THE WARREN CENTRE

INNOVATION LECTURE

2007

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- Shelston IP
- Victorian Department of Innovation, Industry & Regional Development

DELIVERED BY
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CHIEF TECHNOLOGY OFFICER (EMBEDDED SYSTEMS), NICTA

NETWORKING INNOVATION

THE Warren CENTRE
FOR ADVANCED ENGINEERING

2007 INNOVATION HEROES AWARD

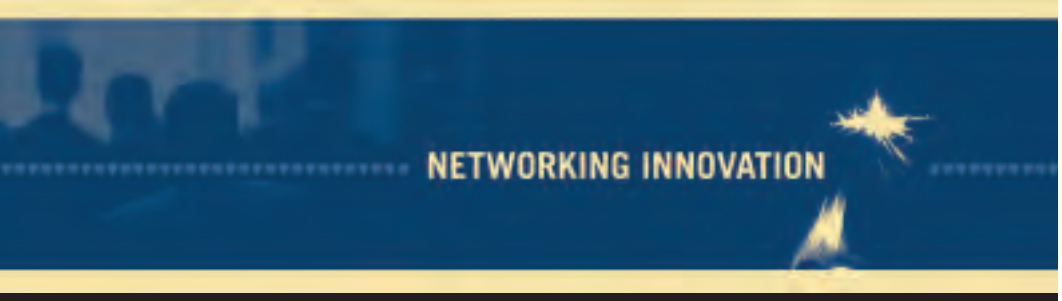
The annual Innovation Heroes Award is an initiative of The Warren Centre, awarded for outstanding Australian innovations in engineering technology. It recognises people who bring great ideas to life, and the role they play in driving economic and social progress. The award is made to Australian-based people or teams that successfully develop a new technology into a commercial product or service and who create great benefit for Australia.

1. ***Elizabeth Lewis-Gray & Sandy Gray***, for inventing an innovative range of equipment providing gravity separation process solutions for the mining industry, and achieving international commercial success with the products through Gekko Systems Pty Limited.

2. ***Dr David Noon and Lyle Bruce***, for pioneering the application of slope stability radar technology in monitoring the stability of rock walls in open-cut mines, and, through GroundProbe Pty Limited, achieving commercial success through deployment of the technology in mines world-wide.

3. ***Dr Julie Vonwiller & Chris Vonwiller***, for development of a range of innovative language processing products, speech data bases and related services, and achieving an international reputation and commercial success through Appen Pty Limited.

4. ***Gary Zamel***, for developing wireless technology to facilitate effective communication with underground mine personnel, and other mining applications, thus enhancing safety in emergency situations, and achieving world-wide commercial success with these products through Mine Site Technologies Pty Limited.



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AusIndustry

THE UNIVERSITY OF MELBOURNE

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AusIndustry is the Australian Government's business program delivery division in the Department of Industry, Tourism and Resources and it provides a range of incentives to support business innovation.

AusIndustry delivers a range of more than 30 business products, including innovation grants, tax and duty concessions, small business services, and support for industry competitiveness worth nearly $2 billion each year to about 10,000 small and large businesses.

To help customers with product and eligibility information, AusIndustry has customer service managers located in 26 offices across Australia, a national hotline and website, plus almost 60 Small Business Field Officers in regional areas.

AusIndustry offers both entitlement and competitive based products. For an entitlement based product, such as a tax concession, a customer qualifies to receive the assistance. For a competitive or merit-based product, such as an innovation grant, successful customers are selected on merit, based on their application.

Melbourne Business School is an influential force in business education and management development within Australasia.

Our strengths and reputation are built upon the principles of relevance and rigour, which are grounded in our heritage of scholarship with the University of Melbourne, and strengthened through our enduring partnerships with business.

We are the largest and most comprehensive business school in Australia, combining a world-class MBA school with the Mt Eliza Centre for Executive Education, the country's unrivalled leader in executive learning and leadership development.

Our management education portfolio is unmatched in its depth and scope within Australasia, reflecting our capacity to prepare managers, leaders and organisations for the challenges of a global future.

Minter Ellison is proud to support the 2007 Innovation Lecture and Innovation Hero Awards.

Minter Ellison is one of the largest full-service law firms in the Asia Pacific region. The firm has more than 270 partners and 900 legal staff located in Australia, Hong Kong, The People's Republic of China, Indonesia, New Zealand, the United Kingdom and the United States of America, and is able to support leading industry and government clients when and where required. The firm is recognised as a market leader in the Asia Pacific region, and advises leading multinationals and Fortune 500 companies. Minter Ellison's people have also been independently recognised among the world's pre-eminent lawyers.

The firm's strength is its technical excellence and commercial acumen underpinned by industry sector understanding, and in-depth local knowledge of how business is done in markets in which it operates.

NICTA is a world-class research institute able to drive innovation through high-quality research, training and technology transfer.

NICTA uniquely combines excellence in research, education, commercialisation and collaboration. It seeks to create intellectual and economic wealth for Australia through the development of the Information Communications Technology (ICT) research industry.

The PricewaterhouseCoopers Technology Industry Group is an international network of specialists from many disciplines who are committed to working with research and technology organisations to help them achieve their goals. Although our clients include some of the world's biggest corporations, they also include thousands of smaller, fast-growing firms in every area of technology. We provide "value added" assistance from the research phase through to development, commercialisation, equity raising and eventual merger/acquisition or float. Being a truly global firm, PricewaterhouseCoopers can provide a seamless service to clients as they grow internationally.

Shelston IP is one of the largest and most respected intellectual property firms in Australia and New Zealand, delivering the full range of IP and related legal services and advice to our clients.

