investment projects, both in Australia and overseas.

- ***Enhanced Project By-laws Scheme (EPBS)***

The EPBS is a Commonwealth Government program which provides an avenue for duty concessions in certain circumstances for imported eligible goods, including machinery, equipment and their components, for projects approved under the Scheme. Access to the benefits of this relief is subject to the terms of Item 71 and the policy and administrative criteria set out in those Guidelines.

All applications for duty concession under the EPBS are assessed against industry policy objectives as determined by the Government. The Minister for Innovation, Industry, Science and Research is responsible for the underlying policy guidelines and administration of the EPBS.

The EPBS is administered by AusIndustry on behalf of the Minister and policy advice is provided by the Industry and Small Business Policy Division and the Manufacturing Division of the Department of Innovation, Industry, Science and Research.

The Tariff Act imposes duties on certain imported goods. Schedule 3 to the Tariff Act establishes the rate of duty to be paid on goods imported to Australia. Under certain conditions, the Government may grant duty concessions in respect of particular imported goods. Schedule 4 to the Tariff Act outlines the duty concessions available.

Sections 8 and 18 of the Tariff Act provide the authority for goods specified in Schedule 4 to be imported at a rate below that set out in Schedule 3. The items contained in Schedule 4 provide the legal basis for the concessional entry of certain imported goods in prescribed circumstances.

Determinations to permit the concessional entry of eligible goods under the EPBS are made under section 273 of the Customs Act 1901.

The EPBS duty concession is directed at eligible goods including machinery, equipment and their components. Goods such as spare parts beyond the commissioning of the project and general consumables such as paints, lubricants, fuel etc are ineligible under the EPBS.

2. DIISR: Trends in Manufacturing to 2020

- **Future Manufacturing Industry Innovation Council, *Trends in Manufacturing to 2020,* DIISR, September 2011**

Executive summary

Australian manufacturing is a diverse and vibrant industry that plays a significant role in the economy. The industry employs close to one million people and its of total industry gross value-add was 10 per cent in 2010-11. In addition, manufactures accounted for one third of Australian exports.

Manufacturing is also an important driver of innovation in industry – being responsible for a quarter of research and development among businesses.

The industry is faced with both challenges and opportunities. Some of these are shorter term 'shocks', while others are longer term trends. Some, such as globalisation, ageing workforce and the small size of the Australian domestic market have been recognised for some time. Others are more recent, including requirements for low carbon production, the impact of terms of trade and the associated rise in the exchange rate of the Australian dollar.

Global 'megatrends' resulting from population growth, economic growth, urbanisation, peak resources and societal changes are contributing both opportunities and threats over the medium term.

Technology, such as information and communication technologies and emerging technologies, is also driving 'disruptive' changes, providing major opportunities and challenges in product and production innovation which will enable the Australian manufacturing industry to respond positively to the challenges and opportunities.

A robust manufacturing sector of the future requires firms that are not only technologically sophisticated, but are also agile, adaptive, and efficient. This is only possible in firms that are knowledgeable, innovative and well managed, and which have access to skills as well as capital. Such assets provide the absorptive capacity needed by successful firms to embrace new knowledge, technology and innovative practices to increase productivity and competitiveness.

Thus, the resilience or robustness of Australian manufacturing lies in firms that:

- recognise that to succeed in the high value-add, low volume products in which they are likely to have a competitive advantage, they must bundle products and services to sell solutions, rather than simply tangible products;
- have the capability to identify, design, develop, make and sell products and services that are in demand;
- operate with high efficiency and productivity, allowing them to optimise the use of their capital – human, intellectual and material;
- have the ability to maximise leverage from strong and sustainable partnerships through local and global supply chains; and
- that seek markets in emerging growth economies, both by partnering in global supply chains, and by meeting demands from their growing middle classes for high value add niche products, rather than low cost commodities.

Finally, there is often a tendency to view the innovation needs of an industry through a sectoral lens. A more system-wide approach to building an innovation system is required.

Policies and programs that support the development of knowledge, skills, competencies and capabilities that can be effectively translated across industry sectors are likely to contribute to the future robustness of Australian manufacturing.

Australian manufacturers operate in an increasingly competitive global environment is constantly changing, where many factors that affect the future of manufacturing are out of the direct control of firms. A good example of this is the impact of currency exchange rates that are putting pressure on Australian manufacturers now, in terms of export competitiveness. Furthermore, a range of mega-trends appears to be increasingly important and may remain in effect over the medium to long term.

Achieving a robust Australian manufacturing sector in the future will require ambitious vision, sound strategy and development of capabilities for manufacturing companies to stay competitive, profitable and sustainable over the long term.

A robust manufacturing sector of the future requires firms that are not only technologically savvy, but are also agile, flexible, adaptive, and efficient. This is only possible in firms that are knowledgeable, innovative and well managed, and which have access to information, technology and innovative practices as well as capital. More importantly, firms need to have the absorptive capacity to embrace new knowledge, technology and innovative practices.

Thus, the resilience or robustness of an industry sector will depend on the ability of its firms to adapt quickly to meet challenges and capture emerging opportunities. This requires that firms:

- Recognise that to succeed in the high value-add, low volume products in which Australian manufacturing is likely to have a competitive advantage, they must bundle products and services to sell solutions, rather than simply tangible products.
- Have the absorptive capacity to embrace the latest technological and business process innovations that provide competitive advantage.
- Have ready access to knowledge and world class capabilities that allow innovation and rapid adaption to changing market needs, tapping into innovative practices and building sustainable and profitable partnerships both domestically and globally.
- Have the capability to design, develop, make and sell products and services that are in demand.
- Operate with high efficiency and productivity, allowing them to optimise the use of their capital – human, intellectual and material.
- Have resilience in a low carbon and resource-constrained economy through resource efficiency.
- Have the ability to maximise leverage from strong and sustainable partnerships through local and global supply chains.
- Secure supply of resource inputs and skills, by direct acquisition, partnering or engaging in global supply chains.
- Harness technology and business process innovation that provides differentiation and competitive advantage. The continued evolution of ICTs, such as cloud computing, provides opportunities for enhancing firm productivity, marketing and product and service delivery.
- Possess the organisational flexibility to rapidly adapt to changing market needs – including changing their mix of skills and production technologies.
- Seek markets in the growing BRIC countries, both by partnering with them in global supply chains, and by meeting demands from their growing middle classes for niche and bespoke consumer products.

Global competitiveness requires world class capabilities that are effectively utilised. A key imperative is to ensure capabilities in supply chains for those sectors that are important to achieve a robust future for Australian manufacturing.

There is a broad consensus that Australia is not deriving the full benefits of our research investment; especially from publicly funded research. Hence it is imperative to improve the strategic alignment between the output from research organisations and industry/market demands. This will only come about through greater engagement and linkage between providers and users (and potential users) of research to ensure that there is an appropriate balance between 'push' from research organisations and 'pull' from firms that can benefit from research. Understanding trends and potential opportunities in the future will also be crucial in establishing a globally competitive manufacturing sector.

There is often a tendency to view the innovation needs of an industry through a sectoral lens. *This needs to shift to a more system-wide approach to building an innovation system that supports a robust future for the entire Australian manufacturing sector.* It would appear that policies and programs that support the development of knowledge, skills, competencies and capabilities that can be effectively translated across industry sectors are likely to contribute to the future robustness of manufacturing.

The future robustness of Australian manufacturing is also dependent on how well firms operate across complex global supply chains. This requires not only comprehensive knowledge of emerging market needs but also localised knowledge to facilitate adaptability to changing environmental and legislative landscapes in export markets. In particular, Australian firms need to be aware of environmental legislation that is increasingly becoming operational. This presents both a challenge as well as an opportunity to tap into an emerging greener global economy.

Having access to world-class capabilities and knowledge is important for a firm’s future competitive advantage. However, it is equally important that a firm has the ability to absorb new knowledge and translate it into practice. Industry, the research community and government need to develop policies and initiatives that raise the capabilities and capacity of firms to absorb innovation in all its forms, to ensure that manufacturing firms of the future are adaptive, agile and innovative.

3. Howard Partners: The Role of Intermediaries in the Innovation System

A survey conducted by Howard Partners found that companies rated as 'important' or 'very important' the following reasons for accessing intermediary services:

- Technology acquisition—all companies.
- Accessing funding and support for innovation projects—63 per cent of companies.
- Product testing and scale up—50 per cent of companies.
- Product development—38 per cent of companies.
- A mediator with bodies already collaborating—25 per cent of companies.
- Brokering a transaction between two parties—19 per cent of companies.

The survey and interviews also found that three quarters of companies had been contacted directly by the intermediary organisation to offer intermediary support. This finding reflects a lack of knowledge within companies of intermediary organisations and what they can do.

Surveyed companies did not identify any immediate benefits from intermediaries in terms of *realised* increases in profitability, productivity, employment or new products entering the market. Several companies advised of *expected* increases in these performance metrics over the next few years as a result of intermediary services.

Surveyed companies reported a number of indirect and intangible benefits of intermediary services, including enhanced strategic management capabilities and business culture (five companies), enhanced innovation capability (11 companies) enhanced collaboration and networking capabilities (14 companies) and increased access to know how and best practice (10 companies).

These findings point to the importance of the *personal/professional contribution* of intermediary services and intermediary staff to building business capability. The extent to which this enhanced capability will be reflected in future economic outcomes is uncertain at this stage. However, the strategic management and innovation literature points to the close association between investment in capability and business success.

A major finding emerging from the interviews undertaken as part of the Study was that intermediaries need to have excellent communication skills and be exceptionally well networked across industry and the research sector, as well as possessing reputation, integrity, and credibility with business, research organisations, and government program managers. They must also understand how a research organisation works—in terms of its mission, its structure, systems, and processes, and the way it measures its achievements and rewards success.

The survey and interviews found that the ability of an intermediary to provide funding for small collaborations is highly regarded by participating companies and other stakeholders. The funding arrangement provides flexibility and speed in responding to collaboration opportunities.

The Study reviewed some intermediary support programs in Europe and North America. The range of programs varies in structure and in the form of support provided:

- A number of programs provide support for brokering roles, such as the Canadian IRAP program and the European Innovation Relay Centre (IRC) program.
- Several programs provide funding for collaborations, such as the UK Knowledge Transfer Partnerships (KTP) program.
- There are also many networking support programs that operate at the state/regional level in Federal systems (or at the 'national' level in small EU states).

It is clear that a great deal has been learned from the pilot programs and there is an opportunity to go to a next stage in providing support for intermediary roles that meet the technology and knowledge access needs and requirements of Australian companies, particularly SMEs. Such support could consider the following possible actions and initiatives:

- Selection, through competitive tender, of a panel of accredited intermediary organisations, to provide the range of intermediary services currently provided in the pilots. Selection should be made on the basis of knowledge of technologies, their *national and international* networks, their communication skills, and their ability to work with SMEs and research organisations.

- Funding SMEs to acquire intermediary services from accredited intermediary organisations on the basis of an identified need to access and/or acquire business relevant and applicable technologies/and or knowledge capabilities through collaboration arrangements. The funding decision should be made by an independent third party.
- Access to knowledge not being limited to *scientific and technical knowledge*—it should also include knowledge related to *industrial design capabilities.*
- Intermediary services should focus on: articulating technology need; finding Australian and international partners; advising on sources of innovation financing; management of intellectual property rights; marketing; and providing assistance with contract negotiations.
- Support for the formation of an *intermediary information and knowledge network* to enable regionally based intermediary organisations to share and access technologies and knowledge.

As the Study was oriented towards the role of intermediaries in the Australian innovation system, it did not look in detail at the role of Research and Technology Organisations—a feature of the British and European systems. These organisations have been formed by *industry/trade associations* and have been closely involved in the establishment and operation of an 'interface' between research organisations and business.

RTOs exhibit a wide variation in their genesis, longevity, modes of governance, and sources of finance (European Research Advisory Board). However, this form of organisation has been the main focus of scholarly research on intermediaries in these countries (Howells 2006; Howells et al. 1998; Howells and James 2001).

In Australia, few industry associations have taken an active role in national innovation systems. Associations such as AEEMA stand out but most industry associations take on a lobbying role in relation to innovation and focus more on industrial relations agendas.

4. Howard Partners: Outlook for Small Business Manufacturing to 2015

Executive summary

Business growth and development is fundamental to employment growth and national economic prosperity.

This can only be achieved if business is internationally competitive and capable of sustaining world-class levels of performance. This applies to all business – large and small. By helping individual businesses to succeed, the Government can help improve the competitiveness of the nation as a whole.

In manufacturing, with the progressive removal of protection over the last 20 years, the performance of

Australia's large businesses has been found wanting. By contrast, Australia's small businesses are proving to be innovative, dynamic and responsive to opportunities and challenges. In the current environment, with the slide in the value of the Australian dollar relative to the US dollar, and the progressive freeing up of the international trading system, there are major prospects for manufacturing.

Manufacturing in the year 2001 is characterised as being:

- Globalised, in the sense that a wide range of functions from R&D and marketing to production and distribution are now undertaken on an integrate global basis
- Knowledge based – it will involve grater application of science based technologies in processes and products
- Networked, in that the coordination of these functions make intensive use of electronic networks and of virtual and geographical clusters of expertise
- Customised, in that methods of production must allow for detailed customisation of products to meet the needs of individual markets and individual consumers
- Digitised, in the sense that many of these processes, and particularly final production, are controlled by advanced computers systems that limit the need for human intervention

It will also reflect business trends towards cooperation and collaboration on a regional, national and global basis. These influences will have a major impact on the way manufacturing is undertaken in the future.

