# The Software Engineering Academic's Role in Industrial Innovation

JOHN HOSKING[1] AND JOHN GRUNDY[1, 2]

Department of Computer Science[1] and Department of Electrical and Computer Engineering[2], University of Auckland, Private Bag 92019, Auckland, New Zealand

{john,john-g}@cs.auckland.ac.nz

## INTRODUCTION

Universities globally are under increasing pressure to diversify revenue, and develop a role beyond teaching and research. Particularly in the technological disciplines, such as Software Engineering, Universities are increasingly expected to be agents for economic transformation. This role diversification creates tensions between investigator-led curiosity-driven research and applied research with potential for more immediate economic impact. The introduction of research quality measurement frameworks such as those in the United Kingdom, New Zealand and Australia exacerbate this tension. Here we discuss how these tensions can be mitigated, in the process generating win-win industry partnerships. This requires compromises for both industry and academics but can be immensely rewarding academically and a financially. We begin by discussing economic drivers that software engineering academics face. These are New Zealand-specific; our international colleagues affirm these resonate strongly elsewhere. We then focus on project level case studies to illustrate how a win-win partnership with industry can be developed. These include a research project resulting in successful product development, and an internship resulting in creation of a new company. We abstract lessons from these collaborations before considering institutional support to foster such win-win partnerships. The latter includes current initiatives we have underway at the University of Auckland which are IT focused, and an interlocking institutional-level framework that encourages industrial interaction and entrepreneurship.

## CONTEXT AND SIGNALS

We begin by examining some of the contextual economic and policy drivers that New Zealand academics face. These are New Zealand specific, but our observation, and peer feedback indicate similar drivers are affecting academics internationally.

Figure 1 shows annual GDP and GDP per capita growth rates over the period 1990-2004 for some of the OECD countries with a weighted average[1]. Superficially, the New Zealand economy performed well over the period with above average GDP growth. However, as Skilling and Boven (2005) point, the GDP per capita growth is less impressive, being below the average, resulting in New Zealand lying at 21st in OECD rankings of GDP per capita. They argue that the GDP growth that has been achieved belies an underlying structural issue with the New Zealand economy illustrated in Figure 2. This graphs labour productivity, as output per hour worked, versus labour productivity, as hours worked per capita, both normalised against the OECD average (given a value of 100 on each axis). New Zealand's position has moved from near the centre to the top left corner of the graph. Thus the growth New Zealand has achieved has been primarily as a result of New Zealanders working relatively longer hours, but with relatively lower productivity. This is clearly unsustainable. Skilling and Boven (2005) argue that low levels of investment in business, research and development (R&D) and information technology plus low Total Factor Productivity growth are major contributors to the relative productivity decline and that these need to be reversed to create sustainable economic growth. However, the underlying causes are not straightforward. For example New Zealand's small market size and geographic isolation may be contributing factors to conservative investment decision making.

Government economic policy has a role to play in addressing the challenges raised by this analysis. Many countries have strategies to increase productivity and economic growth. The New Zealand Government has had two major policy statements: the Growth and Innovation Framework (Clark, 2002) and the Economic Transformation Agenda (Mallard, 2006). The former was "designed to deliver the long-term sustainable growth necessary to improve the quality of life of

---

[1] Data originally from Groningen (2005), reported in Skilling and Boven (2005), reproduced with the permission of the latter.

all New Zealanders" by focussing on four key sectors, Biotechnology, Screen Production, Design and Information and Communication Technologies (ICT), and developing strategies to increase GDP/capita by developing these key areas. Strategies were drawn up in consultation with key stakeholders for each targeted sector. A particular focus in the ICT Strategy was to "Grow, Sustain and Retain a Highly-Skilled ICT Workforce".

