Designing Design Research Within a Collaborative Research Centre: A Flexible Approach to Working with Scientists, Government, Industry and Academia.

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Objectives of the Research

Within an Australian context there are seventy-one Collaborative Research Centres (CRCs) covering a wide range of technologies, sciences and socially orientated areas of research such as health and ecology. The Wood Innovation CRC has seventy million dollars worth of funding derived from industry, government, and the university system. The Wood Innovation CRC concerns itself with the development and commercialization of new technologies designed to solve a number of key industry problems associated with wood processing and new product development. Primary research focuses upon wood modification through microwave processing and resin impregnation. The resultant materials can be further engineered to meet the specific demands of individual industry sectors such as furniture and construction. Material characteristics designed to increase strength, stability, ultraviolet light protection, termite proofing and durability are being developed to meet the challenges associated with both domestic and export markets. The objectives associated with linking design to this CRC are to establish innovation and design as the driving force behind all scientific and technological inquiry.

The Approach or Method Used

Twenty eight doctoral candidates are currently conducting research within the CRC for Wood Innovation, the vast majority are scientists or engineers with aspirations to work as either postdoctoral fellows or industry consultants. Their pattern of candidature and the search for a PhD focus is traditional and linear resulting in a non-adaptable and often formulaic response more suitable to scientific publication than working within a fluid commercial context. In stark contrast, the Design candidates have, throughout their candidature, developed a flexible approach designed to facilitate quick directional shifts and fast response times linked to new scientific discoveries, CRC Board directives and commercial imperatives. Strategies are employed, discarded and revised in real time and in negotiation with key stakeholders linked to the CRC. Design candidates have both an industry and an academic supervisor with a view to ensuring the development of commercial intellectual property and successful completion of candidature. This paper will follow the strategies employed and the resultant consequences of working within a complex matrix of diverse stakeholder needs through the journey of two Design candidates.

An Indication of the Nature of the Main Findings

Advantages associated with inaugural membership within the CRC include playing an active role in the initial stages of scientific research. Whilst scientists have the ability to develop new materials, it is through primary discussions with Designers and the Design candidates that have assured the potential development of materials with commercial viability. The resultant conversation has evolved and informed the decision making process associated with new product development. Disadvantages associated with early CRC participation include a dependency upon the commercial availability of new materials in order to exhibit within the public domain and provide evidence for collaboration with new industry partners. A traditional timeline associated with scientific enquiry moving through technological and market developmental stages is seven to ten years in duration, a timeframe that does not fit comfortably with the first cohort of Design candidates. There is a possibility that the candidates will submit for examination prior to the development of commercial IP, a possibility that whilst unfortunate, will validate the need to have remained flexible throughout candidature. The CRC provides an environment in which a unique flexible and evolving version of praxis takes place. The paper concludes by offering recommendations in regard to including design as a key element within collaborative research centers and suggests how transferable strategies can be employed to provide further opportunities for doctoral education.

Designing Design Research Within a Collaborative Research Centre: A Flexible Approach to Working with Scientists, Government, Industry and Academia.

Whilst certain CRCs use industrial designers on a fee for service basis, few have been involved as key activity drivers from the beginning and for the duration of a CRC. The National institute of Design, Swinburne University of Technology has been involved since the beginning of the CRC for Wood Innovations. Appropriate design strategies suitable for PhD candidates and research in a variety of complex environments have been developed, implemented and continue to evolve.

Background to Australian CRCs

Cooperative Research Centres (CRCs) have existed in Australia since 1990 and represent one of four ways by which the Australian Government supports R&D and technology commercialization. [1] Within an Australian context there are 67 CRCs[2] covering a wide range of technologies, sciences and socially orientated areas of research such as health and ecology. As of 2004 direct Government support to CRCs amounts to $140 million per annum.[3] The Wood Innovation CRC will receive a total of seventy million dollars worth of funding derived from industry, government, and the university system over a seven year period.

Why Does Australia Need A Wood Innovation CRC?