This study has looked at small business manufacturing in NSW in 2001 to understand the strategic, commercial and management issues that they face. It has then brought a vast array of research, knowledge and expertise to understand the challenges and opportunities facing these firms in 2015. A range of scenarios and

Australia's small businesses are proving to be innovative, dynamic and responsive to opportunities and challenges.

As part of the assignment we have sought to obtain the views of successful an innovative small business manufacturing companies. Companies were identified from the following sources:

- The ABL/Industry Science and Resources case studies of innovative companies
- The nominees for Australian Export Awards
- Companies that have received venture capital funding.

These companies are listed in Appendix 5. The success stories of these companies are documented in a number of sources. Their success reflects a number of characteristics associated with "innovation" and are referenced throughout the Report.

The overwhelming find is that small business manufacturing does not have to be big to be global. In fact, we argue that small business manufacturing has distinct advantages over the larger firms. In areas such as the ability to change business direction quickly, enter new markets, develop highly specialised skills, knowledge and expertise for a well defined niche market, form strategic alliances with both competitors and colleagues, adopt new technology, and be close to the customer, are within the power of the small business manufacturer and it is a power that may have and will continue with growing gusto, to exploit.

In particular, the study found that electronic commerce makes personal relationships even more important.

Small business manufacturers must "get on a plane" and travel to their potential markets, and engage their markets. They must understand their customers better than their competition. Having a superior product that is cost effective to produce and well priced is not enough:

in other words, being competitive is a given. The future will demand the small business manufacturer to identify and carve out a small niche market. Businesses will become smaller, highly specialised and continuously research, develop and innovate to stay ahead.

In the technology environment, business owners and managers need to understand that the Internet is, fundamentally, a means of communication. It allows for the transmission of digitised information very quickly over long distances. It also allows for close collaboration between suppliers and customers – but almost paradoxically requires the development and maintenance of a much closer personal relationship with customers.

Small business manufacturing does not have to be big to be global. In fact, small business manufacturing has distinct advantages over the larger firms in a global environment

The future will demand the small business manufacturer to identify and carve out a small niche market. Businesses will become smaller, highly specialised and increasingly technology based

There are a number of specific attributes and characteristics that manufacturing businesses will need to develop to meet emerging challenges and opportunities in the "information economy". These include:

- Information technology competence - small business managers will find that over the next 15 years they will have to fully embrace information technology in the management of their business. Information technology is now recognised for its strategic importance as well as its contributions to operations and "back office" support.

- Technology awareness and access – managers will need to identify the sources of technology competence and capability that may assist in business development and growth. State government awareness and diffusion programs and industry association initiatives can facilitate this process.
- Access to competent, expert and independent advice – investment in information technology – both hardware and software- can be expensive. Many people selling information technology products and solutions, particularly at the small business end of the market, have never actually worked in a business.
- Advice should be sought from business associations and through industry networks.

Access to finance to fund business development and expansion has been an ongoing issue for small manufacturing businesses. There can be no doubt that this issue will continue to be of importance. Investors, whether providing equity or debt, are interested in what is now termed the "value proposition" – how value will be created through the productivity of the capital investment that is made. In addition to this fundamental issue of return on investment, investors also look at other factors such as the risks and how these will be managed, commitment to innovation and continual product development and the actual marketability of new technology products.

Small businesses, and even large businesses, no longer maintain, or wish to maintain all of the capability they require to meet customer needs. Moreover, for many reasons small businesses want to stay small – they do not want to take the risks associated with major capital investment decisions to increase capacity in a market place that is becoming uncertain.

To meet new business challenges, small businesses are increasingly working in local, regional and even networks where capability is shared and accessed on a collaborative basis. Small manufacturing businesses should explore every opportunity to participate in regional and national business networks as a basis for sharing information and knowledge about market opportunities, technology developments and business practices. One of the most important issues for the future of small manufacturing business will be demonstrating a "value proposition" and the capacity to manage business risk

In the emerging business environment, businesses will need to develop "alliance "competence – that, a capacity to work in cooperative and collaborative arrangements based on reciprocity and trust. Over the next 15 years alliances between small businesses, small and large businesses and between small businesses and research organizations will become central to business activity and success. The management of alliances is anything but easy. They require extreme, and often totally unaccustomed clarity in respect of objectives, strategies, policies and relationships.

In the context of alliances, partnerships and networks, the next 15 years will require the development and maintenance of new forms of business organization – new ways of doing business will need to be explored with a sharing of risk and reward between parties. In this "virtual" environment management and leadership will become more critical for success.

5. Howard Partners: Digital factories – The Hidden Revolution in Australian Manufacturing

Through its capacity to integrate and blend a number of knowledge intensive technologies, ICT can enable Australia's traditional manufacturing base to be competitive in a global environment. Innovative use of ICT can result in new sales channels, new product capabilities and product differentiation. ICT can also reduce costs, increase productivity and improve the base for strategic decision-making and risk management. These results should be reflected in enhanced business performance – as indicated by sustained profitability and viability.

A distinction is often made in the manufacturing sector between information technology, which relates to the corporate and business activities of a company, and process control, which relates to the management of production activities. As process control devices move from electrical to electronic (and from analogue to digital) instrumentation, and incorporate more integrated circuitry with a capacity to generate very substantial amounts of information, the technological distinction between ICT and process control becomes blurred.

The study confirms the pervasiveness of ICT throughout the manufacturing industry. The scope of ICT embraces:

- Corporate systems that are oriented towards enterprise resource planning (ERP), supply chain management (SCM) and customer relationship management (CRM).
- Manufacturing systems such as product lifecycle management (including computer assisted design and manufacture (CAD/CAM)) and process execution (such as supervisory control and data acquisition (SCADA) systems).
- Control systems for programmable logic controllers (PLCs), robots and other hardware embedded in machines and equipment
- Monitoring and surveillance systems used in relation to functions such as security, health and occupational safety, and the building and work environment.
- Extensive incorporation of ICT in products and services.

The pervasive role of ICT in manufacturing has been largely overlooked in contemporary discussion and commentary relating to the information and knowledge economy. For example: ICT enabled devices used in production operations are usually described as 'control hardware' and the software that drives them as 'process control systems'; production machinery and a large range of industrial equipment that incorporate ICT hardware and software, including precision tools and welding devices, are rarely described as computer equipment.

Whilst having the technical characteristics of computers, these ICT enabled devices and equipment do not look like computers in that they do not have screens, keyboards, mice and other peripherals attached to them.

Common measures of ICT intensity in industry are frequently based on counts of the screens and keyboards – presupposing an office paradigm and a services sector orientation. ICT intensity defined in terms of programmed processing units would provide a better indicator of integrated or embedded ICT across all industry sectors.

Given the pervasiveness of ICT, the potential for ICT enabled productivity and performance improvement goes far beyond electronic commerce and merchandising across the Internet. However, the study indicates that as with all technologies, the impact of ICT in manufacturing derives from the way in which technologies are adopted, applied and used in business contexts.

- ***ICT applications***

ICT is embedded in tools and equipment used for cutting, moulding and joining. In many of these areas, the high levels of accuracy and precision required in cutting, shaping, moulding and welding can only be achieved by machinery that has embedded ICT design and control systems

In broad terms, ICT applications in manufacturing include the following (National Academy of Sciences 2003a):

Hardware –

- Computers and processors – workstations, mainframes, servers, personal digital assistants, programmable logic controllers (PLCs), bar code readers.
- Communications devices and infrastructure – telephone, local area network, wide area network, wireless networks, radio frequency identification devices (RFIDs).
- Actuators or effectors – robot arms, automated ground vehicles, numerically controlled cutters, micro-actuators.
- Sensors – dimensional gauges, machine vision, tactile and force sensors, temperature sensors, pressure sensors.

Software –

- Commodity products, acquired 'off the shelf' – such as operating systems, enterprise resource planning (ERP) systems, customer relationship management (CRM) systems, supervisory control and data acquisition (SCADA) systems, decision support packages.
- Differentiable and customisable products – such as process models and algorithms, business process configurations.
- Software for the storage and management of intellectual property – including customer information, business capabilities and procedures, resources, designs, formulas, recipes, configurations, analyses.
- Optimisation software – including artificial intelligence.
- Embedded firmware.

Adoption and use of ICT applications have, in effect, changed the orientation of manufacturing operations from predominantly mechanical and electric to electronic and digital.

In addition, ICT makes it possible to transmit, store and process larger amounts of data and information and to access a broader range of knowledge sources. In this context ICT is a core technology in manufacturing in the sense that it can bring information and other knowledge to the key functions of design, production and distribution.

As digital networks and more powerful computing allow companies to collect, communicate, exchange and analyse data more quickly and cheaply than ever before, manufacturing businesses are able to adopt a broader range of approaches (strategies) to the management of their core functions and processes (Hagel and Singer 1999). This can lead to better informed business decisions and reduce levels of uncertainty and risk.

6. Warren Centre: Steel – Framing the Future

The cause: Perception of risks puts steel at disadvantage

Using case studies of multi-storey CBD, suburban and industrial park developments, early assessment identified five root causes affecting the steel-frame construction industry's performance:

- lack of strong leadership
- inability to provide reliably accurate cost estimates
- non integrated supply chain
- inability to articulate the value proposition for steel framing
- poor take-up and integration of proven technology.

Australia has an efficient, competitive and well-established concrete-framing industry. By comparison one of the earliest insights of the Steel – Framing the Future project was that builders and developers considered the use of steel to be a far riskier option than concrete. The perception of high risk2 was based on: apparent price volatility, poor access to consistently reliable data impacting on costs and estimates, concerns about safety on site, confusion about steel's sustainability credentials and exposure to additional supply chain complexity.

Other findings specific to the steel-framed value chain that emerged over the course of the project included the following:

- Decision makers in the preliminary design phase of construction rarely considered a steel-framed solution unless it was a stipulation of the design or if concrete was not viable, and when selected, rarely involved fabricators at the design stage.
- Engineers were largely unaware of the improvements brought about by modern fabrication technology.
- Few projects exploited the benefits of an integrated steel design and manufacture process, which can significantly reduce both cost and time to completion.
- The accuracy of cost estimating for steel-framed structures suffered from a lack of reliable cost data and an absence of regular communication between quantity surveyors, fabricators and engineers.

- There was a lack of critical-size fabricators providing the builder/developer with pricing and delivery confidence.

There were also general construction value chain issues which contributed to the problem:

- Adversarial contract structures, with parties locked into fixed price contracts, provided no incentive to collaborate to achieve better results during the construction process.
- The take-up of 3D modelling and 3D documentation, enabling broad and accurate access to project information, is poor.

These and other insights from the work of the Steel – Framing the Future teams suggested three drivers of change:

- Communication: Articulate steel framing's value proposition in a compelling way to the decision makers early in a project's development cycle. Share commercial information where that can improve efficiencies and reduce risks.
- Collaboration: Develop relationships within and along the steel-framed value chain and develop effective collaboration models, and agreed frameworks within which to quote, share information and models, share risks and share profits.
- Capability: Continuously improve productivity; adopt proven technology, in particular automation and management systems in the fabrication process; embrace innovation.

Much of this is not new. Other sectors of the Australian steel products industry are benefiting from these technologies, as are overseas competitors.

The project found overwhelmingly that the steel-framed value chain suffered from a broken value-delivery system across its many disconnected parts, which, if mended, could offer real advantages over the concrete alternative.

This project found new technologies can be applied to steel- framing that make it easier to design and alter, and allow builders to fully capitalise on the new collaborative business models delivering steel-framed structures to the market.

The proposed steelwork-contracting model consolidates the value chain to give a single point of responsibility that reduces risk, ensures a flow from one part of the building process to the next and retains rather than loses innovative processes and experience. Virtual buildings are designed in a digital space and key players such as fabricators, quantity surveyors and estimators are able to give accurate cost forecasts using shared value-chain information. While these practices are far from the norm, their existence amongst the emerging Key Leaders shows the new deal with steel is real.

Since the inception of the Steel – Framing the Future project the share of steel in multi-storey buildings in Australia has risen from 3 per cent to 13 per cent and many initiatives put forward in the project documents are being adopted. The experience of some of the Australian steel construction sector's international counterparts shows the 'size of the prize' for adopting the recommendations of this project is substantial. Some supply chain participants are well under way in their transformation, while others make incremental movements and the cost of steel framing, in real price terms, continues to fall worldwide.

If this continues, as is the objective of this project, the future of steel in Australian building construction will be secured.

Background: By Sandy Longworth

Australia's fabricated steel output is predominantly resources and industrial in form, i.e. approximately 65 per cent being resources and industrial with 35 per cent building construction. Why then, has the Steel – Framing the Future project elected to focus on the building sector? Such a course was adopted, after considerable debate, primarily because the multi-storey sector contained high levels of repetition.