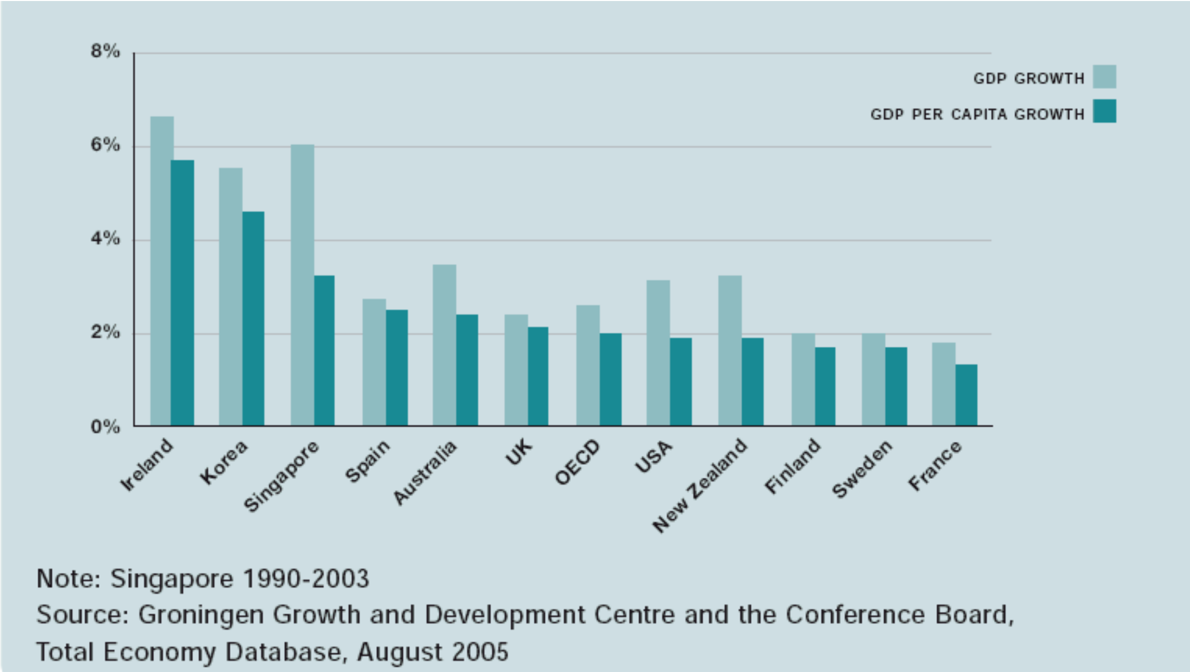


**Figure 1: Compound annual growth rate of GDP and GDP per capita 1990-2004, from Skilling and Boven (2005)**


**Figure 2: Hours worked and labour productivity 2004, from Skilling and Boven (2005)**

For a New Zealand Software Engineering academic, these messages provide a level of optimism. Government strategy implies increased investment in R&D; ICT has a significant role to play in increasing the country's economic performance; and the tertiary sector has an important role in development of a skilled ICT workforce and enhancing innovation. However, strategy and reality are often divergent. Figure 3 shows New Zealand research expenditure in ICT and Agriculture against government, industry and tertiary (mainly University) sectors. The tertiary component is primarily a "research top up" component of the bulk funding to Universities for teaching. Universities also bid into the government funding pool. It is clear that, despite a government strategy to develop the ICT sector that strategy has not translated into significant research funding. In contrast the ICT industry sector is investing heavily in R&D, much more so than the Agricultural sector despite significant differences in sector sizes. Given the paucity of government research funding available, the obvious signal to a Software Engineering academic is to build research relationships with industry to access their R&D spending; a simple application of Sutton's Law: "Go where the money is" (Hull, 2006).

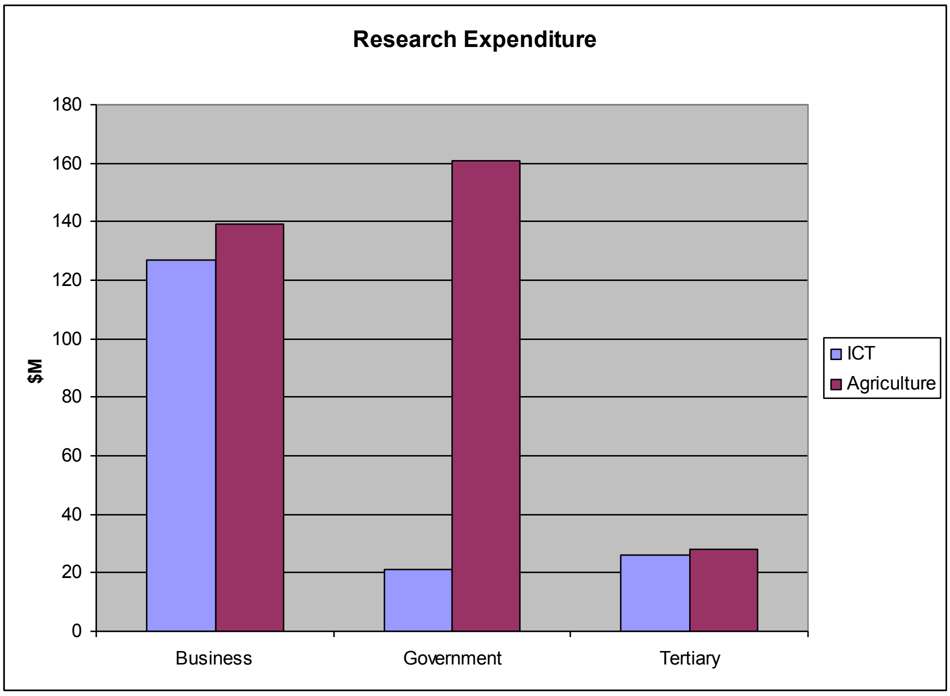


**Figure 3: New Zealand government, industry and tertiary research expenditure on Agriculture and ICT 2004, data from (Statistics New Zealand, 2005)**