There are three main industry sectors that could benefit from the development of more sustainable timber derived from the CRC Wood Innovations program: the forestry sector, the furniture industry and the construction industry. As a primary industry, the forestry sector largely depends upon the successful transition of its harvested product to both the furniture and the construction industries[4]. The

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[1] For a full discussion about the four mechanisms by which the Australian Government supports R&D and technology commercialization, see Dr. Brian Hickman, Illawarra Technology Corporation Ltd., Australia in National Science Foundation Tokyo Regional Office, "International Workshop on Cross Regional Science and Technology Corporation in Asia", www.nsftokyo.org/rm98-09.html (viewed on 23/03/04) p. 10

[2] "International Panel recommends extending water research center", http://enterprise.canberra.edu.au/WWW/www-
media releases.
Nsf/26fa382df8bar1554a25664f0046672e/a666863d2c7bc9db94a25664f00463e09?Open Document (viewed on 23/03/04) p.1

[3] Dr Brian Hickman, Illawarra Technology Corporation Ltd., Australia in National Science Foundation Tokyo Regional Office, "International Workshop on Cross Regional Science and Technology Corporation in Asia", www.nsftokyo.org/rm98-09.html (viewed on 23/03/04) p. 10

[4] In 2001 the Australian forest sector directly and indirectly employed .86 percent of the national workforce or 78,400 employees. This includes people "directly" employed in activities such as Forestry and harvesting, Wood and wood products, Log saw milling, Resawn and dressed timber, Veneers, plywood and fabricated wood manufacturing, Wooden structural fittings and other

furniture and construction industries have multiple and unique problems with the performance of timber: whilst the construction industry has shifted towards alternate materials such as "engineered wood products (MDF, particle boards and craftwood) with steel, plastics and concrete products used on house construction"[5], the timber furniture industry is affected by products that compete by utilising materials that better meet the needs of various user groups and market requirements such as, transportability, maintenance, longevity and price[6].

A Technology Led CRC

To Develop and commercialise revolutionary technologies that establish wood as the sustainable material of choice.[7]

The CRC for wood innovations is primarily involved in developing a commercially viable method for wood processing and wood modification through the use of microwave technology[8]. Once microwave modified, timber is resin impregnated with a view to creating an innovative, high strength material suitable for high-value uses within an international market place. The resultant material, Vintorg[9], significantly extends the possibility of using low-grade timbers, has greater dimensional stability and is more durable in extreme climatic conditions.

The Wood Innovation CRC: Structure

In order to maximize the capabilities of various industry sectors, specialists and research centres associated with the CRC, an organizational structure that promotes synergies whilst allowing individuals and various centres a degree of

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joinery, Hardwood woodchips, Other wood products forming a total of 45,300 employees. "Indirect" activities include Paper and paper products, Pulp, Paper and paperboard, Paper Bags (including sack), Solid fibreboard containers, Corrugated fibreboard containers, Other paper products, forming a total of 19,700 employees. These figures do not include truck drivers, managers or conservation staff. See Australian Government, Department of Agriculture, Fisheries and Forestry, *Australia's State of the Forests Report 2003* Canberra: Commonwealth of Australia, 2003. Table 102, p. 282.

[5] IBISWorld *E4111- House Construction in Australia* IBISWorld, 8 January 2004. p. 17.

[6]The reasons for the increase in demand for "non-wood" furniture may be explained by the needs of the healthcare furniture industry, the shopfittings and retail furniture sector and the industrial warehousing and storage systems furniture manufacture. These three sectors are estimated to account for around 10 per cent of Australian furniture industry revenue each, and use little wood. Added to this, the commercial office furniture sector is estimated to account for around 30 per cent of industry revenue. These sectors use plastics, metals and glass more than wood in their respective furniture. See IBISWorld *C2929- Furniture Manufacturing n.e.c. in Australia* IBISWorld, 8 December 2003. p.11

[7] The mission state is short but succinct, in CRC Wood Innovations, Annual Report 2001-2002, imprint page.

[8] Vinden, P and Torgonikov, G, Modified Wood Product and Process for the Preperation Thereof. International Patent Application No, PCT/AU02/00315

[9] Vinden, P and Torgovnikov, G, A Method of Microwave Treatment of Wood. Australian Patent Application No. PR5963/01

autonomy, provides a platform from which all activity takes place [10]. The CRC is divided into 4 programs that in part represent various stages within an evolutionary process of commercialization and technology transfer.[11] Program 1 is responsible for microwave processing of wood[12], in principle, program 2[13] primarily builds upon and concerns itself with the development of new products derived from research conducted in program 1. In practice, the relationship is more circular than linear[14] with interdependencies that directly determine the nature and scope of research activities in both programs. Program 3 is responsible for Innovation, Technology transfer and Commercialisation[15] whilst program 4 relates to education and training.[16] Programs are further subdivided into projects designed to meet specific milestones (see, Fig.2).

For the purpose of this paper, focus has been placed upon synergies between program 1 and program 2 and how a Technology-Push[17] product design strategy has been established and continually adapted in order to provide firm foundations for Program 3 (Innovation, Technology Transfer and Commercialisation). The paper also highlights the necessity for interaction between various projects within program 2.