Built on a strong foundation spanning 150 years, Shelston IP's teams of highly qualified and commercially astute specialist patent attorneys, trademark attorneys and IP lawyers are finely attuned to the needs of modern business.

Delivering services that extend from patent, trademark and design registration to strategic portfolio management, due diligence, licensing and litigation, Shelston IP demonstrates a thorough commitment to our clients and their commercial achievements, in Australia and beyond.

"Mind to market" reflects a crucial difference between Shelston IP and other firms. Our experience and knowledge of the processes involved in converting ideas and innovations into intellectual assets, and a deep appreciation of what it takes for our clients to successfully commercialise those assets, sets us apart.

Victorian Department of Innovation, Industry & Regional Development

"Innovation and creativity are essential in a global economy where knowledge is the key to competitiveness."

Worldwide, innovation is now recognised as the single most important element in a successful modern economy. The Victorian Government has long supported innovation for this reason. Innovation is not only about technology. Innovation is about people. It is about making sure we use ideas, technology and knowledge to give all Victorians a higher standard of living, more satisfying and rewarding jobs and a better environment in which to live, work and raise their families.

The Victorian Government, through the Department of Innovation, Industry and Regional Development, is delivering an unprecedented boost to innovation. Since it was elected the Bracks Government has committed around $1.8 billion to innovation initiatives which cover the full spectrum of innovation activities from infrastructure to skills, from technology to collaboration.

The Victorian Government is pleased to be supporting the Warren Centre Innovation Lecture 2007 because we recognise that knowledge and innovation is important for building a Victorian economy that is innovative, internationally competitive and globally connected - an economy that can generate new opportunities from the changing world economy for all Victorians.

PROLOGUE

2007 sees the expansion of The Warren Centre Innovation Lecture to Brisbane and Adelaide, which is appropriate as Dr Chris Nicol has recently been appointed Chief Technology Officer (Embedded Systems) of NICTA after brilliantly leading an Australian team at Agere Systems to take on the world and win.

A year ago I praised the Victorian Government for their support of innovation and that continues with the recently held "Innovation Summit".

The Call to Action delivered by Dr Terry Cutler at that conference is included in the latest edition of Fast Thinking, the journal of InnovationXchange. He believes that 2007 may be the year that innovation moves into the mainstream because;

1) it is the only lever we have to be globally competitive; and
2) only inventiveness and ingenuity will solve the great national challenges of our day - water, drought, ageing, obesity as well as response and adaptation to climate change.

Following Victoria's lead, the Queensland Government appointed Treasurer and Deputy Premier Anna Bligh as Innovation Minister. Unfortunately, that portfolio has now been passed down to the Minister for State Development John Mickel, but the thrust remains high on the agenda. For example, we had to postpone the Brisbane lecture to July to avoid clashing with the Smart Awards.

I am delighted to report that the NSW Government has moved strongly to support Innovation in the recently released "NSW Government Statement on Innovation" which is based on 3 principles;

- focus on those industries that are most likely to produce benefits for the broader NSW economy;
- evidence based approach to supporting innovation;
- government intervention should aim to complement not substitute for or compete with activities of private companies.

A newly formed Innovation Council will report directly to the Premier and will adopt 5 goals of innovation policy.

1) Improve human capital.
2) Upgrade knowledge and information infrastructure.
3) Reduce the cost to business of utilising science & technology.
4) Encourage capital allocation to invest in innovation.
5) Reduce regulatory barriers to innovative NSW companies.

The disappointing theme in the statement is the downplaying of the importance of technical and engineering based innovation. It is early days and we need to do all we can to convince the Innovation Council of the importance of technology based innovation.

The Warren Centre has several projects in formation which align with State and National initiatives such as;

- *Low Energy High Rise*;
- The *Energy Essay Competition* for Generation Y;
- The setting up of an *Embedded Systems* Cluster; and
- *ICT in education K-12*.

Please check our website for more details: www.warren.usyd.edu.au

Professor Michael Dureau
Executive Director
The Warren Centre for Advanced Engineering

THE **Warren** CENTRE
FOR ADVANCED ENGINEERING

DELIVERED BY

DR CHRIS NICOL

INTRODUCTION

Distinguished guests, Ladies and Gentlemen,

I am honoured to have the opportunity to address such a diverse and distinguished audience tonight.

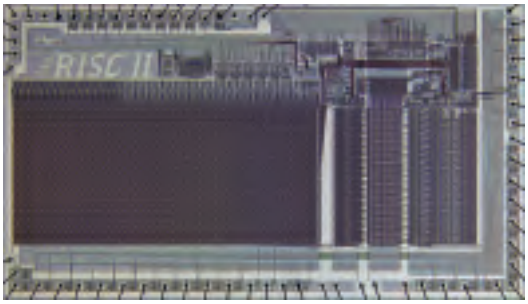
In 1961, Arthur C. Clarke wrote, *"Any sufficiently advanced technology is indistinguishable from magic"*. I love this quote because it is saying that creative researchers and engineers are magicians. We create the structures, the products, the inventions that stop people mid-stride. They see us as magicians for they know not what we do.

I would like to start by dedicating this lecture to the memory of an Australian legend and magician extraordinaire, Professor Richard Newton whose brilliant life was tragically cut short by cancer in January. Richard was Professor and Dean of the College of Engineering, University of California, Berkeley. He created the roadmap for the Electronics Design Automation industry, playing key roles in founding two great companies: Cadence Design Systems and Synopsys. In 2006, these companies employed 10,300 people and earned revenue of $2.5 billion dollars. Almost every electronics device today was designed on a system built upon the software that Richard developed. In 2001, I had the privilege of working with Richard on the selection committee for the ICT Centre of Excellence that led to the founding of NICTA.