The erected cost of this form of beam and column construction (stick construction) should therefore be in the lower cost quartile, being relatively simple and repetitive. Furthermore there was a relative value proposition to be advanced, given the competitor pre-stressed and pre-cast concrete alternatives: a factor not at all clear-cut with most industrial structures that generally embrace steel solutions as a single candidate.

In the past decade there have been significant advances made in design documentation and detailing software, 3D modelling, NC output and fabricating shop automation by way of beam lines incorporating automated cutting, coping, drilling and welding. Automation, at all levels of fabrication, is being driven by the more capital-intensive industries, such as shipbuilding, heavy mobile plant manufacture, bridge and infrastructure construction.

The building structures fabricators have traditionally been slow to take up technology pioneered by the more capital-intensive industries. It became apparent to the Steel – Framing the Future project promoters that there was ongoing potential for significant reduction in fabricated steel real costs through these technology advancements. Structural steel therefore has the potential to remain competitive, which further endorsed the need to restore its market position.

There has been, in parallel with design and fabrication technology advances, development of structural steel metal deck, which has opened up the field of composite construction. The renewed interest in fire engineering, with a focus on performance-based outcomes, has also been a significant catalyst to the enhanced competitiveness of multi-storey composite construction.

It became apparent, after The Warren Centre's consultation with sectors of the building construction industry, that there was a lack of knowledge of the benefits of composite steel construction. There was one narrow well-informed sector of the industry and another sector, which freely admitted lacking the experienced personnel to confidently adopt a structural steel composite system, choosing to work in concrete.

The Technology Group had not been able, in the time available, to identify suitable expert views on the direction of technology developments, specifically relating to steel erection. Research and development of self-positioning steel component grippers and self-aligning and securing connections are clearly areas that will improve steel's cost position and workplace safety.

Scope of the Structural Steel Industry

By Anthony Ng, in Steel – Framing the Future, the Warren Centre, 2007, OneSteel Market Mills for The Warren Centre

It is appropriate in considering the structural steel multi-storey building sector to understand the market distribution of product and what are the drivers.

This market sector of the steel industry is characterised by the involvement of a steel fabricator. Typically the steel fabricator will be contracted by the client to supply, fabricate, deliver and in some cases erect the steel.

The market segments to which a steel fabricator will supply its services can be broadly divided into the following:

- mining and resources structures
- factories and warehouses
- domestic construction (houses)
- single-level offices and retail
- multi-level offices and retail
- education, health and social buildings
- transport and infrastructure.

Most steel fabricators will have a preference or specialty in one of these market segments. However, given that each segment has its own cycle that is not necessarily dependent or in phase with each other, a fabricator will offer services to the segment based on demand from market forces.

Impact of Emerging Technologies

Sandy Longworth, Impact of emerging technologies on steel fabrication for the construction industry, in Steel – Framing the Future, the Warren Centre, 2007

Steel fabricating processes for building construction

The major processes are:

- Cleaning: typically by some form of blasting, which may be done before or after most of the other processes depending on the extent of work being done on that component.
- Cutting and profiling: sawing is the most commonly used method for cut-to-length beams and columns. Oxy cutting and plasma cutting are both widely used for cutting plates for welded beam webs and flanges, and profiling the end of beams (also known as coping).
- Bending/forming: bending presses to produce a camber are sometimes incorporated into beam lines. Roll forming is also commonly used for lighter sections.
- Drilling/punching: holes for bolted connections are usually made by drilling, but occasionally punching is found to be more efficient.
- Welding: fully automated welding is used for the production of beams and columns fabricated from three plates, usually with the submerged arc welding process. Most other welding is done with hand-held, semi-automatic gas metal arc welding (GMAW).
- Machining: load-bearing end faces of columns are often machined by milling to achieve the desired tolerances.
- Protecting: steelwork is spray-painted or metal-sprayed for corrosion, and usually with intumescent paint for fire protection.
- handling: although this is a non-value-adding process, the awkwardness of handling large steel components and the importance of timely supply to site demand that close attention be paid at the time of design to component or module size, erection handling and sequence.

Existing commonly used technology

Existing Commonly Used Technology Beam lines are designed for processing columns and beams.

Beam lines are designed for processing columns and beams. In Australia there are an estimated 40 beam lines, with 14 on order. The vast majority of beam lines have a saw for cut-to-length, including a mitre capability, and hole drilling or punching capability. It is common to have dedicated in-line blasting facilities for cleaning of regular shapes, while cleaning of irregular shapes and coating are manual operations. Several beam lines include oxy or plasma cutting for coping (profiling)

Several beam lines include oxy or plasma cutting for coping (profiling) the ends of the beams.

Markings are also mechanically engraved on the beams for identification and traceability.

Whilst the majority of these beam lines do have CNC capability, the machine controls do not generally provide for download of data from steel design packages at present.

There are at least three beam lines in Australia for production of beams by welding three plates. One of these, at BlueScope Steel in Unanderra, welds one side of the web to both flanges using two tandem submerged arc heads at one station. The web is in the flat position. The beams are then turned over, and the other side of the web-to-flange joins are made in a second identical station. While very productive, this configuration is not set up for the production of asymmetrical beams.

The other two beam lines make both fillet welds between one flange and the web in one pass. The second flange is welded in another pass, and it is therefore relatively easy to make an asymmetric section in these lines.

The welded beam lines are typically partial penetration welds. That is, the fillet welds on either side do not penetrate the full thickness of the web, leaving the surface between the web and the flange unwelded at the centre of the web.

The major market for all this equipment in Australia has been for infrastructure projects rather than building construction. Innovative building design incorporating slim-floor construction, chilled beams and large spans could change this.

Virtually all other components, such as cleats and stiffeners, are welded with hand-held, semi-automatic GMAW processes.

The majority of beam lines are with fabricators, but some steel distributors have also installed beam lines to provide partial pre-fabrication.

Emerging technologies

Hole-drilling

New designs of low-vibration machine tools and advancement in drill design have resulted in major reductions in drilling time, to the point where a 26mm diameter hole can be drilled in 12mm plate literally in seconds. As a result, CNC single tool drilling stations

are replacing gang drilling in some applications because of the greater flexibility offered.

New welding power source inverter

Inverter technology development has reached the point where high power (1000amp+) welding power sources are now readily commercially available. As well as much more efficient transformation of high voltage mains supply to low voltage welding current, with more than 95 per cent power factor, these new inverters allow much greater flexibility in the welding current waveform. Until now, submerged arc welding processes commonly used tandem arc for greater welding speeds. The lead wire was supplied with DC power, while the trailing wire was AC to avoid electrical interference between the two arcs. Additional wires can be fed into the weld pool but it is difficult to achieve stable conditions.

With the advent of new waveform control, new configurations are possible that may allow full penetration welds to be achieved in welded beam fabrication, and require smaller external fillets with proportional increases in welding speeds. The result should be higher quality welded beams at lower cost due to less wire being used and lower power consumption.

Laser and high-definition plasma cutting

Laser technology continues to advance rapidly, but is a major capital expense. The energy conversion is also quite poor. Despite these disadvantages, laser cutting is finding more and more application in metal fabrication due to the very rapid and precise parallel-sided cut that can be achieved with very high surface finish.

In the automotive industry, laser cutting has displaced press trimming and punching in many applications due to the flexibility with which shapes can be produced. Could there be similar potential for building construction?

Due to the energy demand, most applications have been for light gauge metals, but laser cutting is now being used in shipbuilding in Europe for cutting steel up to 20mm thick.

Plasma cutting, where an arc is used to remove metal rather than weld it, has been a popular alternative to the more traditional oxy-cutting process. But like oxy cutting, plasma cutting has had the disadvantage of producing a wedge-shaped cut, and a surface finish similar to oxy cutting.

High-definition plasma cutting, where the two cut surfaces are much closer to parallel, improves the precision of the cut and the surface quality. Although still not as precise as laser cutting, it is a much more economical process and arguably superior to oxy cutting at higher speeds.

Laser/laser hybrid welding

Laser welding allows deep penetration and very precise welds, and the heat source can be directed into tight area locations. These advantages have allowed joint configurations not possible before. However, a weld requiring 4kW requires an input power of approximately 340kW with a Nd:YAG laser, compared with approximately 4.2kW with arc welding. Laser welding also requires very precise fit-up as no filler material is added and the weld pool is small.

Laser hybrid welding, where a laser is used in conjunction with an arc weld, overcomes some of these disadvantages. It is being used increasingly in the automotive and shipbuilding industries.

Both laser and laser/GMAW hybrid welding in conjunction with robots can be used for welding in all positions. It is possible to weld connections to large components that are difficult to move with this process.

Robotics

According to the Robotic Industry Association, there are an estimated 158,000 robots in use in manufacturing in the US alone. The number of robots in use in Japan is believed to be even higher. The major industry use is automotive, where small components and high repetition are ideally suited to robotic production. The Japanese construction company, Obayashi has, however, applied the system to the automated butt-welding of beams and columns in its automated building control and big canopy systems (So & Chan 2002).

Robots are ideally suited to cutting and welding of complex three-dimensional shapes where there are a large number of identical parts to be processed. Robots also have application in cleaning, painting and handling. The greatest limitation has been the size of the working envelope, but recent innovations are changing this.

The need for greater efficiency as a matter of survival has seen greater use of robots in the shipbuilding industry, particularly in Europe. This has driven the development of large manipulators and gantry mounting of robots to access large components, as shown in Figure 9.

More recently there has been progressive introduction of gantry fabrication in Europe in the construction fabricating field. Figure 10 illustrates the use of gantry robot plant for construction steelwork fabrication.

In Australia automated fabrication, excluding the application of beam lines, but utilising gantry robots has yet to be adopted for construction steelwork fabrication. The technology is however being applied very effectively by Austin Engineering Limited in the fabrication of complex heavy mining buckets and associated components as well as large off-highway dump truck trays. Austin states in its 2006 annual report, 'The introduction of the robotic welding system has been of great assistance in counteracting the critical skill shortage in Western Australia'.

Automation with robots generally offers better quality for operations such as welding since the parameters are more precisely maintained than can be achieved with manual welding. Higher welding speeds and greater duty cycles ensure a dramatic increase in productivity, typically of the order of 300 per cent.

Apart from the capital cost, the major disadvantage is that the robotic operations require much more precise jigging and tighter part tolerances than manual operations, since correction for these errors is much more difficult. However, this in turn leads to better quality.

Typically, in the automotive industry the welding sequence is taught to the robot controller by manually driving the robot arm through the cycle and saving various program points. As this can be a time-consuming exercise, it tends to limit the use of robots to relatively long runs.

Recent improvements to some robot controller software have made the programs much more intuitive and easier to learn and use, thereby making shorter production runs more attractive. This is a development likely to have appeal to the building fabricating industry.

Software also exists that allows the robot to be programmed off-line in the convenience of the office using the design drawing data. This has the potential to make the changeover for short runs even easier. However, from the author's observation this technology is not yet being widely used although it would seem to have great potential.

An example of one company taking full advantage of robot technology in building construction is ConXtech in the US. It has designed a system that allows virtually all welding to be done at its fabricating plant, allowing self-locating slots to locate the beams onto the columns on site, before the beams are bolted together to produce a moment connection suitable for use in areas with high probability of seismic activity.

Design data is directly converted into manufacturing data with proprietary software for CNC cutting and drilling. In addition to using CNC milling and drilling to produce the end plates, and a CNC-controlled beam line to cut the columns and beams to length, robots are used to weld the connections to the beams. More than 10,000 of these connections have been used in construction (The Fabricator 2005).

Robots for building maintenance, condition monitoring and security are being developed or are under consideration (Spencer 2004) (Weston & Burdekin 2000) and are already in use for façade cleaning on at least one high-rise building in Europe (Elkmann et al 2006) and building construction in Japan (Taylor et al 2003).

Friction stir welding

Friction stir welding (FSW) was developed in the early 1990s by TWI in the UK and has been widely used to join aluminium and other non-ferrous alloys. The technology uses mechanical forces to create a plastic state in which the surfaces of the parts to be joined can be mixed together without reaching a liquid state. This has significant advantages for welding alloys that are too volatile for arc welding.

The process produces high-integrity joins at high speed with little residual thermal stress. The process does not require welding consumables or join preparation, and cost savings of a factor of three or more are claimed in comparison with arc welding process, ignoring establishment cost (Taylor et al 2003). The main disadvantage is the high capital cost of the equipment.

Information technology

The potential to integrate the design model with the CNC commands for beam lines and robotic welding, cutting, cleaning and painting offers an exciting opportunity to improve the efficiency of steel fabrication. Software already exists that translates design data into a format that can be used directly by CNC beam lines, CNC cutting machines and robots, and this technology is finding wider appeal.

The opportunity to create new connections and component design that is conducive to fully automated, high-volume production, as per ConXtech's innovation, also has significant implications for the construction industry. Automation on the shop floor with electronic linkage to design and detail sources has the potential to catalyse innovative construction ideas and slash production cycle time.

The challenge now is how to take full advantage of these innovations.

Cost comparison and implications of emerging technologies

The real cost of fabricated steel in the UK has effectively fallen by nearly 50 per cent over the past 25 years to around £1500/tonne or A$3750/tonne (Thomas et al 1999). This has given steel structures a significant price advantage in the UK as shown in Figure 13. Unfortunately a similar comparison for Australian conditions is not available.