Program 2	High Value-Added Wood Products
Project 2.1	Surface engineering of microwave-processed and resin-modified wood and machined solid wood products for enhanced adhesion and long-term bondability.
Project 2.2	Innovative technologies in the design and manufacture of high value furniture and wood products from microwave modified wood
Project 2.3	Innovative techniques in bending of wood components
Project 2.4	Development of high quality wood products for long-term service in a range of environmental conditions

Fig. 1. Program 2 is divided into 4 projects. Success depends upon meeting unique milestones whilst forming synergies between projects and with other programs; in particular program 1.

[10] CRC Wood Innovations, Annual Report 2001-2002, p.1
[11] Ulrich, Karl T. and Eppinger, Steven D. 2000, Product Design and Development, 2nd Edition, Irwin McGraw-Hill, USA. P. 20.
[12] A full account of Program One can be found in “CRC Wood Innovations, Annual Report 2001-2002”, p.10
[13] A full account of Program Two can be found in “CRC Wood Innovations, Annual Report 2001-2002”, p.14
[14] Snodgrass, A, and R Coyne. 1992. Metaphors and the Hermeneutics of Designing. *Design Issues* IX, no. 1: 56-74.
[15] A full account of Program Three can be found in “CRC Wood Innovations, Annual Report 2001-2002”, p.18
[16] A full account of Program four can be found in “CRC Wood Innovations, Annual Report 2001-2002”, p.20
[17] Ulrich, Karl T. and Eppinger, Steven D. 2000, Product Design and Development, 2nd Edition, Irwin McGraw-Hill, USA. p. 21.

A Pre-Commercial Technology-Push Design Strategy

A generic design process can often be adapted in order to create a technology-push design process. In principle a generic design process is market led whereas a technology-push process must incorporate a particular technology or material at the front end of product development.[18] During the early stages of a technology-push design strategy, a potential market is highlighted as a focus for concept development; once established, the technology-push process can often revert to a generic market led design process. Within the CRC for Wood Innovation, the design process was further complicated because the core technology was at a pre-commercial stage of development which in itself creates an element of risk. Ulman suggests that if the technology is not ready for commercialization, it is necessary to dedicate a separate program to the development of the technology; the Wood Innovations CRC does this (program 1). Ulman argues that this is a risky strategy because the whole development process is dependant upon the outcomes of the discreet program.[19] However, designers entered into conversation with scientists and technologists at an earlier stage of the evolutionary process than is usually expected (see Fig. 2).

Alternative Design Strategies: Plan A			
	Generic Process	**Technology-Push**	**Pre-Commercial Technology-Push (CRC)**
Step 1	Begin with Market Opportunity	Begin with new technology	Find potential market opportunity
Step 2		Find a market opportunity	Feed the market requirements into the technology development process
Step 3		Begin Generic process	Develop the new technology
Step 3			Begin Technology-Push
Step 5			Begin Generic process

Fig. 2. A Pre-Commercial Technology Push Design Process.

I have named the strategy ‘Pre-Commercial Technology Push’ and suggest that it is necessary to find a host market in order to identify a list of requirements to act as commercial goals for the development of the technology. Without commercial market orientated goals, it is likely that non-commercial goals such as publication will dominate the front end of the technology development process; the science-technology-market timeframe may not keep in line with commercial timeframes.

[18] Hayes, Robert H.,Steven C. Wheelwright, and Kim B. Clark, Dynamic Manufacturing: Creating the Learning Organisation, The Free Press, New York, 1988.
[19] Ulman, David G. The Mechanical Design Process, 2nd Edition, The McGraw-Hill Companies, Inc, New York,1997. p. 157

During a meeting involving all CRC partners, the need to focus our collective attention upon a specific industry sector was unanimously agreed upon; the furniture industry was subsequently highlighted as our target market.

Why Furniture?

As of 2002, total Australian retail sales of all types of furniture (wood, metal and plastic) is estimated to be around $6000 million[20]. The Australian "wooden furniture and upholstered seat manufacturing" sector accounts for about half the dollar value of the total Australian furniture industry. "Industry revenue is estimated by IBISWorld to have totaled $3,470 million in the year ending June 2003." In the same period employment in the wooden furniture sector is estimated to be 31,000 persons[21]. The wooden furniture industry also has a billion dollar trade deficit primarily derived from imports exceeding exports[22].

The low economic state of the timber furniture industry certainly provided the Australian Government with reason to select the Wood Innovations CRC as an appropriate area for investigation; it was also one of the reasons why it was selected within the University as a focal point for all initial research. However, the major reason related to the technical parameters that should be considered in the design and manufacture of outdoor furniture. By focusing upon the development of appropriate material characteristics for outdoor furniture, a more generic set of characteristics results from the research; characteristics suitable for external timber cladding, decking, fencing and window frames.