This lecture is traditionally one that presents a lifetime of achievement in the field of engineering and related businesses - like a lecture from the winning podium. Last year, Don Fry gave an account of one of the most impressive careers in Australian engineering. Yet, I feel that my greatest contribution to Australian engineering lies on a path ahead and not in the past - so this lecture will be given from the perspective of someone in Australia's engineering trenches.

BACKGROUND

My two obsessions in high school were computing, and ceramics. Although I wrote a word processor for my Year 12 major work in computing, it was my artwork that was receiving all the praise in those days. My interest in the creative arts led to my career in engineering. During a tour of a secretive lab at the University of New South Wales, I was drawn to colourful posters on the walls. Both geometric and wonderfully chaotic, these were plots of silicon chip layouts, though I did not know this at the time. In that moment, I decided to do a course in VLSI design and change the direction of my life. Turns out, the poster that drew my attention was one of the first Reduced Instruction Set Computer (RISC) chip, designed at the University of California in Berkeley. Today, most microprocessors utilize RISC architectural techniques to achieve gigahertz speeds. For me, since that day, each chip that I have worked on has been about the creation of a piece of artwork.



The UC Berkeley RISC II chip that inspired my career in silicon chips.

Two years later, I crossed paths with an organization called Bell Labs.

AT&T BELL LABORATORIES

It is said that the average home contains at least 25 products that are based on one or more of the 40,000 inventions created at Bell Labs over an 80 year period. Some of the inventions include the laser, the solar cell, the communications satellite, the UNIX operating system, the C programming language and the Digital Signal Processor (DSP). The most-famous Bell Labs invention was the transistor in 1947 for which three researchers received the Nobel Prize. More often than not, the process of innovation involves a commitment to a long-term vision rather than a single Eureka moment. In the case of the transistor, the vision was formed over 10 years earlier (see *Appendix*).[1]

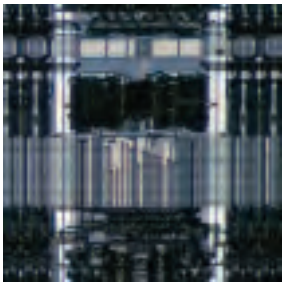
In all, 11 scientists received the Nobel Prize for their work at the Labs. So how did I end up there? A job ad appeared on an Australian newsgroup that said *"Anyone interested in spending 6 months at Bell Labs doing silicon chip design?"* It could have been a hoax - but then why would anyone say they were something they were not? Although I was mid-way through a Ph.D., I packed up my family and boarded a plane to New Jersey - the holiday capital of America.

The Bell Labs site in Holmdel is one of the premier research facilities in the world. Situated on over 470 acres, the 360 meter long, six-storey mirrored building designed by Finnish architect Euro Saarinen housed about 6,000 employees. The site is widely regarded as the birthplace of radio astronomy in the 1930s and it was home to the work of several Nobel laureates.

The atrium of Bell Labs, Holmdel NJ

My first venture outside of Australia led me to this impressive building fronted by a massive roadside water tower shaped like a transistor.

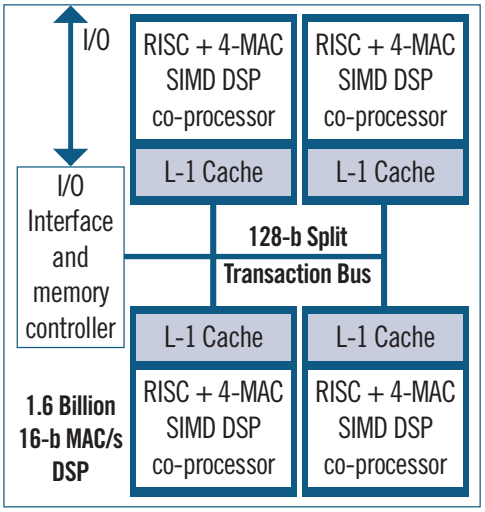
At Bell Labs, I designed Read+Write embedded SRAMs for ATM packet switching applications with Alex Dickinson, who has since founded a company called Luxtera. These RAM's perform both a read and a write in every access. My internship was extended by 6 months so I could prototype an off-the-wall idea we had for a systolic Read+Write SRAM architecture. The chip consumed too much power to be of any real use - but its layout made a beautiful poster. My peers joked about deploying my chip as a coffee cup warmer. The day I returned to Australia, the Bell Labs management told me that if I didn't complete my Ph.D., they would never talk to me again. Wise words that I have repeated to every summer intern since. Upon completing my Ph.D. I was recruited back to Bell Labs in Holmdel. My first project was reducing the power consumption in an embedded microprocessor using an approach known as full custom, where integrated circuits are designed by hand. The walls of my office were soon covered with colourful posters of hand-crafted register files, arithmetic units and memories. A few of us got together to create a multi-processor DSP. Similar to the Intel Core Duo architecture announced recently, our approach also integrates several multithreaded cores onto a single chip (though we did it about 10 years ago).

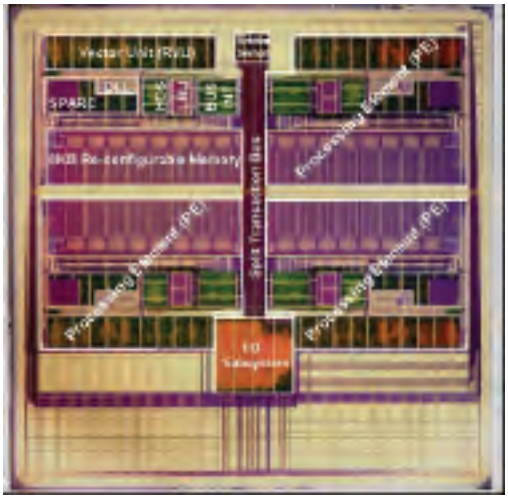


"A block off the ol' chip." Read+Write SRAM decoders, Bell Labs 1992.