Despite the high levels of ICT industry R&D expenditure, a number of infrastructural issues reduce its effectiveness. Firstly, the sector's buoyancy (ignoring the post tech-crash period) means most students enter industry on completing a Bachelors qualification, with a low proportion continuing to graduate study. Thus the typical New Zealand software company CTO, if there is such a position, is a Bachelors graduate with little exposure to research methodologies. Board level research experience is even scarcer. This is exacerbated by the many Small to Medium sized Enterprises (SMEs) in the sector, often one product companies lacking scale and appreciation of how research can leverage them to more complete software product lines, a factor common to many economies. It should also be noted that New Zealand is unusual in the OECD in offering virtually no tax incentives or write-offs for R&D expenditure. These factors together mean that much of the business ICT sector R&D expenditure is directed to relatively "low grade" R&D activities. The factors also act as a barrier to research engagement between industry and academics. However, this can also be viewed as a set of opportunities for academics: assist business to understand the value of research by developing a research culture in industry and help industry spend their research funds more effectively by leveraging academic research expertise, in the process accessing some of that funding. To assist this, the New Zealand Government provides matching grants through their Technology New Zealand portfolio of research investments (Foundation for Research Science and Technology, 2006).

The final set of contextual signals relates to mechanisms for funding tertiary institutions. There is a worldwide trend to make Universities more accountable for the "research top up" funding referred to above. Mechanisms such as the United Kingdom's Research Assessment Exercise, Australia's proposed Research Quality Framework, and New Zealand's Performance Based Research Fund (PBRF), all emphasise and reward research quality, particularly using proxy measures such as publication avenue quality of. On the face of it this would seem to militate against industry collaboration as a distraction from more basic research. However, New Zealand's PBRF has significant researcher weighting on Peer Esteem and Contribution to Research Environment factors, which together reward industry impact of research, and institutional weighting on total research income, including industry contracts. Hence, a deeper analysis of PBRF suggests industry research collaboration is positive, provided it is based on transferring good basic research results into practice.

The second funding signal, related to the first, is a worldwide trend to reduce government direct "teaching related" investment in Universities in real terms. This means that Universities worldwide have sought to diversify incomes streams and have been more eager to undertake industry engagement activities such as funded contract research.

Combining these contextual issues and signals, we observe that New Zealand Software Engineering academics have greater personal, institutional and governmental incentives to undertake industry research activities, albeit in an industry climate that lacks a strong research culture and understanding of the usefulness of engaging with academics, and limited tangible government support for R&D expenditure write-offs. In the following section we describe two case studies of software engineering industry research engagement activities we have undertaken that have been successful, and generalise to lessons for successful engagement.

## PROJECT LEVEL INDUSTRY COLLABORATION

Our case studies involve research related to a healthcare message mapping system for Orion Health (Orion Health, 2006), and a secure e-commerce system for EDIS International (EDIS International, 2006). Neither involves "earth shattering" research results, however they are both win-win, exhibiting successful commercial and academic outcomes, and have led to "repeat business" through subsequent research contracting.

### *Orion Symphonia Mapper*

Orion Health is a Health IT company producing products related to healthcare systems integration (www.orionhealth.com). An important element of health systems integration is the ability to compose and decompose healthcare messages in standard formats. Healthcare messages are typically large and the formats complex making this a difficult and time consuming programming task (Grundy et al, 2001). Orion Health's Symphonia product (Orion Health, 2006) is a software development toolkit that allows addition of standardized messaging to any application, providing the ability to quickly specify message formats, and generate programming interfaces that can be used to simply compose and decompose messages. It is relatively easy and efficient to use and has been deployed on thousands of sites. The product's success has led to Orion Health becoming a market leader for Electronic Data Interchange (EDI) messaging in the Healthcare domain.

However, while Symphonia was successful, the proliferation and customisability of Healthcare messaging standards meant that Orion Health's customers continually had to write programmes to convert between different messaging formats. This, too, is time consuming, requiring a skilled programmer to write boring and repetitive and hence error prone code. Thus Orion Health was interested in developing a new product to allow its users to simply specify and generate code for mapping between healthcare message formats. However, they lacked the resources and research experience to undertake significant research themselves on the problem.