Australia has not benefited from improvements in efficiency and fabricating to the same degree as the UK, where designers have more flexibility, particularly in section selection.

It would be fair to say that Australia's concrete industry is more efficient than the UK's. Notwithstanding this, for similar grid layouts and building types, it has been established that steel composite construction in metropolitan areas is marginally (10 per cent) cheaper than post-tensioned concrete (Marjoribanks 2006)

Arguably, for steel fabrication to gain significant market share from a highly competitive concrete industry, fabrication costs will need to be more competitive relative to the UK despite the market size being smaller. To achieve this, the industry must take full advantage of the technologies available. The authors believe this is achievable within the steel value chain and will result in some rationalisation and consolidation within the industry

Conclusion

If steel is to make significant inroads into areas of the construction market currently met by concrete, it must be able to offer greater economic benefit. Whilst there may be other design and timing advantages to steel, cost will remain an important factor. Given that industry practices for concrete construction are more efficient in Australia than in the UK, and given the more favourable taxation treatment of concrete in Australia, it is reasonable to assume that despite the smaller volumes, steel fabrication costs will have to be lower in Australia to be competitive in the construction market. This will require adoption of world's best practice and the latest technology

7. PM's Manufacturing Taskforce: Report of the non-Government Members

Report of the Non-Government members for the Prime Minister's manufacturing Taskforce, August 2012

Note: Report is very good on how business might be able to access capability that exists in research organisations and industry – but does not address issues about how universities particularly can work more effectively with industry. Much is being done in the area of work based/integrated learning, Faculty Advisory Committees, university engagement with business – but there are constraints – institutional and financial.

Arguably, Australia needs a new form of higher education institution – the polytechnic – modelled on the European versions.

Smarter Networks

Collaboration and networks are critical to manufacturing innovation and competitiveness. Collaboration represents a fundamental challenge for Australia due to our constraints of scale and geography.

In Australia, collaboration is more serendipitous than systemic. In a world where personal relationships and social norms of collaboration are among the most critical characteristics of successful innovation industries and regions, we are lacking. There is considerable scope to generate greater value from our public investments in science and research by improving incentives for collaboration and creating more collaborative mindsets among researchers and businesses.

A new Smarter Australia Network, supported by an online platform, could leverage high speed broadband to expand systemic opportunities for collaboration among and between businesses, researchers and governments.

To provide a practical focus for such collaborations, and to build critical mass around our comparative advantages, the non-government members of the Taskforce propose new Innovation Hubs to develop solutions for global value chains and forge new models of working together.

The non-government members of the Taskforce propose a national hub pathfinder project on food, an area in which Australia enjoys natural advantages in the Asian Century.

For manufacturing more specifically, a strategy is proposed to ensure that manufacturing capabilities and knowledge diffusion are both developed.

The non-government members of the Taskforce propose a review to develop a Design Innovation Strategy, so that Australia can translate its engineering strengths into a new national design edge and bring design thinking into business strategy.

- **INDUSTRY AND RESEARCH WORKING TOGETHER TO BOOST PRODUCTIVITY**

Australia needs to develop better connections between manufacturing firms and the research-education sector. A primary concern of the non-government members of the Taskforce is the tenuous nature of linkages between industry and research in Australia. Examples of good linkages between research and industry are encouraging and are exemplars of how businesses can be grown with research input. However, these are the exception to the norm.

For over three decades, Australia has performed below average in international measures of linkages between industry and research. This is in contrast to competitor nations where manufacturing businesses, large and small, not only have regular interaction with the research sector but actively drive the research agenda. This occurs across manufacturing sectors – high, medium and low technology. For Australian manufacturers to compete internationally, linkages with the research and education sector are a crucial piece in the puzzle.

Consultations with stakeholders have shown that this is a complex and multi-layered problem. Chief among these is that of differing cultures and drivers. Research organisations fulfil many roles, of which engagement with industry is one and of varying priority. Some research organisations place primacy on basic research which may, in the short to medium term, appear to have limited commercial application.

For Australia to improve, reciprocal benefits must be derived and recognised by both the research and education sector and industry. The development of strong relationships based on understanding mutual needs, and capabilities, can lead to not only more internationally competitive businesses, but also to considerable high standard, leading-edge, and nationally-competitive grant funded research with high academic merit. These need to become the rule rather than the exception. Generally, the primary source of recognition of an academic's research achievement is by peer-reviewed publication of research outcomes, preferably in a highly ranked journal.

Publication performance has traditionally been the key consideration in an academic researcher gaining promotion, and so it is an important driver of behaviour (ie. the 'publish or perish' mantra). On the other hand, the conduct of applied research, such as to directly address an industry problem, will generally not involve such leading-edge research, and so may be viewed by researchers as being less valuable in career progression terms.

Even where collaborative, industry-focused research is involved, perhaps to solve a longer term industry problem, commercial considerations may inhibit rights to publish, and so diminish the academic merit, making it less attractive to researchers.

A number of measures are in place that need to be significantly improved upon to build Australia's performance in this area. The non-government members of the Taskforce also believe that other measures could be implemented to address the structural and cultural barriers existing between industry and researchers. This includes involving students in driving creative solutions in a business context.

- **EXCELLENCE IN RESEARCH AUSTRALIA**

Excellence in Research Australia (ERA) identifies and examines the quality of research across the full spectrum of research activity, identifies areas of excellence, emerging areas and opportunities for further development and allows international comparisons to be made.

While this is a laudable and important initiative, this work needs to be taken to the next level. Further work needs to be undertaken to measure the impact and application of research for industrial transformation, not to diminish the drive for excellence but to complement it, and to understand the extent to which research institutions are able to respond to demand-led application and development of research.

The non-government members of the Taskforce are of the view that a more significant weighting should be placed on the measurement of the impact and application of research. Without this the

ERA will not facilitate more meaningful relationships with end users, will not develop young researchers and engineers with a greater capacity to work within industry, and will not deliver on the government investment in research and development.

▪ INDUSTRIAL TRANSFORMATION RESEARCH PROGRAM

The Industrial Transformation Research Program aims to support quality R&D partnerships that will help transform Australian industries. The Program will:

- Focus on research areas that are vital for Australia's future economic prosperity, such as engineering, materials science and nanotechnology, communications, robotics, chemical engineering and biotechnology.
- Support Industrial PhD students and researchers to gain 'hands-on', practical skills and experience in these important areas.
- Foster important partnerships between business and universities.

To achieve this, the Program will fund Industrial Transformation Research Hubs and Industrial Transformation Training Centres. Without these, the program will have little impact on manufacturing competitiveness and productivity of the sector and the broader economy.

While the non-government members of the Taskforce strongly support the government's recent announcement of the Industrial Transformation Research Program, it believes that the Program needs to be implemented with maximum impact. To achieve this, two outcomes need to be achieved. Firstly, the Program needs to be targeted to create critical mass to create strong research and innovation precincts. There is a risk that program funding will be spread too thinly.

Program criteria should be developed to ensure that research hubs and training centres are sustainable and will grow, including as part of global research networks. Secondly, the Program needs to be implemented so that it has a strong business creativity and problem-solving focus, with outcomes for business accurately measured to ensure that the Program is achieving its goals.

▪ COOPERATIVE RESEARCH CENTRES

A CRC is an organisation formed through collaborative partnerships between publicly funded researchers and end users. CRCs must comprise at least one Australian end-user (either from the private, public or community sector) and one Australian higher education institution (or research institute affiliated with a university).

The non-government members of the Taskforce note that there are some very successful manufacturing related CRCs but is of the view that the timing of co-funding requirements can restrict industry collaboration.

Although it is understood that the CRC Program has been recently reviewed, the non-government members of the Taskforce believe that the government should consider whether further adjustments to governance structures and processes can be made to establish more agile, more globally oriented collaborative partnerships through the CRC Program.

▪ RESEARCHERS IN BUSINESS – BUSINESS PEOPLE IN RESEARCH?

This Report has identified the Researchers in Business Initiative as an essential and practical method of 'bridging the gap' by directly supporting the placement of researchers within businesses. This approach has proven to be particularly beneficial to SMEs and to the researchers.

In keeping with the notion of building research and industry linkages and the need for reciprocity, further measures should be introduced to bring industry into research institutions. Industry experience can be crucial to the learning experiences of future generations of students, whether they remain in research or move into the business sector.

This could be achieved through a range of mechanisms. Other countries have introduced models to foster the creation of adjunct roles for business people within research institutions, and for students to work on short projects with industry. There would be significant value in the government investigating those models and supporting local models that best fit the Australian environment.

The non-government members of the Taskforce also note the role of multidisciplinary 'innovation and design (living) labs' in universities which provide a framework for creative student engagement with industry challenges, as well as promoting student ventures and entrepreneurship. This would be a fruitful direction for the Students in Business program, which is currently confined to identification of internship opportunities.

THE WAY AHEAD

The non-government members of the Taskforce propose two first steps to addressing these issues:

1. Formal ongoing dialogue

A formal and ongoing dialogue should be established between industry and the research and education sector. The purpose of this dialogue would be to:

- Promote greater understanding of each other's cultures and structures, including areas of common interest.
- Better understand how mutual benefit can be derived from closer collaboration.
- Identify best practice examples internationally of research/industry collaboration.
- Improve the performance of university technology transfer offices in commercialising ideas.
- Support the establishment of innovation labs at the interface of industry and universities.

2. Directly incentivising industry-research links

The research sector is the source of new and applied knowledge and innovation for Australian industry (large and small) and is a key reason for MNEs to invest/re-invest in Australia.

In a high cost economy, our SMEs will be competing on the basis of differentiated solutions rather than price, and the research sector can assist in helping SMEs develop these.

n order to address deficiencies in current industry-research links, the non-government members of the Taskforce recommend that the lack of incentive in the research sector for collaborating with the manufacturing industry be addressed by introducing a research impact measure tied to funding, and that consideration be given to diverting a modest proportion of current research funding streams into third-stream funding aimed explicitly at knowledge exchange between users and the research sector, as has successfully occurred in the United Kingdom.

▪ SMARTER AUSTRALIA NETWORK – A NEW PLATFORM FOR GROWTH

As discussed, the social and information networks that underpin collaboration and innovation in Australia are weak. Where collaboration occurs it is usually based on existing relationships, existing networks and existing markets. Given Australia's scale and geography constraints, there is a need to consider more systemic options to boost collaboration.

The Smarter Australia Network would connect precincts and other centres nationally through a collaborative and open online network. This would leverage the benefits of high speed broadband and step boldly ahead of the global trend towards collaborative and open innovation.

The Smarter Australia Network would provide Australian businesses the opportunity to connect locally, nationally and potentially globally, with a specific focus on industry value chains.

The Network would be virtual and viral, making it easy for participants to opt-in and communities to self-organise as they see fit. It would show struggling businesses 'what good looks like', help to establish peer groups in areas such as high growth firms or high performing workplaces and enable 'SME clustering' options.

New sources of business collaboration and innovation include (in increasing order magnitude) company research development exclusively generated by internal development); open together with a well-established network suppliers, academics, consortia, etc, long-term, trust-based, stable relationship); mass Innovation reaching out to larger external participants lead users, specialists, enthusiasts etc) who can contribute on more variable self-defined basis).

While virtual collaboration is no substitute for personal relationships, it provides an ideal environment for firms to engage wider user networks and communities, an approach currently confined to high performing firms as illustrated in Figure 5.1.

The Smarter Australia Network would encompass all levels of collaboration outlined in Figure 5.1, while within this innovation hubs would provide a focal point on those industries and capabilities that can generate the most value for the nation.

The network would be a platform that empowers industry networks (such as Industry Innovation Councils and the Industry Capability Network), applied research networks (such as the Commonwealth Scientific and Industrial Research Organisation (CSIRO)), the Defence Science and Technology Organisation (DSTO), Rural Research and Development Corporations (RRDCs), Cooperative Research Centres (CRCs)) and regional networks (such as the Regional Development Australia network) – encouraging bottom-up as well as systemic collaboration.

The network would be designed from the outset to focus on innovation, and particularly business innovation. Its connections would not to stop at borders – the Network would be a mechanism to showcase Australia's strategic directions and capabilities to the world, and connect us to the 98 per cent of knowledge generated elsewhere through links with international research, business and government communities.

- **INNOVATION HUBS – BUILDING CRITICAL MASS**

Hubs would be national resources of global significance, built on regional comparative advantages and competitive strengths. Their scale would involve agencies and stakeholders working to attract global investment, research and talent, and connect with global value chains – offering participants a springboard into Asian and other markets. 82

Policy advocacy is arguably the critical factor in attracting foreign direct investment.83

Where global competition demands it, governments need to send the clear signal to multinationals and to other governments that Australia will compete with a coordinated whole-of-governments approach – that we are serious in our intent to build critical mass around our comparative and competitive advantages.

While investment support in such areas already exists, at both Commonwealth and state levels, it is ad-hoc and disconnected from strategic national priorities. To remedy this, the Commonwealth should consider a Strategic Investment Facility with an ability to co-invest in economically significant activities in line with national priorities. In particular, this Facility should leverage the profile of innovation hubs to attract Tier 1 manufacturing firms to anchor value adding bases in Australia.