The four 64-bit processors on the chip run four programs simultaneously. To allow the processors to operate faster than external memory, each processor has a local store of program instructions and data values in small memories known as a cache. The idea is that by keeping the most frequently accessed information as close to the processor as possible, the processor spends more time doing useful operations and less time waiting around for the information it needs. We allowed the processors to manipulate the same data set by keeping copies of the data in the caches of more than one processor. This works fine as long as the data is not modified. However, if one program modifies the data (for example by changing a value of a variable), the system must ensure that the other processors abandon the old value and update the contents in their cache memories with the new value. To accomplish this, the cache memories communicate with each other behind the scenes to see if the value of any variable is being changed. This multi-processor data cache coherency can get very complicated (for example, if two programs want to change the value of a variable at the same time) and many multi-processor systems fail to do it well. For the technically-minded an overview of the processor is described in the *Appendix*.[2]

I was responsible for the design of the cache memories for each processor that provided this shared memory functionality. These consisted of several cache "banks" that could be configured under software control as a part of the instruction cache, the data cache or a local scratchpad memory. One reason we did this was so that

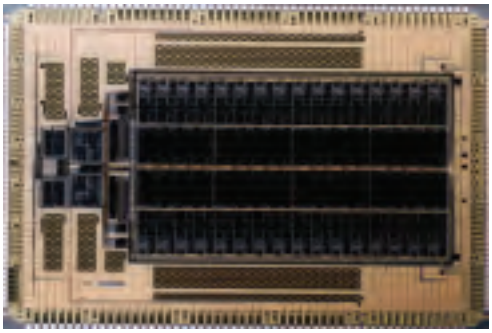




Architecture and photo of "Daytona", a 3.2 GoP Multiprocessor DSP Chip, Bell Labs 1999

programs could maximize the instruction cache when executing control code & then reconfigure the cache to maximize the data cache when executing inner-loop DSP code. The other reason for doing it - was because it was a really cool cache architecture that nobody had ever built before - and I suspected it would look great on a poster.

I appreciate that I have lost many in the audience with this - however I hope that the processor architects in the room are thinking that this was one heck of a project for its time. Indeed, we were all very proud of it, and secretly surprised when it worked so we presented the work at the world's leading IEEE conferences and journals. *However as a product, it never saw the light of day*. Another great project was a low power digital adaptive filtering chip for broadband access systems like xDSL and digital television over copper wires (unshielded twisted pair or UTP). When pitching this project, I remember making an embarrassingly simple error in a back-of-the-envelope power estimate that committed us to a power budget that was 1/4 of what we felt we could do. Rather than admitting to a simple mistake, an ultra low power filtering project was born. Not knowing what we couldn't do, the erroneous power target turned out to be lower than any previously published filter in the literature.[3] While the techniques we developed for that chip have been deployed in various broadband modems since then, that particular chip - as a product - also never saw the light of day.



Ultra-low power digital filtering chip for DSL. Bell Labs 1997

THE RISE AND FALL OF BELL LABS

Bell Labs was a carefully managed brand that was about being first, and being the best. The environment nurtured teamwork, collaboration, cross-discipline projects, research excellence and invention. The day-to-day focus was on research outcomes like patenting, publishing and long term impact - all of the things used to describe research life at NICTA today. Within a stable research environment, we were able to explore research ideas that took us way out into the future. Of course, we weren't actually in a stable research environment, we just thought we were.

With the spin-off of Lucent Technologies, Bell Labs staff were granted stock options as the company concentrated on stock market performance. This reduced the effectiveness of long term research strategies by changing the attention of research staff from the future to the present. I encourage organizations to reconsider stock options as motivators for research staff.

Bell Labs is no longer the same institution that is was 20 years ago. Commercial realities of a corporation under great financial stress led to widespread concern about falling revenues, unsustainable expenses and a diminishing operating margin. Researchers were encouraged to address near term problems being faced by the business. In later years, drastic cost reduction measures transformed the culture of Bell Labs and in 2005 the beautiful site at Holmdel was sold and is likely to be demolished by developers.

BELL LABS RESEARCH, AUSTRALIA

For family reasons, I relocated back to Australia in 1998 where I worked remotely from New Jersey for 12 months. During this time, I developed a business case for a Bell Labs Research team in the Asia Pacific region. Primary factors included the reputation and research outputs of Asian Universities, as well as the availability and quality of Doctoral candidates. I also considered the global competitiveness index, quality of life, information infrastructure index, as well as economic and political stability, work ethic and labour laws. The study concluded that for the type of research that Bell Labs wished to do, Australia and Taiwan were the leading candidates at the time. In the eleventh hour, I was granted approval to recruit 4 researchers and the first Bell Labs research facility in Asia-Pacific was born.

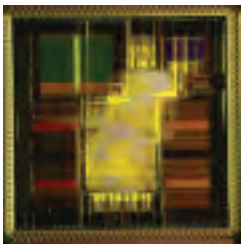
The wireless business required a processor that could perform the channel coding for all of the common 2.5G and 3G mobile wireless standards. Three of us architected the first known channel codec with a shared architecture to do both Viterbi and turbo coding / decoding. The processor was flexible enough for a single user (i.e. for mobile handsets) as well as scalable to do multiple channels for deployment in mobile infrastructure. About 5 patents were filed on the architecture. With some arm twisting, the processor was placed into the roadmap of the company's infrastructure products. I argued that Australia would be a good place to also develop the product and so approval was granted for me to recruit a product team in the Wireless ASIC division of Bell Labs.[4]

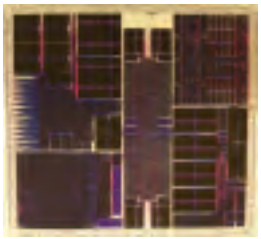
Bell Labs Research - Australia, 2000

First person to wear a baseball cap in the Cabinet Room, Parliament House, June 2000

In 2000, I addressed the Prime Minister and the cabinet ministers on the state of the microelectronics industry in Australia and outlined my plans for Bell Labs. Lucent agreed that I would take my Lucent hat off after 5 minutes and speak about anything I chose. For effect, I wore a corporate baseball cap into the Cabinet Room and took it off half way through the talk - completely unaware of the protocols I was breaking.