Nearby, at the University of Auckland was a research team with more than 10 years experience in researching related areas, including: representation of buildings for Code of Practice compliance (Hosking et al, 1988; Hosking et al, 1991); managing consistency between building design tools (Amor et al, 1993; Amor and Hosking, 1995; Amor et al, 1999); and frameworks for multiple-view multiple-notation software development environments (Grundy and Hosking, 1996; Grundy et al, 1996; Grundy et al, 1998). This research had generated many research papers, much international academic credibility, and, importantly, a track record of experience working on industry research contracts. Orion Health was encouraged to take advantage of this expertise by the availability of a Technology New Zealand matching grant. They saw this mechanism as lowering their investment risk allowing them to consider less conservative solutions by leveraging University research expertise. Hence a collaborative research project was initiated.

The methodology applied to the project was exploratory and iterative reflecting its research nature. Both parties recognized they could not be too prescriptive about requirements and deliverables at the outset. An early scoping exercise divided up activities between the parties. The University team did what it is best suited to do: research potential approaches; conceptual design for selected candidate approaches; and proof of concept implementation. Orion Health did what it was best suited to do: detailed product design and implementation; and injection of market knowledge. The University focused on the key research issues: the mapping language and specification environment and mapping engine, while Orion Health focused on the outer framework leveraging existing products, such as Symphonia. Regular meetings between the University and Orion Health teams supported a "no surprises" approach and a steady stream of technology transfer. At these meetings candidate approaches would be presented and direction decisions made. The "80:20" rule was important in design and decision making: the mapping language design aimed to make the common things simple to express and understand with escape to conventional code for more complex and rare operations.

The implemented Symphonia Mapper product (Orion Health, 2006) was launched January 2001 at a price of US$10,000. Figure 4 shows the product in use. Initial showcasing brought extremely favourable feedback and a rapid rise in sales. The Mapper is now a key component of the Rhapsody integration engine (Orion Health, 2006b), priced at

US$100,000 with a very large number of installed sites, including the United States Centre for Disease Control and Prevention. Importantly, customers are often attracted to the Mapper product and subsequently buy Rhapsody making it a significant market entry mechanism for Orion Health.

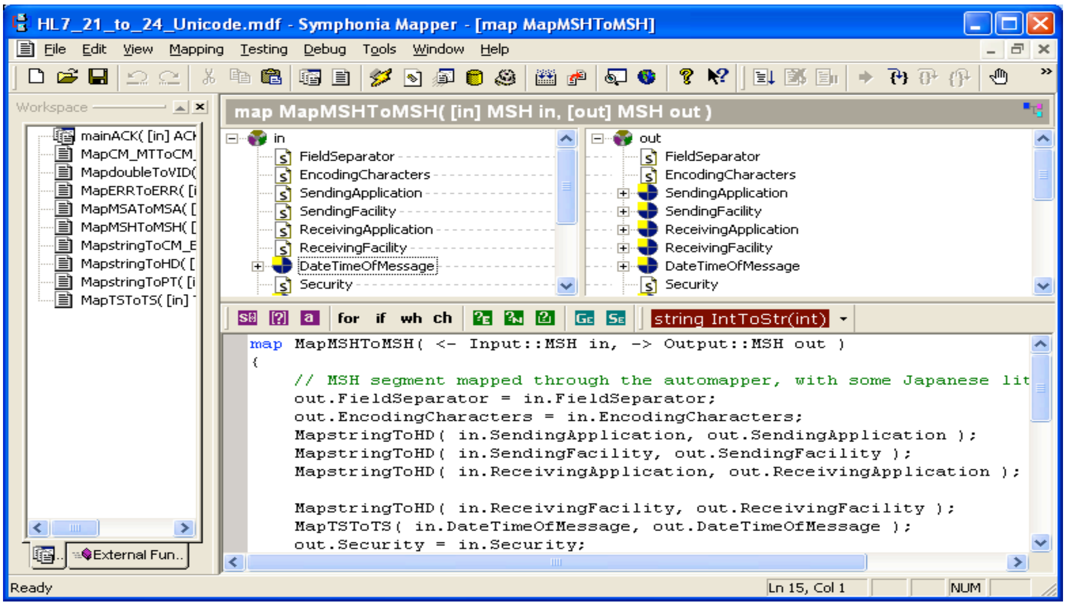


**Figure 4: Screen dump of Symphonia Mapper product in use**

A number of benefits from the collaborative project accrued to Orion Health. The partnership allowed more rapid development of a new product that was more innovative in its approach than if Orion Health had attempted the project themselves. The product was thus quicker to market and with enhanced points of difference with competitive products. Also Orion Health's research activities were accelerated due to University's previous experience; it is notable that Orion Health has now established their own research division.