Beneficiaries of such support would be required to be active participants in the supply chain enhancement strategies that all hubs would be required to publish, thus supporting new paths to market for Australian SMEs through larger firms.84

Hubs would generally address major economic and societal needs – with a whole of value chain approach that crosses manufacturing-services-systems divides.85 They would build on and learn from the experiences of other nations.

The positioning of the UK Catapult Centres discussed in Section Three is between market pull and technology push as shown in Figure 5.2 below.

With Australia having a smaller scientific base, a more applied model of innovation and a clear picture of major opportunities are required. It is therefore proposed that Smarter Australia Hubs would be relatively more focused than UK Catapult Centres on market pull.

The critique of Singapore's 'high-tech' innovation path is also relevant to Australia. With a range of existing strengths that offer comparative and competitive advantages, Smarter Australia Hubs would be built on these existing strengths. However, hubs would also consider potential alongside revealed advantages.86 This dual focus recognises that comparative and competitive advantages are dynamic, and would be a counter to the short-term bias of Australian management.

On these criteria, candidates for precincts would include the related opportunities in food, forestry, resources, engineering, health and the environment, as well as national defence. Capability-based hubs (and networks to disseminate knowledge) could also be considered for manufacturing technologies and design.

The focus and location of Smarter Australia Hubs should be determined based on a total assessment of Australia's capabilities and industry strengths, and their potential to solve our existing problems and seize our emerging opportunities. Hubs would host modern technology and equipment, but also critically the people, organisations and relationships needed for problem solving. They would connect leading technology with leading practice in management, design and marketing.

Hubs would not operate under the existing rules, cultures and incentives of existing research facilities. Rather they would enjoy governance autonomy, be led by business, and have flexibility with operating models to discover what rules work best for collaboration and innovation.

This carries significant advantages for the skills agenda, as it creates an opportunity for existing and prospective researchers to pursue an alternative career path that involves solving practical problems, making a difference and being rewarded for their achievements on a more flexible basis.

Hubs would also provide a space to consider options to better integrate the work of student teams, across scientific, managerial and creative disciplines, into the task of practical problem solving for industry. Overseas evidence suggests that these models can be a win-win, as students discover a passion for practical innovation, while firms are introduced to new ideas and new talent.87

The national footprint of innovation hubs would reflect not only existing strengths but also the aspiration of a broad-based economy, encompassing all major cities.

This could also extend to smaller hubs for narrower regional specialisations.

Hubs based on regional specialisation are not only how regions successfully compete, trade, grow and evolve; they are also how Australia can build a broad-based national economy that supports many successful industries and regions.

- **MANUFACTURING CAPABILITIES**

Earlier in this report we emphasised that there is a strong case for focusing on applied knowledge. More than ever in today's high-cost environment, manufacturers need to be able to value add. This requires business and government to focus on innovation.

There is also a need to recognise that it is business, based on market needs, that drives most innovation. This is despite the fact that the vast bulk of our innovation policies reflect an out dated supply-side way of thinking.

Finally, this report emphasises that there is a need for new skill sets to absorb knowledge, but also new mindsets that support constructive relationships within workplaces, research organisations and government agencies – and across all three. This is about relationships, not rules.

An important mechanism to help realise this focus on applied knowledge and building the capabilities of manufacturing firms is the proposed establishment of a Manufacturing Technology Innovation Centre (MTIC). The non-government members of the Taskforce welcome the Minister for Industry and Innovation's invitation to be part of the due diligence for the Manufacturing Technology Innovation Centre.

We propose a new committee be established that would be chaired by a senior business leader with a Deputy Chair being an eminent person from the private sector able to help undertake a two stage due diligence process of the funding and activities of those entities (CSIRO, universities, CRCs, Australian Research Council (ARC) etc.) with relevant connections to applied knowledge application and dissemination in Australia.

This review committee would, among other things, test the non-government members of the Taskforce's view that there are deficiencies in the manufacturing innovation system in Australia that need to be addressed. The review process would report on:

- Who does what and where are the key entities located?
- Who are their clients, both at Commonwealth, State and Territory level and within the private sector, and what are their engagement strategies with their clients and how successful have these been?
- What is the current balance of support for science based R&D versus production technology adoption and adaption, and non-technological knowledge adoption and adaption (eg. design, business model change)?
- What is the most effective contribution the Manufacturing Technology Innovation Centre or Network can make and what role should be played by agencies such as QMI and Enterprise Connect?
- Whether current funding of manufacturing innovation is sufficiently strategic to ensure the government and the sector are generating the benefits they should?
- How and whether The Manufacturing Technology Innovation Centre (MTIC) or Network could be a Smarter Australia Precinct (though potentially involving multiple sites given the tendency for manufacturing subsectors to cluster in different locations), bringing together globally and nationally relevant manufacturing technology and expertise, with an innovation agenda defined by the needs of industry?
- How and whether the ARC's Industrial Transformation Research Hubs would form part of a Manufacturing and Technology Innovation Network, operating as applied knowledge centres that connect with the MTIC, Enterprise Connect, QMI and other agencies?

The non-government members of the Taskforce note that other industry sectors have functional, strategic innovation systems (mining, agriculture) underpinned by effective interaction between demand and supply forces. We note that other countries (eg. Germany) have clearly defined roles and responsibilities within their manufacturing innovation systems and that these systems appear to work well. Manufacturing deserves to have the same both for its own competitive future, and also to ensure the taxpayer receives full benefit for their investments.

The non-government members of the Taskforce stress the need to consider the range of manufacturing initiatives as one package, and to do so from the perspective of what can support businesses to collaborate and innovate. In that respect it is imperative that the establishment of MTIC is worked in with other developments in the innovation system such as CSIRO's plan for its manufacturing precinct highlighted below. It is also imperative that the proposed Smarter Australia Network is one interconnected virtual reality across the innovation system rather than a series of silos and isolated islands of excellence.

- **HOW CSIRO AND MONASH MAY DEVELOP THE AUSTRALIAN MANUFACTURING AND MATERIALS INNOVATION PRECINCT IN CLAYTON, VICTORIA**

In response to Australia's need for a more connected, globally recognised and sustainably competitive manufacturing industry, Monash University and CSIRO are working together through a strategic relationship agreement to develop the Australian Manufacturing and Materials Innovation Precinct (AMMIP) in Clayton, Victoria.

Clayton forms a natural location for the AMMIP, as it is within the South East metropolitan region of Melbourne, which houses a significant number and range of advanced manufacturing companies, the Australian Synchrotron and the Melbourne Centre for Nanofabrication.

The vision for AMMIP is to act as a hub for a wider network of interconnected industry and research based facilities (eg. National Food Innovation Hub, Queensland Manufacturing Institute, design innovation collaboration with Queensland University of Technology, Swinburne University National Faculty of Design and Advanced Manufacturing Centre on its Hawthorn campus, RMIT's Advanced Manufacturing Precinct), that can translate know-how and promote the development of existing Australian manufacturing companies, as well as the growth of new companies across Australia, including in regional centres.

CSIRO is committed to the success of AMMIP and its ability to provide innovative technologies and boost the competitiveness of Australian manufacturers, and is therefore actively seeking capital investment in-excess of $10 million from non-government sources (eg. application to Science Industry Endowment Fund, Universities, industrial investment) to assist with the realisation of AMMIP.

In order to act as a hub and bring together the wider capability network, AMMIP must be successful in working in a virtual way across Australia. This will require the implementation of broadband networks and new tools for collaboration at a distance or 'telecollaboration', which will transform the way we work. Many innovative tools to facilitate telecollaboration already exist around the world, which can be leveraged and combined with various CSIRO-developed tools to allow design, modelling and other services to be provided online. These types of productivity-enhancing services can be delivered online anywhere, anytime.

Combining these services with high definition video conferencing and tools for data collaboration will allow manufacturing and design teams to dynamically form and work together across Australia. For example, CSIRO computational modelling capability has been used to optimise processes including metal castings, milling and bio-mechanics. Other online capabilities could include risk modelling, supply chain logistics and transport optimisation.

Through its 'hub and spoke' collaboration model, AMMIP will bring together advanced manufacturing facilities from around the country creating scale and connection and an environment in which the proposed Manufacturing Technology Innovation Centre (MTIC) could be hosted. Whilst the MTIC could be housed at AMMIP, its crucial industry-led focus would still be maintained through the proposed establishment of a Board of Governance with leading multinational corporations, representatives of leading SMEs, Enterprise Connect, Queensland Manufacturing Institute, universities and State Governments.

Finally AMMIP is also proposing to house a new 'open access' Factories of the Future initiative. The Factories of the Future would be a facility made available to industry on an open access basis to provide advanced prototyping and production capability to Australian Industry.

The facility will be supported by research and development from the relevant research agencies and designed to be a reconfigurable multi-user facility for manufacturing companies for design innovation, micro automation, advanced processing and additive manufacturing with industry, complemented by technical advice and R&D services to assist firms' process and product development and business model innovation needs.

- **AN EMERGING AUSTRALIAN ADVANTAGE: DESIGN**

As discussed, design is a critical enabler of productivity and innovation, and has been shown to play a significant role in the growth of firms and sectors. Building on a strong engineering tradition, Australia can and must succeed in design if its manufacturing industries are to create the differentiated products and services that consumers want and are prepared to pay for.

Aspects of Australian industrial design, particularly those stemming from a strong engineering base, are world class. Similarly our related marketing and branding capabilities are world class.

Until recently, Australian industrial design has primarily been focused on efficiency concepts such as lean manufacturing and resource productivity. However, today design is evolving as a broader and more compelling concept for business.

Design should be seen as a ubiquitous capability for innovation. The non-government members of the Taskforce propose that the Commonwealth Government commission an independent panel to advise on the changes needed to maximise the potential of design thinking on innovation in Australia. This review would consider implications for design research, design education, design practice, national design collaboration and the absorptive capacity of firms, and would involve open engagement of the entire design community.

The non-government members of the Taskforce also consider that that the design thinking approach form significant elements of the curriculum of the proposed Australian Leadership Institute.

Figure 5.3, based on the work of Professor Göran Roos, captures this emphasis.

- **IMPLICATIONS FOR ROLES AND RESPONSIBILITIES**

The scale of change implied by the proposal for Smarter Australia Network requires that such an initiative be led by our national government, and integrated into our national economic strategy and global brand positioning. However, the network and innovation hubs need a prominent role for industry to reflect the new emphasis on applied knowledge.

More broadly, while this is a national approach, it is also about building regional specialisation in order to build a broad-based national economy. As such, individual hubs should have a large element of local stewardship, should involve State Governments as partners, and should (generally) be based around local universities. This approach has a number of implications for the roles of various stakeholders:

- For manufacturing businesses, it would mean a rebalancing of the national innovation system in support of their practical needs, a requirement to engage more actively in collaboration, and a need to better connect large and small firms through value chains.
- For universities, it would mean a greater focus on applied research in areas relevant to regional advantages, supporting new spaces for researchers to develop solutions beyond the confines of existing rules and incentives, and reclaiming their public role as bearers and transmitters of valuable knowledge.
- For publicly-funded research organisations (PFROs) such as CSIRO, DSTO and CRCs, it would mean a more coherent and collaborative role within an open national innovation system, and the opportunity to leverage international reputations for national benefit.
- For CSIRO specifically, it would mean a stronger and broader leadership role within the national innovation system, including in support of the Smarter Australia Network, requiring greater systems, managerial and creative skills, and a partnering ethos in business-led Innovation Hubs.
- For Governments, Commonwealth and State, it would require a new degree of cooperation and focus, with both recognising the need to harness local specialisation, national coordination and global engagement. It would also require the redirection of existing funding to this aim, and a change in the incentive structures for funding and research to support applied knowledge. However, the largest implication is for national economic strategy, which would specifically aspire to build a broad-based economy underpinned by the strength of numerous industries across numerous regions.

Smarter SMEs

A package of measures to support smarter SMEs is designed to improve access to knowledge and resources for SMEs, and to support those with the commitment and potential to grow into the globally oriented medium-sized firms Australia lacks.

This includes a more cohesive and streamlined business interface that draws on all relevant resources to help manufacturing SMEs – an enhanced Enterprise Connect. It also includes practical and proven measures to strengthen the limited contribution researchers and government agencies currently make to innovation in SMEs.

Most successful manufacturing companies and their leaders understand that success or failure depends on their own commitment to growth.91 The schemes proposed here involve mutual obligations and a spirit of partnership. Participating firms in these programs need to co-fund activities and need to agree to share their experiences with others. In return, policy will be more heavily focused on their specific needs for growth and services will be more joined up than currently.

- **ENTERPRISE CONNECT – FOCUSED ON VALUE ADDING FOR SMEs**

The non-government members of the Taskforce consider it important that Enterprise Connect be focused on effective and efficient service provision. To help achieve this, it is recommended that it be established as an entity with similar or greater management and operational flexibilities as are enjoyed by Austrade and Commercialisation Australia.

The non-government members of the Taskforce also recommend that Enterprise Connect be upgraded, its funding to support manufacturing firms be significantly increased and its relationships and connections with other agencies be formalised. This will help Enterprise Connect exercise greater leverage and capacity in assisting manufacturing firms meet the competitiveness and productivity challenges they face, specifically Enterprise Connect should be configured as:

- An entity with similar or greater management and operational autonomy as that enjoyed by Austrade and Commercialisation Australia.
- The 'one front door' for SME support, with a series of partnership agreements with other agencies to ensure that businesses receive appropriate support.