In that address, I announced the formation of the wireless ASIC team that would transfer our research into product. This team was formed in a couple of months, and quickly developed the Soft Information Processor for Lucent's infrastructure products. The chips containing the SIP are currently being deployed in a U.S. 3G mobile network. Lucent's handset division designed the SIP into a 3G chip they were developing for a customer. The mobile phones containing these chips were among the first 3G phones to be deployed in Australia, Hong Kong, Italy and the U.K. I remember seeing the phone for the first time - on a billboard at Rome airport in 2004. I was so proud, I issued one to every member of the SIP team.





The SIP Chip and 3G Infrastructure chip, Bell Labs Australia 2001

To grow the international standing of the team, our strategy was to only focus on the top conference. The International Solid State Circuits Conference (ISSCC) is the leading conference in the world for silicon chips. To the industry, it is like the Academy Awards. Our research calendar was tuned to suit the submission dates of this conference. Our SIP test chip was accepted into this conference, and then invited into the special issue of the top journal dedicated to conference highlights.

With this publication, we were on the map - with an internationally recognized lab in two years. Our first research project led to the formation of a development team, was to be deployed in millions of 3G handsets, tens of thousands of 3G base-stations, was accepted into the top academic conference, invited into the top IEEE journal, and produced 5 patent filings. So these chips ***did*** see the light of day - and are still being deployed. To me a successful project in a remote R&D lab must deliver on the following criteria:

1. Business Impact

2. Academic Impact

3. Wow Factor

The *business impact* is the most-important. When you are 10,000 miles away, you need to be adding value to somebody's bottom line. The *academic impact* helps to build the reputation of the team, recruit top international talent, as well as further the academic careers of the staff. The *wow factor* is important to sell the research to executives, customers and the community.

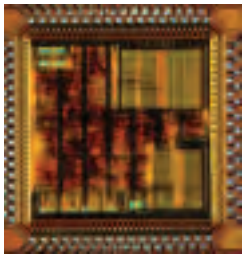
To follow up we did it all again. The team developed the first high-radix turbo decoder for the HSDPA 3.5G mobile wireless standard. Today's HSDPA data rates offer 3.6Mb/s to the phone, PDA or notebook. In 2002, our HSDPA chips were achieving speeds in the range of 19 - 28.8 Mb/s using a new technique known as MIMO.

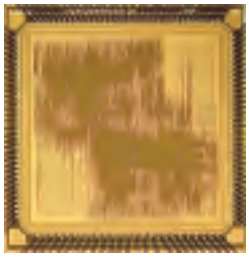
THE BLAST WAVE

Ask any wireless researcher about MIMO and they will tell you that space is the final frontier - and MIMO is the next big thing. It is the technology that boosts the data rates of 802.11n WiFi to over 100Mb/s. It will also boost the data rates in WiMAX (due any day now) and 3GPP Long Term Evolution standard (which should be deployed in about 5 years).

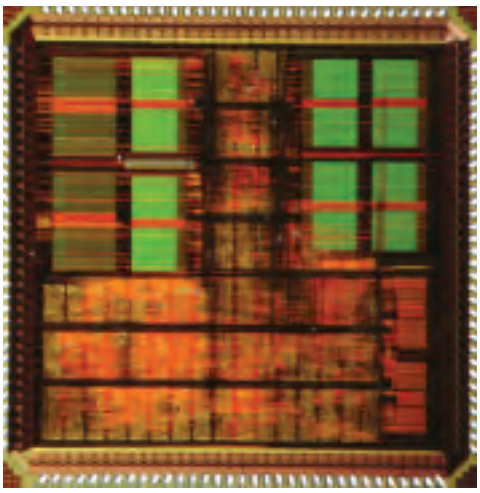
The MIMO technique was invented at Bell Labs (where it was called BLAST which stands for **B**ell Labs **La**yered **S**pace **T**ime). The patent was considered a killer patent to watch by MIT Technology Review in 2002 - and at that time, in Australia we were adding the finishing touches to the first silicon chip implementation of the technique. The BLAST chips were launched with a global media release and considerable fanfare. The CEO placed pictures of Australian researchers in her introduction to the 2002 annual report. USA Today, The New York Times and EE-Times did a feature on them. Over 100 media articles appeared around the world, including USA Today, the New York Times and Red Herring. We did 2 BLAST chips, the second contained a space time adaptive equalizer with 16 filter banks to improve mobile performance.

In 2003, the Australian team won the highest honour in Bell Labs - The Bell Labs President's Gold Award - for the





BLAST Chips, 19Mb/s and 28.8Mb/s 4x4 MIMO - HSDPA, Bell Labs Australia, 2002 & 2003



The Radix-4 Turbo HSDPA Chip, Bell Labs Australia, 2003

MIMO HSDPA chips. The chips were demonstrated at the CTIA tradeshow in New Orleans 2003 in what was the first over-the-air demonstration of any HSDPA system (let alone one that supported MIMO). To maintain our academic standing, the chips were presented at ISSCC in 2003 and 2004, and were again invited into the leading journal. We were invited to prepare a paper for the IEEE Communications magazine - and an article featured the turbo decoding chip in IEEE spectrum.