A range of benefits also accrued to the University team. Firstly, the team obtained practical validation of research results through their application to practical problems. Secondly, funding obtained provided more freedom for them to develop related research activities. Thirdly, conventional academic rewards also accrued, including one journal (Grundy et al, 2004), and three refereed conference papers (together with inclusion of it as a case study here). These academic papers did not conflict with Orion Health's intellectual property (IP) requirements: our experience is that the rapid product development cycle in the IT sector means that such publications are naturally useful to industry partners as white papers. Finally, the relationship that had developed provided a ready conduit for employment of students, support for grant bids, and other such non tangibles.

### *EDIS International E-commerce Platform*

Our second case study is a project with EDIS International who had developed an e-commerce integration platform featuring secure messaging, integration solutions and flexible development tools. EDIS were concerned that the new AS2 secure e-commerce standard (SearchOracle.com, 2005) could break their competitive advantage. As a small company, they felt they did not understand the complex new standard and that implementation to meet the standard was beyond company resources. Their concern was that customers would insist on compliance with the standard forcing them out of the market.

To obtain a better perspective on these issues, EDIS joined our ICT Innovation Academy, which provides structured summer internships with academic and industry mentorship (the Academy is described later in this chapter).An intern investigated AS2 implementation feasibility for the company and was able to demonstrate feasibility of implementation and incorporation into EDIS product. The academic mentor guidance, provided by Professors Clark Thomborson and Dr Gerald Weber, in addition to the authors, was crucial to the project's success as they were able to bring considerable research expertise in the area of secure communications to bear on the problem.

EDIS' response to the intern's report was immediate and dramatic. The report used as the basis for an adopted board paper recommending development of an AS2 solution for the EDIS product via a new startup/spinout company, AARN Innovation. AARN's focus was R&D for new product development to support the EDIS Group. AARN completed AS2 implementation for EDIS within 6 months and well ahead of schedule. AARN now supports a PhD and several project students in an ongoing relationship with the University. Many academic papers have resulted from both the internships and the PhD project (e.g. Dowdeswell and Lutteroth 2006). The company's Research Director is a regular industry lecturer in our programmes and an enthusiastic supporter and promoter of the department. He reports that he now "sleeps well at night and his wife is happy" due to the radical transformation of his business to be proactively research driven rather than reactive to immediate market pressures.

### *Some lessons*

The two case studies are typical of our experience with industry research projects. Generalising, a number of lessons are useful for those commencing industry-academic engagement. Importantly, such collaborations require considerable effort to initiate. Development of trust and credibility on both sides is a vital first step. We often find that an initial small trust building project, such as the EDIS internship, is an important precursor to more substantial collaboration. Once a project idea has been agreed, a necessary next step is documented agreement on IP issues, recognising both prior and to be developed property, and contract management mechanisms. Important in the former is agreement on academic publication, so that conventional academic rewards can accrue for the research undertaken. We have found, as discussed earlier, that this is rarely an issue and can be made to be win-win.

A related issue is the need to understand roles both sides are best able to take and how to best make the project win-win. This latter usually involves some education so that both sides understand how the other side wins. Communication between parties during the project is also vital to avoid divergence of activity as is the need for compromise: from an academic perspective it is important to remember the 80:20 rule so commonly applied in industry. Solving the remaining 20% is useful academic "future work" (that you may well convince the company to fund) but should not impinge on the immediate commercial needs.

Finally we have always seen it as important to approach initial industry collaborations as the first step in a long term relationship. Having invested time and effort on both sides building trust and understanding how both parties win, it is senseless throwing that investment away when it can be capitalised on to mutual benefit.

The rewards for such industry collaborations are high for both sides. However, we argue that institutional framework support makes development and maintenance of such collaborations simpler and more effective. Next, we explore initiatives we have taken at the University of Auckland to institutionalise that support.

## INSTITUTIONAL SUPPORT

We describe several University of Auckland initiatives aimed at supporting industry engagement. Two are ICT specific, but able to be generalised for other disciplines, The ICT Innovation Academy and Centre for Software Innovation, the others are more general.

### *ICT Innovation Academy*

New Zealand ICT companies have a poor record in providing internship, yet readily complain that students are insufficiently work ready on graduation. This is compounded by the large number of SMEs in the sector, lacking infrastructure or understanding of how to run an internship programme.

To address this, we have developed the ICT Innovation Academy (Hosking and Grundy, 2006) as a structured summer internship scheme for multiple ICT companies. Aims beyond providing simple internship opportunities for our students are to:

- Develop an internship culture in local ICT industry, particularly SMEs;
- Make our students more work ready;
- Help students (and academics) better understand ICT company business drivers;
- Allow employers to better understand student capabilities; and
- Develop ongoing industry – university linkages.