To achieve this, the government should carefully consider the option of merging or more closely integrating the operations of Enterprise Connect and ICNL Ltd. The Minister for Industry and Innovation and the Minister for Trade and Competitiveness should play a more active role in the prioritisation of joint activity between Austrade, Enterprise Connect and the Industry Capability network.

While continuing to report to the Minister, such an arrangement would enable Enterprise Connect – beyond providing a base level of service that reflects general market failures – to dedicate resources to those areas it believes will add most value.

Importantly, greater integration with ICNL and a new approach to co-operation with the state ICN network would help leverage up the rich architecture of resources that exist (supply advocates, national sector managers, the formal and tacit knowledge of the staff of the ICN and Enterprise Connect networks).

This architecture is not currently delivering the high level impact it is capable of delivering. It currently lacks strategic co-ordination and the kind of collaboration that helps industry win more international business opportunities by connecting up the getting access and getting competitive functions of trade and industry policy. Australia can do better than this. We must do better than this.

A reconfigured Enterprise Connect would ideally involve:

- ■ Continuing to be the front door for business support services for all SMEs.
- ■ Working with other agencies interacting with SMEs (such as Austrade, Commercialisation Australia, Supplier Advocates and state-based providers) to ensure that there is 'no wrong door' for businesses seeking support.
- ■ Complementing the Manufacturing Technology Innovation Centre (MTIC) and the Industrial Transformation Research Hubs, and providing input to those measures that emphasise the applied knowledge needs of SMEs.
- ■ Reprioritising time, support and services towards those SMEs it assesses as having the highest potential to value add, subject to those firms demonstrating a commitment and potential to grow.
- ■ Actively promoting and prompting industry supply chain initiatives, such as under its Supply Chain 21 (SC21) offering where primes and SME suppliers work together to lift quality and productivity, with scope for modest incentives to de-risk experimental collaboration for large firms and SMEs.
- ■ Continuing to refer to Austrade, Commercialisation Australia and other specialist providers those firms that need more specialist advice on expanding into international markets or financing development.

- ■ Connecting SMEs to specialist providers and policies to support access to technology, managerial and creative capabilities (through linkages to programs such as Leadership 21 and Ulysses).
- ■ Identify and work with industries facing transition in demanding value chains to transform their capabilities to align with the needs of related value chains.

The non-government members of the Taskforce propose a business-focused approach, through a 'one front door, no wrong door' philosophy across all government agencies providing business services. This would include commitments to making knowledge, resources and market insight available via the Business Entry Point, service agreements that support collaboration and information sharing, and co-location of physical offices where feasible.

The objective of these proposed changes is to ensure that the existing suite of activities within Enterprise Connect that support manufacturing activities are enhanced and attract additional resources so that it can help drive the systematic upgrading of manufacturing SME capability and management skills, better supply chain links and performance. This includes segmenting its existing client base and, in partnership with other agencies, identifying and supporting high growth high performance firms, a theme that has been central to this report.

Better interaction between Enterprise Connect, its manufacturing clients and the research sector is also essential. As manufacturing firms upgrade their capabilities, they need to plug into different types and sources of assistance at different times. They face real transaction costs, so Enterprise Connect and related services need to continue to ensure they address these transaction costs. The non-government members of the Taskforce strongly believe that government support needs to be joined up and client focused, not transaction/KPI focused. When it is joined up and client focused, it can deliver enormous value to SMEs at very little cost.

- **IMPROVING RESEARCHER RESPONSIVENESS – MAKE IT EASIER FOR SMEs TO ACCESS KNOWLEDGE**

As discussed, the non-government members of the Taskforce are concerned with the implications of Australia's supply-side model for innovation for the manufacturing sector. There is a need to develop new mechanisms that encourage researchers to directly assist SMEs in tackling their practical innovation challenges.

One such mechanism employed by a number of nations and regions around the world is Innovation Vouchers. Innovation Vouchers would increase the engagement between knowledge providers and SMEs. While the immediate focus is to raise the SMEs productive and innovative capacity, a wider goal is to increase linkages between SMEs and providers by creating new spaces that encourage collaboration.

Vouchers would also be used to enable the identification of good providers. To minimise the transaction costs for SMEs and knowledge providers, brokerage support would be available to connect SMEs and relevant researchers. Red tape involved in administration should be minimal. Vouchers would be redeemable for activities intended to introduce new technologies, products, processes or services, or significantly improve those currently existing. The value of the vouchers could vary, with vouchers for innovation activities such as:

- Accessing facilities for specialised measuring equipment, e-research, supercomputers, or nanofabrication as well as accessing design expertise.
- Accessing process improvement expertise and other technical assistance by drawing on the expertise of staff in the research or technology diffusion facilities.
- Accessing skills analysis, workforce planning and development expertise as it relates to building firm capability.
- Trial production runs or processes to demonstrate technical concepts.
- Validation or demonstration of the technical capabilities of the product, process or service, including scale-up, stability or reproducibility of a process.
- Implementation of new technology and Implementation of new business models.

The purpose of vouchers is to refocus research effort on helping businesses to solve their practical problems through direct relationships.

- **SMARTER PARTNERSHIPS – MEETING SOCIETY'S NEEDS THROUGH INNOVATIVE SMEs**

The non-government members of the Taskforce recommend that the Commonwealth Government introduce a whole-of-government Small Business Innovation Research (SBIR) or Smart SMEs style initiative. It also recommends that the Commonwealth, through COAG, actively encourage State Governments to develop their own versions of such programs.

Smarter Partnerships would see the Commonwealth itself becomes a more effective partner in Australia's manufacturing SME innovation effort by introducing an initiative across Commonwealth agencies with significant research needs. This could be either a SBIR-style initiative that requires a small percentage of the external research for SMEs, or an internal market approach that enables government agencies to bid for projects. Tackling discrete challenges can enable governments to tap into distributed expertise in a range of areas where government alone lacks capability.

Innovative SMEs can be particularly adept at developing solutions for government agencies. Globally and in Australia, programs have been devised to meet the multiple barriers to innovation and firm growth, while also improving policy outcomes. Examples include the USA's SBIR program and the Victorian Government's Smart SMEs Market Validation Program, as described in Box 5.4.

It is telling that both programs are very heavily oversubscribed. These programs support pre-commercial collaboration, and help to address finance, skills, product development and uncertain demand risks, thus enabling growth.

Evaluations of such programs reveal benefits for both participating departments and firms, who work together to translate ideas into practical solutions. But above all, they contribute to systemic innovation capabilities and outcomes. For participating firms, Smart SMEs is regarded as a better way to partner with government, as it involves collaboration in defining the problem and provides access to practical insight that is otherwise very hard to access. And it generates commercial gains – through new IP, new networks, new markets and new exports.

For government agencies, early collaboration around experimental concepts can avoid larger cost blowouts at a later stage. For example, in the reviews of SBIR, this was the major benefit cited by the USA's Navy. Such programs enable government agencies to draw on distributed expertise and apply it to a diverse set of complex challenges that government agencies know they cannot meet alone.

- **ACCESS TO CAPITAL FOR SMEs**

Well-established gaps in early stage finance markets, including venture capital, have widened considerably in the post GFC environment. Government programs to meet these gaps, such as Innovation Investment Funds, have limited coverage. Further, these programs have not affected the underlying problem that Australia lacks a vibrant venture capital market and that it is likely to continue to lack this.

Other small economies such as Israel, Denmark and Chile have met similar scale challenges by developing their own venture finance models. They have adopted various financing, stage-gate and governance processes to maximise impact, ensure cost-effectiveness and (particularly) leverage professional management. The non-government members of the Taskforce are conscious that a wider range of start up and SME finance needs are not being adequately catered for, with the covenants and other requirements attached to loans in many cases unacceptable.

The non-government members of the Taskforce therefore recommend that a Canadian-style loan guarantee scheme be considered for its applicability to the Australian context. Parallel schemes operate in the automotive industry and will soon operate through the Clean Energy Finance Corporation to assist manufacturers wishing to diversify but facing access to capital issues because of the perceived risk.

▪ IMPLICATIONS FOR ROLES AND RESPONSIBILITIES

To lift the limited contributions researchers and governments in Australia make to SME innovation, the suite of measures proposed place greater emphasis on the demand-side, while also recognising that it is ultimately relationships between demanding customers and responsive suppliers that generate innovation. Building SME connections and capabilities would imply change for all actors:

- SMEs, in return for greater support in accessing capital, developing capabilities and managing the risks and costs of product development, will need to commit to change themselves and embrace more rigorous management support.
- Large firms receiving government support will need to commit to good faith efforts to strengthen SME engagement in their value chains, recognising that the breadth and depth of these value chains ultimately affects their own performance and opportunities.
- Researchers will need to adapt to mechanisms that refocus relationships of solving practical problems for businesses, with this implying a more direct and collaborative partnership.
- Governments will need to recognise that a strong pool of innovative SMEs is in their interests and that of the wider economy. This pool can help overcome the systemic lack of medium-sized firms and the practical need for government agencies to tackle new challenges that they cannot meet alone.

Smarter workplaces

To recognise that productivity gains are ultimately realised in workplaces and firms, a new national partnership for Smarter Workplaces is proposed. This requires sustained commitment from industry, unions, employees and government to build the managerial and workforce skills – and the innovation culture – that high performance workplaces demand.

This would involve a new partnership and national conversation – with employer organisations and unions assuming responsibility and stepping up to lead – that can not only have practical impact in workplaces, but also start to shift cultures towards collaboration and innovation, and maintain momentum beyond political cycles.

▪ A NEW NATIONAL PARTNERSHIP FOR SMARTER WORKPLACES

One renowned workplace expert recently argued that Australia stands a chance of being a world leader in management and workplace practices. Given the large gap between that aspiration and practice, this suggests very significant scope for gains.

The non-government members of the Taskforce submit that smarter workplaces can deliver business productivity, rewarding work, and a stronger economy and society. Change needs to address management and workforce capabilities, and cultural attitudes.

The non-government members of the Taskforce also recommend showcasing good practice to help develop a wider national conversation on high performing workplaces as a new element of economic policy.

▪ WORKPLACE CAPABILITIES

Improved management practice opportunities would be made available through a national expansion of program offerings through Enterprise Connect. As is currently the case, this would involve a range of service providers and encourage healthy competition over time.

In addition, the non-government members of the Taskforce note the potential for improved management education through the proposed Australian Leadership Institute.

▪ RESEARCHERS IN BUSINESS

Given the significant cultural divides between research and industry, the non-government members of the Taskforce recommend a significant effort to expand take-up of the Researchers in Business program as a first step to overcome the cultural barriers between research and industry.

As this brings researchers into firms on a local basis, the personal relationships that are critical to collaboration can start to develop. This form of proximity is difficult to replicate other than on a personal basis, making this program a model that could ultimately underpin stronger knowledge flows between research and industry.

A common barrier to the ability of SMEs to develop differentiated solutions is a lack of skilled workers. The number of researchers engaged in innovative activities in Australian manufacturing reveals a significant disadvantage, as shown in Figure 5.4.

8. National Academies: Making Value – Integrating Manufacturing, Design and Innovation

National Academies – September 2012

Manufacturing is in a period of dramatic transformation. But in the United States, public and political dialogue is simplistically focused almost entirely on the movement of certain manufacturing jobs overseas to low-wage countries. The true picture is much more complicated, and also more positive, than this dialogue implies.

After years of despair, many observers of US manufacturing are now more optimistic. A recent uptick in manufacturing employment and output in the United States is one factor they cite, but the main reasons for optimism are much more fundamental. Manufacturing is changing in ways that may favor American ingenuity. Rapidly advancing technologies in areas such as biomanufacturing, robotics, smart sensors, cloud-based computing, and nanotechnology have transformed not only the factory floor but also the way products are invented and designed, putting a premium on continual innovation and highly skilled workers.

A shift in manufacturing toward smaller runs and custom-designed products is favoring agile and adaptable workplaces, business models, and employees, all of which have become a specialty in the United States.

Future manufacturing will involve a global supply web, but the United States has a potentially great advantage because of our tight connections among innovation, design, and manufacturing, and also our ability to integrate products and services.

The National Academy of Engineering normally conducts studies at the request of government and delivers its conclusions to the requesting agency. In this case, the NAE has been sufficiently concerned about the issues surrounding manufacturing—and sufficiently excited by the prospect of dramatic change—to take action on its own. On June 11–12, 2012, it hosted a workshop in Washington, DC, to discuss the new world of manufacturing and how to position the United States to thrive in this world. The workshop steering committee focused on two particular goals.1

First, presenters and participants were to examine not just manufacturing but the broad array of activities that are inherently associated with manufacturing, including innovation and design. Second, the committee wanted to focus not just on making things but on making value, since value is the quality that will underlie high-paying jobs in America’s future.

The workshop opened with presentations on the changing nature of manufacturing, design, and innovation; the future of work; building the ecosystem for manufacturing, design, and innovation; and manufacturing for sustainability. The remainder of the workshop consisted largely of two extended breakout sessions, followed by reports of the breakout deliberations to the entire group.