Determining Commercial Characteristics

The design team developed a set of material characteristics that represented our understanding of market and manufacturing needs; the list was derived from conversations with industry, a review of quality furniture and related products and a brainstorm session in which future ideals were tabled for consideration (see Fig. 3).

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[20] IBISWorld *C2929- Furniture Manufacturing n.e.c. in Australia* IBISWorld, 8 December 2003. p. 5.

[21] IBISWorld *C2921- Wooden Furniture and Upholstered Seat Manufacturing in Australia* IBISWorld, 20 Ocober 2003. p. 5.

[22] As of 2002-2003 "imports of wooden furniture and upholstered seating estimated by IBISWorld to account for almost 22 per cent of domestic demand." These mostly come from China and Malaysia with lesser numbers from Italy, Indonesia and Thailand. By contrast, Australia only manages to export around 2% of its production. See IBISWorld *C2921- Wooden Furniture and Upholstered Seat Manufacturing in Australia* IBISWorld, 20 Ocober 2003. pp. 7,8.

Needs	Desired Characteristic
Function	Smooth, easily edge finished Surfaces - long life Appropriate and standard sections (and profiles) Suitable stress grade at least equivalent to H3/H4 Treated Pine Sections 19x42/65/90, 32x65/90/110, 42x65/90/135, 90x90 Lengths 2.1, 2.4, 2.7 and 3.0 meters
Safety	Splinter free - minimal end and surface splintering No resin off gas, surfaces safe to touch Appropriate sectional strength - long clear grain Min. section for maximum strength Strength and Stiffness - similar to MGP12 (Pine)
Handling	splinter free, smooth, weight per volume as low as possible Able to withstand climate temperature extremes - to be determined
Ergonomics	Timber sections and performance will determine ergonomics for function Colour, especially relevant to commercial applications (e.g. Corporate) - TBA Ability to texturise and machine surfaces to create non slip grips Stability of colour, finishes and surfaces
Aesthetics	Own, natural aesthetic. A material that enhances the natural timbers used Ability to take stains, colours and other finishes Natural colours - durability, minimal fade Applied colours developed from market research data Textures and finishes from natural timber (Vintorg enhances natural properties) More aesthetic proportions for timber sections to be developed at a later date
Environmental Considerations	Appropriate resins and additives Material/resin life assessed against environmental cost of resin production Long material life Disposal of off cuts - how can off cuts be used
Other	Improved durability Resistance to warping, twisting - improved stability Stain resistant e.g. bird droppings, resin stains from surrounding trees and plants Minimal shrinkage/expansion strong - comparison with pine grades Ability to float Able to withstand heat - e.g. sunlight, close proximity to BBQ, etc. Rain, moisture resistant UV stable resins, colours and finishes Ease of machining - minimum requirements - cross cut, drill and rout

Fig. 3. Desired Characteristics of an ideal timber material for outdoor furniture. Provided to program 1 by Dr Lyndon Anderson and Lotars Ginters.

Conversations, Timeframes and Meeting Expectations

The CRC for Wood Innovations had an official review at the end of its second year of operation[23]. As a result of the review, the panel reported that they were

[23] All CRCs are reviewed on an annual basis by a panel derived form experts in the particular field and experts with previous CRC experience. The panel make recommendations to government.

concerned that concept development was occurring too early in the project; at a point prior to the commercialization of technology.

Concept development has indeed occurred before the commercialization of the technology; this was and still is a conscious element of the design strategy; a strategy that has evolved in line with CRC developments[24]. Within the CRC, technological breakthroughs, potential spin off companies, new directions and the requirements of other CRC members create a dynamic environment in which it is neither desirable nor appropriate to remain static; the design strategy is dynamic and able to respond to changing circumstances within a commercial timeframe.

The conversation between scientists and designers has been useful but slower than originally anticipated. Scientists are still attempting to meet the criteria relating to the material specifications provided by the design team two years ago. However, expectations have changed, and both parties are continually reviewing the extent to which usable material characteristics will be developed within an annual timeframe; for this reason, it is necessary to continually develop new concepts. New concepts act as visual goals to scientists, stimulating a greater understanding of what could be commercially possible once the technology has been fully harnessed. To date, certain concepts have been fully developed within the digital domain and act as useful devices for internal discussion, publicity and interaction with external manufacturers and interested third parties. There are also many problems associated with early concept development (see Fig.4).