Companies' obligations in the scheme are to propose projects, typically requiring 1-3 students, and provide a project sponsor, a project mentor, and funding support. The project mentor is often someone the company is looking to develop into a leadership role. Companies are encouraged to propose projects that are "technology exploration", and slightly off a company's critical path, but where successful outcomes may provide a new product direction or enhanced capability.

Students are selected on grades and communication ability and matched to projects according to project skill needs. They obtain academic credit for the project work undertaken and a scholarship and work on projects over the summer University break, often at the sponsor company premises.

The Academy provides academic mentors, and, very importantly, professional project management. The latter involves careful scoping, milestone setting, regular meetings, formal project tracking, variation management, etc. All members of the Academy attend a seminar series which introduces students to topics such as "Life after University", "How to set up a company", "How companies grow", "What's the market doing", involving former students, industry "warhorses", incubator managers and residents, and other entrepreneurial role models. These are important, both to create a bond between academy members and to expose them to a broader range of industry opportunities. Academy members must also present a seminar to the Academy at the end of the project summarising results.

The programme has had excellent support from students and industry. Student over-subscription has allowed A grade students to be selected, contributing to successful project outcomes. The scheme has commenced it's third year of operation with student project numbers ramping up from approximately 25 in the first year, to 35 for the following years, most with SMEs. Company feedback has been strongly positive. Companies have been uniformly impressed with the student capability, being surprised at both the productivity and quality of the work undertaken. This has had a very positive effect on their view of both student recruitment and the value of internships. Some companies were initially resistant to the level of project management provided but most realised the value later. The project management approach was deliberately a firm one. Technology New Zealand had advised us that weak project management was the largest reason for failure of industry projects funded by them. We feel the exposure to sound project management approaches has been a beneficial secondary outcome for both the students and also many of the SME companies.

We have seen an excellent progression of industry-academic relationships formed during Academy projects. Again, involvement of both industry and academic mentors could be seen as overkill for a simple internship, but the resultant trust building was deliberately sought and has been very valuable. The experience of EDIS/AARN is at the upper end of positive outcomes, but is not completely atypical. Many companies have continued sponsorship into capstone projects, and research contracts, and many have supported the Academy in following years or, equally usefully, have set up their own internships. A further major side effect has been an increased pool of "pracademics", people who are equally comfortable in both academia and industry. Industry based pracademics are much more amenable to take part in practitioner lectures, support research contract bids, etc, while academic based pracademics better understand business drivers and are more amenable to undertaking industry projects.

### *Centre for Software Innovation*

The Centre for Software Innovation (CSI) (Auckland Uniservices Ltd, 2006a) was established recently as a focal point for IT academic-industry engagement at the University of Auckland. It is embedded within the Department of Computer Science, but supports projects spanning all aspects of IT, including interdisciplinary projects. While theAcademy's primary aim was to develop an internship culture, the primary aim of the CSI is to develop a *research* culture in local industry to address one of the structural issues affecting the sector identified earlier in this chapter. The wider aims for the CSI are to:

- Develop a research culture in local industry;
- Develop an industry application culture in academics;
- Act as a "one stop shop" for IT sector industry engagement with the University, providing a variety of entry points for industry engagement;
- Improve retention of:
    - Undergraduate students into post-graduate study, and
    - Postgraduate students into industry and university research positions;
- Diversify the University's income stream through industry research contract funding.

As the Centre has only been established recently it is too early to report on the longer term aims, but the development of research contracting has been encouraging with a rapid build up of "soft money" positions enhancing the University's ICT research capability. Apart from facilitating contracting, the Centre is establishing a set of courses on the value of research for industry, café scientifique-like industry-academic social interaction opportunities, and structured focus groups to socialise the commercialisation of new intellectual property. Figure 5 shows the intended engagement points and pathways to further develop relationships.