Sure enough, within six months, the entire team was laid off. As Kurt Vonnegurt so aptly put it - *"so it goes"*.

AGERE SYSTEMS AUSTRALIA

Seeing that the team was at risk, I set about finding a new home about 9 months prior - either as a management buy-out, with a U.S. start-up or another multi-national. In the end, it made sense to transition the team to another multi-national. After a very difficult set of negotiations, the team was retrenched - and immediately hired by Agere Systems. Agere is a semiconductor supplier that was spun out of Lucent Technologies in 2001. While that sounded like a smooth move, it was actually a very challenging week and the team came close to disbanding. When your back is against the wall and you are facing job redundancy, with financial and emotional commitments at home - it is very hard to use that moment to stand up for what you are about and place concepts like national benefit ahead of personal needs. But it is exactly these moments that define us. I believe that what held the team together was the belief that the team was a significant asset in the Australian ICT R&D landscape - and that we should therefore place national benefit over and above individual needs. The true definition of a high performing team is one able to collectively reorganize and adapt to change in such a way that maximizes the outcome for the team, even if sacrifices were to be made by the individuals. In my opinion, this cannot happen without a definition of team that extends beyond employees and includes partners and families.

The team at Agere is now in new facilities - opened in 2005 by the Prime Minister, and is busily designing advanced chips for deployment in handsets by Samsung, and several emerging OEMs. Once I was convinced they were stable - and a successor was in-place to take the centre into the next phase of growth, I announced my intention to leave Agere and join NICTA. Within days, Agere merged its operations with LSI Logic. It is my hope that the new LSI Logic team grows to become a part of the furniture in the Australian ICT R&D industry. I will always speak of them with great pride and expectations. At some point, I will have to stop taking all the credit for their accomplishments.

Now I am ready for new challenges - and this country has a few.

AUSTRALIA'S ICT INNOVATION PERFORMANCE

I thought we could do a performance review of the Australian ICT industry. Given that everybody in the room has at least some personal stake in this, it might be something we could all benefit from.

Performance reviews are supposed to be an uplifting experience - where you go into your managers office and they tell you all the great things you are doing, you provide feedback on their leadership, some goals might be discussed around areas of improvement - but for the most part, the attention is placed on areas of strength that can be leveraged to mutual benefit. I have heard that some managers take the performance review as an opportunity to tell their staff what their faults are - to assign blame, and generally allow the relationship to disintegrate into an *"up yours"* situation, but that would be the minority I am sure. So tonight, we will attempt to identify strengths - and then see if there are ways we can leverage them.

In 2001, Professor Brian Anderson, as President of the Australian Academy of Science, gave an address to the National Press Club where he issued a call to arms for Australia's ICT industry. The Government had announced the *"Backing Australia's Ability"* plan. A part of that plan was the funding for an ICT Centre of Excellence. Since learning of the proposal for what we now know as NICTA, I have wanted to roll my sleeves up and get involved.

In Prof. Anderson's speech, he showed several charts that revealed Australia's poor performance in achieving real impact with our ICT R&D. Recently the OECD released new data that tell us how things have changed since that time.

The first chart *(next page)* shows the growth of ICT spending in the period 2000-2005 as a percentage of GDP. Australia continues to increase its expenditure on ICT. As Prof. Anderson pointed out, it is unclear how much of this spending is on *Playstations* and DVD players, and how much is on ICT to boost productivity. So we have to dig further in our performance review.

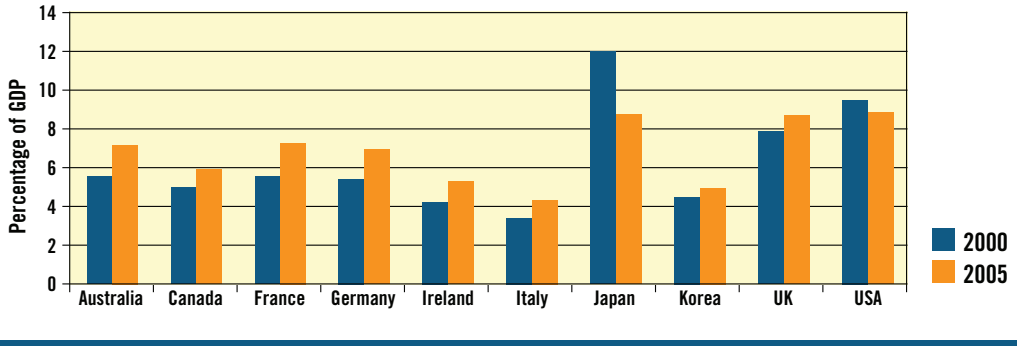


Chart 1 - ICT spending as percentage of GDP

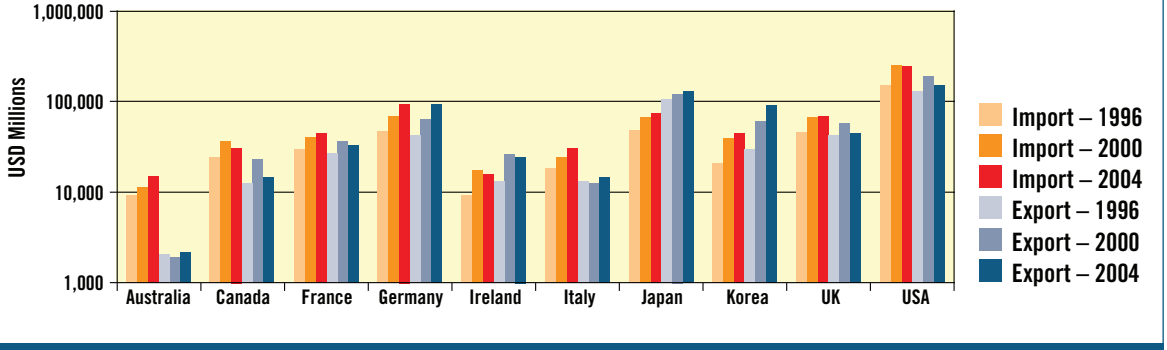


Chart 2 - ICT Imports & Exports (1996 - 2004)