Science and Design: Different approaches

Within the CRC, many projects run in parallel. The following example demonstrates the effect of Design not being involved at the very beginning of a project; at a stage when targets are being set for the development of a technology.

Within project 2.3 '*Innovative techniques in bending of wood components'*, Scientists are attempting to focus upon one timber species, with one cross sectional size with a view to achieving a minimum radius of 300mm. Within a scientific context, this is extremely publishable and valid; it is highly likely that such a project will secure a scientific based PhD for one or more candidates. However if we now examine the effect this has upon a Design based PhD candidate working in parallel, with a mission to find commercial opportunities derived from the scientific research, it is clear that a totally different strategy must be developed. The 300mm radius has been selected for no particular commercial reason, it is simply a round number far smaller than published data suggests is possible.

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[24] Ulrich, Karl T. and Eppinger, Steven D. 2000, Product Design and Development, 2nd Edition, Irwin McGraw-Hill, USA. P. 139.

Developing Concepts at a Pre-Commercial Technological Stage of Research		
	Advantages	Concerns
PhD Candidates	Ability to visually communicate What could be achievable and to map the gap between desired and actual readiness of technology[25].	A perception that the designer is not aware of the technological limitations or readiness for commercialisation
Publicity	An ability to gain magazine and exhibition exposure at an earlier stage of the research process	External opportunities may present themselves that, at present, cannot be accommodated
Scientific Research	Scientists can better contextualise the extent to which the technology can be transferred and of benefit to the larger community [26]	timeframes associated with moving a new technology to the market place can take 10 years. Are designers being too optimistic
Review Panel	Desired outcomes are contextualised	The early development of Concepts can reinforce the notion that Design should be added at the end of the process rather than act as a key element of technological development

Fig. 4. Concept Development

In the first instance, the design candidate must identify existing products that could benefit from bent solid timber with a dimension and radius that matches the scientific targets; circular table edging for example. The project has tight contextual parameters, and will not require the attention of a PhD candidate for the duration of candidature. Therefore the strategy must be one of running several projects at the same time; a further project could focus upon a future scenario such as a minimum radius of 100mm and therefore open up the possibility of developing hardwood bent furniture that could compete with plywood furniture. In developing a strategy that enable a multitude of smaller projects to take place, we must ensure that the strategy is dynamic and that the original project proposal submitted to the Swinburne University higher degrees committee reflects the need for the candidate to work within a real world scenario, one in which projects will continually adapt, change, stop or begin.

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[25] This strategy has been discussed and agreed upon by all CRC supervisors. Certain Design PhD candidates are near to completion. Upon enrolment it was anticipated that the technology would be commercialized before the end of candidature; this has not occurred forcing candidates to think laterally about how to position and communicate their research.

[26] Ulrich, Karl T. and Eppinger, Steven D. 2000, Product Design and Development, 2nd Edition, Irwin McGraw-Hill, USA. P. 138.

Such a strategy, dynamic and capable of responding to real world needs in a commercial timeframe, perhaps suggests that a traditional PhD system is not always appropriate, and that perhaps an alternative model should be developed[27].

The Next Step

The design strategy has been further refined, external commercial partners and opportunities have been identified. Various needs within the CRC have been identified as a result of working in the field for two years; initial needs were based upon early discussions in which all parties had expectations that far outweighed commercial reality. The Design strategy has evolved into a multi-pronged approach; in certain circumstances more than one approach will be linked to a particular project. In part, each subcomponent strategy can be viewed as a separate entity and can therefore be considered as similar to a scientific experiment; some experiments will be more successful than others.

Conclusions

Further CRCs have invited the National Institute of Design to participate as either founding members within new initiatives or as new members within CRCs attempting to gain funding for a second or third iteration. In conversation with members of these CRCs it is clear that the fundamental aim of the invitation, is to position design as a key creative resource capable of assisting in the development of all aspects of technological development; not as in-house consultants developing products derived from technology but as members of the technology development team.

Much has been learnt in developing appropriate applied design strategies for CRC activity. The Pre-Commercial Technology-Push strategy has evolved and will continue to do so; it has provided an excellent starting point for almost all areas of investigation. The strategy will be further tested in two ways. The first consists of further developing new products in the Wood innovations CRC; this will test the strategy's usefulness throughout the entire product development process. The second involves transference to an alternative context; will the strategy be useful in a new CRC with an alternate technology development program?

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[27] The National institute of Design, Swinburne University of Technology has developed a Professional Doctorate for Designers. The Doctorate consists of several projects with a shared theme. Such a doctorate may be more appropriate for applied research projects, particularly when a multitude of smaller projects or shorter timeframes are important elements in the product development process.