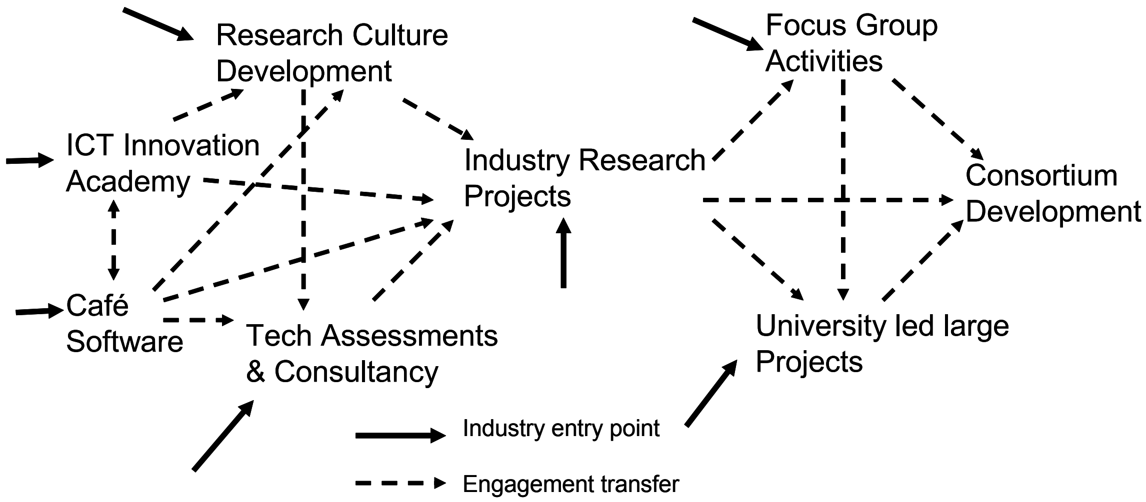


**Figure 5: CSI- industry engagement points and relationship development pathways**

*Broader University Initiatives*

The above two IT related initiatives must be seen in the context of a broader set of interlocking institutional industry engagement initiatives (Spicer et al, 2006). The University of Auckland has, for many years, had a very active technology transfer and commercialisation agency in Auckland Uniservices Ltd (2006b). This agency provides support for research contract management, intellectual property protection and commercialisation. The CSI comes under the management of Auckland Uniservices, as do like focussed technology transfer initiatives in other disciplines.

The Icehouse (The IceHouse, 2006), an initiative developed by the University of Auckland Business School and eight commercial partners, was designed to enable the University to interact with and help the development of both"start-ups" and SMEs. It has a physical incubator which provides: standard business incubation services, such as shared space and facilities; assistance in business planning; mentoring; and access to angel investment. A recent Icehouse/Uniservices initiative is co-location of Entrepreneurs in Residence within University departments, to identify and evaluate IP commercialisation opportunities from staff research. Separately from its start-up activities the Icehouse provides a set of courses targeted at the established SME market. In particular its courses for Owner Manager businesses and for taking businesses global have been influential.

Another significant initiative is *SPARK The Entrepreurship Challenge, a business planning competition with an associated "Vision to Business" course (Spark, 2006) providing substantial rewards, including free IceHouse incubation for the best team.. This has been highly successful at encouraging entrepreneurial activity. This student lead competition, modelled on those at Cambridge University and MIT and run in conjunction with the Business School and the Icehouse has been very popular with students and staff.

## SUMMARY AND CONCLUSIONS

We have argued in this chapter that economic and policy drivers within New Zealand, which are repeated elsewhere in the world, make industry collaborations attractive for Software Engineering academics. These drivers include a need for the country to improve economic performance and strategies to achieve that by growing the IT sector. These drivers are counter-balanced by a lack of research culture in the mainly SME-based IT sector. Our experience is that such collaborations can be made to be win-win provided the roles and drivers of industry and academia are well understood by both parties ahead of time and IP and contracting issues are resolved before project commencement. Recognition of the important role publication plays in the lives of academics needs to be clearly understood by the industry partners and reflected appropriately in the intellectual property agreements. In a rapidly moving area like software engineering our experience has been that provided that is well understood and that publications itself can be made win-win. However, in order to create a climate where such collaborations flourish, institutional support is needed. We have described several initiatives to foster and develop industry-academic engagement, including IT specific ones such as structured internships and research culture development activities, together with pan institutional ones such as technology transfer offices, entrepreneurship raising programmes, and business incubation.

## ACKNOWLEDGEMENTS

The authors acknowledge support from New Zealand's Tertiary Education Commission and Foundation for Research Science and Technology who funded aspects of our work. We also acknowledge our industry partners in allowing us to reference relevant case studies, the New Zealand Institute for access to data used in Figures 1 and 2, and Geoff Whitcher for helpful comments.

## REFERENCES

Amor, R.W., Hosking, J.G., & Donn, M.R. (1993). Integrating design tools for total building evaluation, *Building and Environment*, 28(4), pp 475-482

Amor, R.W., & Hosking, J.G. (1995). Mappings: the glue in an integrated system. In Scherer, R.J. (ed) *Product and process modelling in the building industry*, Rotterdam, The Netherlands, A.A. Balkema Publishers, 117-123.

Amor, R. W, Hosking, J.G., and Mugridge, W.B. (1991) ICAtect-II: A framework for the integration of building design tools, Automation in Construction, 8, pp 277-289.