The next chart *(above)* shows the level of ICT imports and exports for 1996, 2000 and 2004 for various countries in the OECD. As you can see, the growth in Australia's ICT imports is not matched by a corresponding growth in exports. Noting the logarithmic scale, we see that the ratio of imports to exports is 5X, far greater than any other country. Korea actually exports more ICT than it imports - presumably shiploads of mobile phones and LCD TV's to Australia.

The news is not good for Australia (nor Italy it would seem) but great for Germany, Japan and Korea. Most people in the room are probably not surprised by this. Some might be thinking that our ICT imports are being used to boost productivity and therefore our exports in other areas are not revealed in this chart. In March 2005, the World Economic Forum's Chief Economist, Augusto Lopez-Claros said that:

"As wonderful as the performance of the Australian economy has been in the last few years, there is actually quite a lot of scope for improvement in specific areas and certainly in technological innovation is one that I would highlight as being one of the challenges that you face. Not that you're doing poorly, rather that other countries, very often smaller countries, are doing much better."

The message here is that while the Australian economy appears to be doing well - if we were a stock, analysts would be downgrading us from a hold to a sell.

NICTA

A part of the solution was the creation of NICTA in 2002 to drive innovation through high quality research and technology transfer. As the gap between research and development widens, this bridge is needed more than ever. NICTA's role is to add to Australia's ICT innovation system by producing research results of the highest standard, facilitating technology transfer, supporting innovation and new opportunities in Australian industries. We also strive to increase the quality and size of Australia's ICT skill base. We aim to be a world-class institute with a reputation that attracts international academic and industrial research organisations to work with NICTA in Australia.

Our long term contribution will be to create new industries in ICT and to transform existing industries. We have laboratories around Australia with 677 staff and students.

NICTA is only a new organisation but we have some very important work to do. We aim to be one of the world's top ten ICT research centres by the year 2020. By 2010 we aim to increase Australia's ICT competitiveness, grow Australia's ICT industry, enhance the education of over 225 PhD graduates and accelerate Australian innovation.

In NICTA we have a microcosm of innovation. We have researchers that are supported by business development and liaison staff to help develop spinouts, licensing arrangements and partnerships with existing Australian SMEs. Our linkages program sets up industry groups and clusters to help support industry growth.

THE INNOVATION GAP

A few years ago, the Australian Research Council identified a research continuum on the flow of outcomes from public-funded research to private-funded organizations that would then provide the societal, economic and environmental benefits to the community. However in the ICT space, there is a huge gap between public-funded research and industry take-up. This gap is growing to become a chasm - primarily due to the absence of large companies with development arms to transfer the research into competitive products. So in the Australian ICT landscape, we have an even greater challenge to bridge the chasm because there are too few companies on the other side.

Consider Australia's success stories like Resmed, Cochlear and Mincom. In each case, a differentiated product was developed that combines multi-disciplinary research with some ICT. Each company focused on a niche market and quickly grew share to become the market leader. This is essentially applying Geoffrey Moore's crossing the chasm theory. He suggests that technologies will most likely fall into the chasm between early adopters and early majority unless some basic marketing principles are applied. The proposed solution is to grow a market leadership position in a niche market first, what he calls securing a beach-head in an invasion strategy. You then use this position as a reference to jump into other markets. The key to success in this is clear segmentation of an appropriately sized market where the customers are able to reference each other. While the gap referred to in Moore's theory is in the technology adoption lifecycle, it could also apply to the Australian innovation system. As Kurt Lewin said: *"There is nothing more practical than a good theory"*.

Another way to bridge the innovation chasm is to leverage those who have already crossed it. A partnership with an established Australian company can be a viable way to get a new technology across the chasm. This is part of the benefit of forming a technology cluster containing a diverse mix of companies with different competencies, technologies and market strength. NICTA is taking a leadership role in the formation of industry clusters to help facilitate this process for Australian SME's.

THE ICT TALENT POOL

Even if we were to grow companies that bridge the gap between research and development, we would need to make sure that we had enough highly skilled ICT talent to fuel their ongoing growth and innovation. Unfortunately, recent trends have shown a reducing number of students studying IT at University as the graph below reveals. The numbers of IT students have fallen as a percentage of the total number. In 2001, 7% of students commenced IT degrees but this dropped to only 3.5% in 2005.

So the fountain of ICT talent - the magicians that will underpin the growth in all of the other sectors - is diminishing, right at the time when it should be experiencing rapid growth. If we do not rectify this we will either have to import talent, or outsource more of our ICT - the very part that will be adding the most value.

We could assume or hope that the other disciplines are teaching the ICT needed to effectively operate in their sectors. However, as the use of ICT becomes more pervasive, the off-shore providers of the technology in the value chain will capture an increasing share of value - and weaken the buyer strength of Australian industry.

In short, we need more students to go into ICT related careers. This is an image problem. Teens manipulate digital media on portable devices, shared over broadband networks as they play in virtual environments ... all enabled by ICT innovations, and yet somehow, ICT is not considered a great career choice in Australia. The spectacular collapse of the telecommunications market a few years ago and terms like *"tech wreck"* have harmed the perception of ICT in the community. This is a marketing problem and I encourage the media to get on-board and help us out.