9. CSIRO: Manufacturing a Better Future - the Role of Science, Technology and Innovation

CSIRO, Manufacturing a Better Future: the role of science, technology and innovation, Canberra, 2012.

Executive summary

Globally, the manufacturing industry is increasingly dependent upon innovation to remain sustainable and competitive through increased productivity, customised products and access to new markets

Australia's high dollar, wage costs, distance from global markets and high proportion of small to medium size manufacturers requires it to rapidly adapt if it is to position competitively for new Asia-Pacific and other regional market growth in technology, health care products, energy , green chemistry and food product innovation and export. However, currently, Australian manufacturing is only a middle-ranking investor and user of advanced innovation, inhibiting its capacity to respond to rapid global change.

Australia has natural endowment in food and resources. These sectors offer a uniquely Australian platform for growth in manufacturing innovation and the opportunity to recapture a global leadership position built on a sustainable comparative advantage. Nevertheless, a sustained competitive advantage in manufacturing increasingly requires advanced digital design, automated processing, high speed broadband access and the capacity to simultaneously optimise and customise product manufacturing and product distribution nationally and globally.

Increasingly, economic growth will need to be balanced by environmental responsibility, as the cost of managing energy, water, materials and labour become increasingly explicit. Meeting this objective for green growth will see the need for more sustainable manufacturing.

Stimulating and sustaining innovation is key to the adaptation of Australia's manufacturing industry to these requirements. By mapping comparative advantages and competitive requirements, innovation opportunities emerge as follows:

- Stimulation of innovation through improved connections between research development and industry application. Whilst Australia has significant strengths in R&D, the translation and absorption of that R&D into industry needs improvement. Linkages between research institutions (both publically funded research organisations and universities) and manufacturers are also low.
- Sustained innovation to modernise our existing mature manufacturing industry and skills base to operate competitively across a range of sectors through:
    - Faster discovery and improved design to enhance the responsiveness of firms to dynamic market conditions
    - Development and introduction of new enabling technologies for mass customisation – such as additive manufacturing and advanced, automated processing, which can potentially lift productivity
    - Leveraging off national infrastructure, such as high speed broadband to promote regional distributed manufacturing
    - Encouraging a better understanding of supply chains, value creation and resource constraints to support the linking of companies into competitive and sustainable supply chains
- Concerted partnering to underpin the renewal of Australia's food manufacturing sector through consumer insights and product innovation for exports. Enhanced networks and capability in food science, engineering, pilot plant scale-up and advanced logistics can deepen linkages between the global scale food industry in Australia and the proximal Asian consumer markets.

Models for achieving this integration and collaboration are set out in the paper, including the concept of a National Food Innovation Hub and Network to anchor food manufacturing at scale, with food pilot plant and processing centres in Victoria and Tasmania. Additionally, opportunities for incentivising linkages, knowledge sharing and skills development between industry (particularly small to medium enterprises), publically funded research organisations and universities are presented.

Underpinning all these priority areas for manufacturing innovation is a requirement for platform R&D capabilities at scale, based on connectivity and collaboration across all players in the National Innovation System. A Global Manufacturing Innovation Precinct is proposed, with a hub centred on an advanced manufacturing technology centre (focussed on automated processing and additive

manufacturing) at Clayton, Melbourne and a spoke in Geelong for smart textiles, Werribee for food processing and perhaps Swinburne (Hawthorn) for industrial design.

Stimulating Innovation

The consequence of these shifts has been captured in Terry Cutler's 2008 review, Venturous Australia27. This review discussed the increasing complexity and challenges of translating innovative advances in science and technology into industry. Two critical issues emerge:

- For Australia to capitalise on its inherent capacity for R&D it needs to remain an attractive destination for research talent.
- For the manufacturing sector, this places an onus on maintaining scientific excellence in manufacturing R&D.
- Without the ability to translate, transfer and apply scientific capabilities within industry, Australian manufacturing cannot advance towards a sustained and globally competitive manufacturing base.

It is this ability to translate, transfer and apply science that offers an opportunity for significant improvement in support of a re-invigorated manufacturing sector. There are many examples of close and enduring connections between R&D organisations in Australia and the companies they serve. Nevertheless, in an analysis of submissions to the review of the NIS in 2008, whilst the content identified a "consensus about the high value of innovation and its contribution to economic and social life", it highlighted that "it is a disconnected system where there are few bridges between its major players".

Evidence supporting this view is also reflected throughout the most recent Innovation Systems Report released in 201129. The Australian Industry Group has also indicated that, "less than five per cent of businesses reported that they obtained information about new technologies from research institutions" and "only six per cent of manufacturers collaborated with publically funded research organisations (PFRO's) as part of their investment in new technologies over the past three years"30.

This lack of connection is of concern since Australia's research and development is largely undertaken by these organisations and universities. This R&D capability is large and includes 44

Cooperative Research Centres (CRCs), 15 Rural Research and Development Corporations (RDCs), 40 Universities, and a number of PFROs, the most significant of these being CSIRO. The capabilities in these institutions are increasingly being coordinated in collaborative ventures aimed at manufacturing, such as:

- Building industry skills in Green Chemistry at Monash University 31
- Bioplastics at Swinburne University of Technology
- Robotics at the University of Sydney 32
- Hydrogen Storage at the University of Queensland33
- Food Processing pilot plant at CSIRO 34
- Synchrotron in Melbourne 35
- Centre for Intelligent Mechatronic Systems at University of Technology Sydney 36
- Artificial Intelligence Group at The University of New South Wales 37
- Australian Institute for Nanoscience at the University of Sydney 38
- Australian Future Fibres Research and Innovation Centre at Deakin University 39
- Manufacturing Technology Training Centre in Ballarat at the University of Ballarat 40
- ARC's recent provision of $249 million for the Industrial Transformation Research program 41.

Despite signs of a gap between the science and innovation of Australian PFRO's/Universities and manufacturing companies' uptake of technology, Knowledge Commercialisation Australasia's (KCA) recent Commercialisation Metrics Survey Report offers some positivity. Their findings indicate a growing improvement in technology commercialisation across Australia. It states that in areas such as resourcing for commercialisation, intellectual property protection, licensing activity, start-up company formation and capital raising, that the connections between PFRO's and industry are stronger42.

Nevertheless, various nations with large manufacturing industries, such as Germany, show much greater connections between PFRO's and industry and can produce highly innovative and competitive manufactured products for export markets.

The Fraunhofer example43 exploits a range of factors that contribute to successful connections – in particular the establishment of a critical mass of capability, a clear focus in key areas of innovation, SME's determined to take full advantage of the science and technology available and a culture which views innovation as an intrinsic part of competitiveness. Whilst Australia can learn from these, European cultures and systems are not always transferable to the Australian context. There are some barriers to research translation in Australia, which must be addressed.

Barriers to Research Translation

Barriers to research translation Australian manufacturing organisations span a wide range of sizes, skill levels and appetites for engaging with research organisations. Some companies can be regarded as dynamic in seeking and using knowledge and these may have a larger ratio of academically skilled people, whilst others with a lower ratio may be regarded as static44, in that there is a lower level of interest in absorbing new information.

The ability of the organisation to transfer knowledge is the crucial factor that will enable them to learn and adapt new information for their business. This 'absorptive capacity' may sometimes be a challenge for the small to medium enterprise sector (SMEs), which make up the greatest number of manufacturing companies in Australia.

SMEs can find it difficult to evaluate the value of services45 and assess the differences among service providers46. Hence, access to science, development and innovation can be difficult for those very organisations that are best placed to make use of it in industry – small to medium enterprises with the drive and energy to bring new ideas to the major industry players. The key challenges lie in three main areas:

- Project size and risk: In developing a project with a company for the first time, cost can sometimes be an issue, as there is generally a poor understanding of the true cost and value of research activity. The inevitable size and risk means that SMEs are not able to engage in the process and hence reap the potential rewards.
- The human factor: Entrepreneurship, mutual trust and the alignment of individual goals and respect are highly significant in a successful technology transfer47. However, research organisations and industry organisations have very different performance measures, which can make it difficult to align these cultural aspects. Other challenges also exist around the lack of knowledge of IP and its uses, as well as the different bureaucratic systems of operation between organisations of different sizes, especially if there are multiple stakeholders involved. These factors combined can become a cause for confusion and a barrier to making the choice to engage in R&D projects.
- Market pull/technology push: A significant barrier to successful transfer of knowledge results from misalignment between market pull and technology push. Technology push refers to the development of general purpose or platform technologies despite no clear and established relationship to apply the technology to meet a particular market need. On the other hand, a market pull approach is much more directed at a commercial outcome. The linkage of the two fosters the best scientific outcomes—both problem and future oriented.

These barriers can be overcome by understanding the cultural differences that drive them and encouraging linkages between the research and entrepreneurial cultures.

Innovation to support responsive manufacturing in a digital age

Whist by no means the only route to heightened productivity, innovation has a significant role to play in unlocking Australia's competitive strengths for the contemporary market place – both through the incremental evolution of current practice and through the development of disruptive processes and options to enable change to the nature of manufacturing and create a new paradigm for the delivery of manufactured products to customers.

- **New materials and process technologies**

The discovery and manufacture of new materials using advanced processing techniques offers a solution to many of the trends in manufacturing relating to optimisation, more from less and the incorporation of smart functionality. As product lifecycles become increasingly shorter, the ability to manufacture and adapt rapidly becomes critical for maintaining a competitive edge. In an Australian context, this potential for flexible, scalable production enables evolution from a reliance on inefficient batch processing techniques, which require capital intensive infrastructure that is difficult to justify due to the lack of market scale.

Science and technology developments that canwork towards this flexibility, cost effectiveness and responsiveness are summarised on Figure 5 and include:

- Accelerated materials discovery: using robotic enabled facilities capable of producing materials and/or completing hundreds to thousands of parallel experiments at a time
- Additive manufacturing: a suite of processing techniques linking the digital and physical worlds by directly translating digital (design) information to the desired prototype, tool or production part
- Advanced processing: technologies such as continuous flow processing leading to substantially smaller, cleaner, safer and more efficient chemical processes with wide application in a number of industries, including fine chemicals and food.

- **Towards mass customisation**

Several trends point towards the increasing blurring of the line between manufacturing and services, coupled with a drive towards mass customisation (see Figure 5). The ability to rapidly respond to changing consumer needs and to customise product and service offerings in multiple markets becomes a competitive strength – one already alluded to in additive manufacturing.

A core enabling aspect of this innovation will be increased collaboration amongst players through the manufacturing supply chain to enable advanced design, automation and simulation through the convergence of the creative arts, science, engineering and ICT, the latter leveraging the power of the broadband network to develop Factories of the Future.

- ***Resource sustainability, value creation and supply chains***

A key aspect of any contemporary industry is the management and use of labour, water, energy, materials and waste, many of which also have added environmental and social costs attached to them. Initiatives such as the OECD's Green Growth strategy59 have been developed to respond to these changes, emphasising the need to balance future economic growth with environmental responsibility.

Technology can play a critical role in enabling the efficient management of these precious resources with increasing attention being paid to the cost and potentially embodied energy/carbon along the supply chain. Encouraging a better understanding of supply chains, value creation and resource constraints is an important innovation to modernise and extend the Australian manufacturing system for the 21st century.

This is likely to have an increasing effect on the value created and extracted by a manufacturing company, such that markets can be accessed or potentially denied based on performance in terms of resource management through the product lifecycle60. Increasingly complex supply chains are emerging in response to these competing economic and environmental drivers on business.

For Australian manufacturers, the globalisation and networking61 of supply chains creates pressure to maintain supplies to and from partners locally and internationally. The complexities involved in dealing with the dynamic nature of supply chains62 as companies manage the move to smaller volume, mass customisation, will significantly increase. There is opportunity to achieve efficiency gains63 and address these challenges through the application of new methods of monitoring and control, both in the production process and in the management and logistics of supply.

Adaptive Supply Networks achieve efficiency gains64 through the application of new methods of monitoring and control, both in the production process and in the management and logistics of supply. Businesses can cooperatively identify and adapt to challenges alongside their suppliers and partners. These technologies can deliver an enduring competitive advantage by improving the coordination of joint activities and by balancing both shared and individual objectives amongst the parties in the supply network, to bring efficiency and harmony in decision-making.

This approach has already been effectively implemented in steel manufacturing for steel coil export, in wine to manage grape harvesting and wine production and in health in relation to patient transfer65.

- **Smart Information Systems**

The potential contribution to Australian manufacturing In 2003, the Productivity Commission estimated that ICT application impacted national productivity growth by 0.2 percentage points, a significant amount within the context of Australian multifactor-productivity (MFP) growth of 1.8% per annum during the 1990s. Impacts observed in major ICT-adopting sectors, such as financial Smart Information Systems, were even more pronounced.

One recent report estimates that the adoption of smart technology in energy, water, health and transport and the roll-out of high-speed broadband could add more than 70,000 jobs to the Australian economy and 1.5% to the level of Australia's Gross Domestic Product within a few years66.