Auckland Uniservices Ltd (2006a). Centre for Software Innovation, retrieved 20 November 2006 from http://www.uniservices.auckland.ac.nz/csi/

Auckland Uniservices Ltd (2006b). Uniservices, retrieved 20 November 2006 from http://www.uniservices.auckland.ac.nz/

Clark, H. (2002). *Growing an Innovative New Zealand*, retrieved 20 November 2006 from http://www.executive.govt.nz/minister/clark/innovate/innovative.pdf

Dowdeswell, B. and Lutteroth, C. (2006). A Message Exchange Architecture for Modern E-Commerce. In: *Trends in Enterprise Application Architecture*, LNCS 3888, Springer.

EDIS International (2006). EDIS, retrieved 20 November 2006 from http://www.edisinternational.com/

Foundation for Research Science and Technology (2006). Investing in innovative business, retrieved 20 November 2006 from http://www.frst.govt.nz/Business/

Groningen (2005). *The Conference Board and Groningen Growth and Development Centre), Total Economy Database, August 2005*, retrieved September 2005, http://www.ggdc.net.

Grundy, J.C., Mugridge, W.B., Hosking, J.G. and Kendal, P. Generating EDI Message Translations from Visual Specifications, In Proceedings of the *2001 IEEE Automated Software Engineering Conference*, San Diego, 26-29 Nov 2001, IEEE CS Press, pp. 35-42.

Grundy, J.C, Hosking, J.G., Amor, R., Mugridge, W.B., & Li, M. (2004). Domain-specific visual languages for specifying and generating data mapping system, *Journal of Visual Languages and Computing*,. 15(3-4), Elsevier, pp 243-263

Grundy, J., Hosking, J., & Mugridge, W. (1996). Supporting flexible consistency management via discrete change description propagation, *Software Practice and Experience*, 26(9), pp1053-1083.

Grundy, J.C. & Hosking, J.G. (1996). Constructing Integrated Software Development Environments with MViews, *International Journal of Applied Software Technology*, 2(3/4), pp.133-160

Grundy, J.C., Hosking, J.G., & Mugridge, W.B. (1998). Inconsistency Management for Multiple-View Software Development Environments, *IEEE Transactions on Software Engineering*, 24(11), pp 960-981.

Hosking, J.G. & Grundy. J.C. (2006). ICT Innovation Academy, retrieved 20 November 2006 from http://www.cs.auckland.ac.nz/research/groups/ict/ict.php?module=home

Hosking, J.G., Mugridge, W.B., & Hamer, J. (1991). An architecture for code of practice conformance systems, in Kahkonen and Bjork (eds) *Computers and Building Regulations*, VTT Espoo, Finland, pp171-180.

Hosking, J.G., Mugridge, W.B. & M. Buis (1988). Expert systems for building regulations and codes. In P.W. Newton, M.A.P. Taylor and R. Sharpe (eds) *DESKTOP PLANNING: Advanced Microcomputer Applications for Physical and Social Infrastructure Planning*, , Hargreen, pp 385-394.

Hull, J.W. (2006). *Sutton's Law*, retrieved 20 November 2006 from http://www.drhull.com/EncyMaster/S/Suttons_law.html

Mallard, T. (2006), *Securing New Zealand's Future Prosperity*, retrieved 20 November 2006 from http://www.med.govt.nz/templates/MultipageDocumentTOC____23427.aspx

Orion Health (2006). Orion Health, retrieved 20 November 2006 from http://www.orionhealth.com/

Orion Health (2006b), Orion Health Rhapsody Overview, retrieved 20 November 2006 from http://www.orionhealth.com/rhapsody/index.htm

SearchOracle.com (2005). *AS2*, retrieved 20 November 2006 from http://searchoracle.techtarget.com/sDefinition/0,,sid41_gci901539,00.html

Skilling, D., and Boven, D. (2005). *No country is an island: Moving the New Zealand economy forward by taking it to the world*, New Zealand Institute, retrieved 20 November 2006 from http://www.nzinstitute.org/Images/uploads/pubs/No_country_is_an_island_Full_Report_November_2005.pdf

Spicer, B., Dunn, W., & Whitcher, G., (2006). Transforming Knowledge into Wealth in a New Zealand Research University in *Toward an Ecosystem for Innovation - Implications for Management, Policy, and Higher Education*, Special Issue, *Industry and Higher Education*, 243-248

Statistics New Zealand (2005). Research and Development in New Zealand 2004, retrieved 20 November 2006 from http://www.stats.govt.nz/analytical-reports/r-and-d-nz-2004

Spark (2006). Spark, the University of Auckland Entrepreneurship Challenge, retrieved 20 November 2006 from http://www.spark.auckland.ac.nz/

The IceHouse (2006). Icehouse, retrieved 20 November 2006 from http://www.theicehouse.co.nz/index.html