This impact can be achieved in a number of ways. For example:

- Customer databases can be mined to glean insights about preferences and behaviours, leading to enhanced service offerings, reduced customer turnover and new business and/or management approaches
- Inventory and asset management systems are used to provide a better understanding of the level of raw materials used, the cost of manufacture, the amount of waste produced, the number of days inventory is kept, supplier prices and selling prices. Such 'simple' reporting systems can be extended to include modelling and scenario planning to optimise the production processes, or to support customisation of products to specific customer preferences
- Plant and equipment used in a production can be fitted with low cost sensors to provide a view of operating performance and highly localised operating conditions. When networked, this can be extended to provide a real time understanding of the entire production process. Individual products or subassemblies can be fitted with radio tags and micro-devices to offer a means of tracking and recording the whole lifecycle of the product. The 'cloud' also provides a new paradigm for delivering computing resources to manufacturers on demand, in a similar manner that utilities provide water, electricity or gas. Cloud computing architectures and software infrastructure enables clients to interact with computing servers and storage by providing layers of services:
- Software as a Service (SaaS) provisions complete applications as a service, such as Customer Relationship Management (CRM) and email
- Platform-as-a-Service provides a software platform for developing other applications on top of it. An example of such a platform is the as the Google App Engine
- Infrastructure-as-a-Service (IaaS) provides an environment deploying, running and managing virtual machines and storage. IaaS provides incremental scalability (scale up and down) of computing resources and nearly unlimited, ondemand storage.

Simple repetitive tasks have largely been addressed by automation in manufacturing environments. Many complex tasks still require human involvement and in some cases may be performed under hazardous conditions. The ability to remotely control equipment delivers benefits by removing people from hazardous and inhospitable working environments, as well as providing opportunities for increasing efficiency, productivity and profitability in manufacture.

Traditionally, remote operation in industry has involved video being transmitted to a remote operator, who makes decisions based on the visual evidence and responds by commanding the equipment to take action (i.e. tele-operation). Unfortunately, for many manufacturing applications, this type of interface does not offer the human decision-maker sufficient situational awareness to effectively maintain manual production levels. This means that there has been, until now, limited economic benefit for remote operation of manufacturing equipment over traditional in-situ operation.

Smart Information Systems potential exists for a much higher degree of automation or improved situational awareness for a remote operator.

- **Attributes of a smart information system innovation**

Technology-led Smart Information Systems innovation is important not only through the direct application of discoveries, but also by enabling the uptake of innovation and discovery made elsewhere67. This is particularly true for ICT, which is frequently associated with innovation in other domains. In all cases, we are looking to develop 'Smart' Information Systems for businesses which are differentiated from 'Ordinary' Information Systems in that they must meet the following key requirements:

- Scalability: Dramatic increases in the size of a network or in the level of use have always been a source of complexity. For example, the number of actual devices connected to the Internet is expected to climb to over 50 billion by 202068. Smart Information Systems must be capable of rising to the challenge of accommodating dramatically increasing usage
- Interoperability: Any Smart Information System should enable mediation between different protocols, as well as mediation between multiple providers and devices. Smart Information Systems must operate in a manner that shields the end user from the underlying complexity of the network
- Adaptability: Smart Information Systems should not be solely aimed at mitigating present-day complexity. Rather, such Smart Information Systems should be designed to adapt to new developments in public good, commerce and communications as they occur, and be flexible enough to meet the reality of a constantly evolving form and functionality
- Availability: As critical transactions within a Smart Information Systems (such as legal, supply chain, and financial transactions) are processed across digital infrastructure, and as that infrastructure becomes the basis for increasingly high-value and high-volume transactions, the service must maintain high levels of reliability and availability. However, since design decisions to increase availability and reliability frequently come at the expense of adaptability, this requirement will generally pose a significant challenge
- Security: The key role that Smart Information Systems play in coordination, control, and safety can make them a target for individuals who have an interest in disrupting the underlying communications and information management. Therefore Smart Information Systems will need to be built in a manner that makes them exceptionally resistant to physical, logical, network, and social engineering attacks
- Visibility: The intelligent collection, correlation, and interpretation of data in multiple formats from multiple sources are generally at the heart of any Smart Information System. A Smart Information System therefore must be able to provide visibility into usage, trends, and anomalies throughout the entire operating network as well as any larger network of which they are a part.

- **Barriers to implementing smart information systems in manufacturing**

Challenges remain however, even in a fully connected manufacturing process. New and emerging uses of technology with increased reliance on electronic delivery of critical and commercially sensitive information carry concerns around security and privacy. There is a need to increase consumer and business confidence through improved solutions for privacy protection, e-security and trusted computing.

Unfortunately, the links between science, technology and Smart Information Systems innovation is poorly understood in most sectors in Australia. Aggravating these problems are alarming declines in the number of students choosing careers in mathematics and computer science69.

Critical issues to address include:

- A focus on raising awareness of Smart Information Systems in the manufacturing sectors. Often small or boutique manufacturers are not aware of the range or potential of information rich tools or systems

- Providing assistance to SMEs to introduce Smart Information Systems into their unique processes
- Fostering links between the National Innovation System and SMEs
- Developing a workforce skilled in use of Smart Information Systems
- Addressing "ICT literacy" within the education system to develop early stage understanding of the role of ICT within many sectors of the economy including manufacturing.

10. Intelligent manufacturing: Towards the process industry of the 21st century

Intelligent Manufacturing (IM): Towards the process industry of the 21st century (Steel: a key partner in the European low-carbon economy of tomorrow, European Steel Technology Platform, March 2009.)

Four main topics are addressed:

- The intelligent manufacturing programme of ESTEP can both contribute to a global optimization of energy production and high standards of quality within the supply chain
- Steel can offer "holistic" economic solutions not only for energy efficiency but also for all other areas of sustainable construction
- Through light-weight solutions and innovative methods for complex components associated to surface technologies, steel can contribute to "green cars"
- New high-performance steels and engineering can bring solutions for sustainable energy exploration, transportation and production (oil, gas, power generation and renewables)

As all these initiatives require the creative thinking and continued dedication of researchers and skilled personnel the role of education and training towards a skill intensive industry is also addressed and the document suggests future European initiatives, in particular the creation of a European high education and training school for steel related matters.

Increasing the use of intelligent technologies in manufacturing is one of the 3 major partnerships initiatives in the Recovery Plan of the European Commission. It is also a major R&D theme of the ESTEP platform and its objectives have recently been updated (roadmap to be published).

What has been done so far:

For a long time, process R&D performed by the European industry succeeded to enhance the control of each step of the very complex steel production chain. It has been done by developing new sensors, e.g. surface inspection devicesor non destructive techniques for measuring bulk properties, by modelling the numerous processes and process/product related properties, by improving the quality of products and increasing the productivity of the industrial tools, whose reliability have been upgraded.

It allowed a highly competitive industry to develop, which is top level with the Japanese and Korean steel industries in the World.

Nevertheless, the situation is still far from being optimal. The practical operations are not state of the art for many reasons: lack of reliability of sensors and data, difficulties to implement in practice new solutions, etc. The distance between R&D and practical diffusion of the innovation is always underestimated !

Moreover, the biggest challenge is to integrate in a coherent way, all the developments realized by people working each in their own field of expertise. This global integration and optimization, allowed by the huge development in IT, will be the key point for the future.

Future initiatives

To strengthen the long term competitiveness of the European industry, innovation is also required in the production processes and manufacturing technologies in order to achieve the highest standards of quality, just in time delivery at minimal cost with high production through safe and sustainable processes. At plant level, the objective is to achieve global modelling and integrated control of the global production chain supported by a fully integrated IT system.

For steel, Intelligent manufacturing is the progressive building of an integrated control of manufacturing chains including all technological aspects (utilization of sensors, process control loops, IT systems, production scheduling …) with the addition of intelligence provided by modelling, advanced control, diagnostic tools, advanced maintenance concepts, optimization and simulation, expert knowledge, artificial intelligence.

This concept mainly developed in discrete manufacturing is being extended to high-energy intensive process industries. IM will lead to the global control of the whole production chain supporting the sustainable manufacturing deployment. High-Tech SMEs will be associated to develop new innovative functions.

Moreover, the steel sector has discovered the benefit of more compact lines with very short response times and extended ranges of capability. These shorter production routes, integrating the operations from liquid stage up to final shape whilst avoiding the most oxidizing processes, are being considered and investigated (towards scale free processes).

Beside important savings in energy and rough materials, great flexibility is needed in the whole production chain to cope with the expanding range of products that will have to be supplied at low cost. Intelligent manufacturing technology should contribute to developing these more flexible and lower raw material and energy consumption processes.

This IM programme is fully in line with the sub-programme Intelligent Manufacturing of the Manufuture platform and the 3rd R&D major partnership initiative “factories of the future” of the European Recovery Plan.

11. DIISR: Absorbing Innovation by Australian enterprises: The role of Absorptive Capacity

A Report prepared for DIISR in 2007 contains a number of findings.

1. Innovation is becoming increasingly important as a driver of competitiveness. At the same time firms are becoming more specialized as industries move away from vertical integration towards networks of production. As a result of this specialisation, firms are less likely to hold knowledge and capabilities required for innovation in-house, and must increasingly look outside for new knowledge.

2. Just as firms are building production networks (or systems) involving close cooperative links with other firms, so also are they building new innovation systems involving more external links. Building relationships to access distributed knowledge and capabilities is a key issue for firm managers. New knowledge often comes from interactions and collaboration with other firms, especially customers and suppliers. Research organizations are another source of new knowledge, although they interact with firms less frequently.

3. Absorptive Capacity involves a firm's intent and ability to recognize opportunities presented by new knowledge. Firms need a foundation of inhouse knowledge that allows them to recognise and evaluate new knowledge. But recognition alone is not enough; it needs to be allied with an effective strategy/capability for exploitation/ implementation.

4. Firms may develop Absorptive Capacity through explicit measures, such as hiring trained staff, R&D activities or establishing strategic alliances. Absorptive Capacity may also develop as the by-product of other business activities, for example through learning associated with problem solving, innovation, and collaboration for other purposes.

5. Firms can more easily add to knowledge and diversify in areas in which they already have a knowledge base. Firms also learn from other firms most effectively when the partners are similar in terms of structure, human resource policies and knowledge bases. Thus a firm's capacity to absorb new knowledge evolves over time within a specific organisational and knowledge context For that reason scientific knowledge should not be considered as a 'public good' in any simple sense, as only some individuals and organisations are capable of using it.

6. Firms face particular challenges in external knowledge acquisition where:

- they have few linkages with the firms or organisations from which they seek to acquire knowledge;
- the fields of knowledge and innovation are new to the firm; and
- the pace of change in technology is rapid and unpredictable.

7. The more firms face such challenges the greater the need to strengthen Absorptive Capacity with purposeful strategies and sustained investments, and often organisational and managerial innovations, to raise the capacity to learn and innovate. It is worth noting that firms with more highly qualified managers tend to invest more in training and establish more external links.

8. Knowledge that is relevant for innovation includes both codified knowledge (know what) and tacit knowledge (know how), with the former becoming relatively more important. Mechanisms that are suitable for acquiring one of these types of knowledge may not be as effective for the other. Codified knowledge is easier to transfer than tacit knowledge, which is generally embodied in people.

9. There is a substantial overlap between the literature concerned with Absorptive Capacity and that concerned innovation more generally. Innovation research extensively covers the issues of identification and assessment of new knowledge, its acquisition and integration with existing knowledge, and the development of capabilities for managing these processes within firms.

Absorptive Capacity is an important part of a firm's innovation capabilities and hence its development is a dimension of innovation management.

10. Absorptive Capacity is largely situation-specific. It is a function of the relationship between capabilities, structures, routines and policies particular to a firm. For this reason it is not possible to develop a set of reliable standard indicators of Absorptive Capacity.

11. Only a small proportion of SMEs are dynamic (i.e. constantly adapting and changing) in terms of innovation and growth.

12. Although clusters are sometimes suggested as a means of stimulating innovation in SMEs, without the capabilities to absorb and use knowledge, membership of a network is of little value. Thus cluster-based inter-firm links do not guarantee knowledge acquisition.

13. Internationally, there is an extensive and increasing range of programs aimed at reducing barriers to capability development, innovation and growth in SMEs. These initiatives are influenced by the perception that SMEs can play a vital role in innovation systems but that significant market failures limit their development.

14. There is increasing interest in evaluating these programs and in developing international initiatives to share experience in SME program design and implementation.

15. SMEs tend not to see government agencies as credible assistance delivery mechanisms.

16. Our review of selected successful programs suggests a set of functional criteria for a program focused on strengthening Absorptive Capacity in SMEs:

- be focused on the more innovation-active SMEs committed to growth;
- be located near to firms, be linked into local networks, and be integrated into national information and support networks;
- have a strong emphasis on developing innovation capabilities, along with technological and market knowledge, but in association with a specific development objective, usually linked to an innovation project;
- have a requirement that the SMEs contribute a significant share of overall
- costs;
- provide access to a broad spectrum of credible experienced professional advisory services;
- facilitate the development of linkages to local, national, and international information sources, service providers, potential business partners and research organisations;
- have a broad portfolio of services (e.g., advice, finance, networking) but a flexible delivery customised to the needs of the SME; and
- delivery through capable experts who work with the firm to develop an effective and sustained combination of objective performance assessment and flexible delivery of services.

See
http://www.innovation.gov.au/INNOVATION/REPORTSANDSTUDIES/Pages/AbsorbingInnovationbyAustralianEnterprisesTheRoleofAbsorptiveCapacity.aspx