The CSIRO, NICTA, Universities and organizations like the Warren Centre and Re-engineering Australia Forum are each doing their part. I encourage Australian industry to take the long term view on this - and rather than complaining about the difficulty in hiring today - rolling up your sleeves and getting involved in addressing this big issue that affects us all. You will find it a very rewarding experience on many levels.

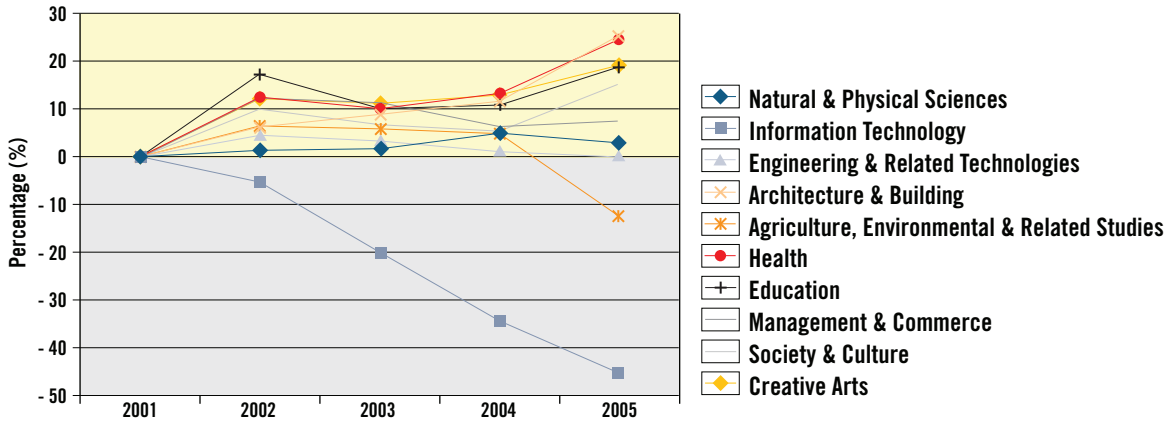


Chart 3 - Students Commencing Tertiary Studies in Australian Universities, 2001 - 2005

While I have heard that the numbers have started to turn around in 2007, I am increasing NICTA's commitment to addressing this effort. As Woody Allen once said: *"80% of success is showing up"*. We have to keep working at this.

TECHNOLOGICAL INNOVATION DRIVES ECONOMIC GROWTH - The Call for e-Leadership in Government

These days - there is an *"e"* in front of almost everything. We have *e-research*, *e-education*, *e-government*, *e-health*, *e-commerce*, *e-manufacturing* and so on. There is a growing understanding, that almost everything requires the strategic application of ICT to add value by improving performance, efficiency, quality and reducing cost. This applies equally to both the public and private sectors. Several governments are recognizing the need for e-leadership at the highest level. These leaders formulate e-policy and e-strategies that drive a nation's economic growth. I attended the opening ceremony of CeBIT 2007. Dr. Angela Merkel, the Chancellor of Germany, gave a speech that reinforced this for Germany:

"If we are to retain our position as one of the world's most innovative economies in the long term, we need more than ever a climate in which ideas can be translated into facts and research into marketable products, procedures and services."

Dr. Merkel indicated that ICT would play a key role as the driver of economic growth. She then outlined a hi-tech strategy that gears innovation policy towards a number of fields. The Australian delegation came out of that speech wishing that we had more of this type of strategic e-leadership driven from the top. It requires an understanding of emerging technology roadmaps and their potential impact on policies, and government agencies and national information infrastructure. It requires courage to take risk at the highest level by outlining strategic plans for national core competencies that leverage where we are - and set the direction for where we want to be, and then put curricular, certification, commercialization policies in place to help us get there. It is more than a plan for the programs that we will deliver over the next few years, it is a vision of what we will become - something to draw the focus and imagination of the nation to a set of challenging goals in the future. Whatever we can imagine, we can become - we must nurture our collective self efficacy to believe we can get there.

As NICTA matures, this is the kind of role that I believe we can play for this country.

EMBEDDED SYSTEMS

Embedded systems are hardware and software systems that are contained within the products they control. They are usually stand alone, with prescribed interfaces for user interaction and programming. Examples are automotive, aeronautical and robotic control systems. Practically all sophisticated modern products are controlled by embedded systems. Whereas this used to be a simple microcontroller and some control firmware, systems these days contain millions of lines of code. 70% of the engineering effort in a mobile phone is in the embedded software, and modern cars have more than 50 embedded processors in them - interconnected by several layers of networks. The embedded systems market is one of the largest in the IT world - estimated to be worth about $2,660 billion dollars. The global R&D spend is estimated to be over $140 billion dollars.

Users of PC's are accustomed to rebooting a computer when the software installed on it fails. They are less understanding when their car engine stalls whenever the air conditioner was activated. A key consideration in the development of embedded systems is the security and reliability of complex hardware / software systems. At NICTA, we believe this lies within our expertise and therefore creates an opportunity. The application of formal methods to improve the reliability and trustworthiness of embedded software is an area where we can have impact.

At NICTA, researchers have developed an embedded operating system called L4 and are proving the functionality of the trusted computing base in the microkernel. This means that we can guarantee that applications will not interfere with each other's operation either intentionally or neglectfully. So if the air conditioner system fails, the engine management system continues unaffected - guaranteed.

In Europe, there is an EC funded R&D initiative called Artemis commencing next year with a proposed funding of 450 million EURO public and 400 million EURO private. It is a joint technology initiative in the 7th framework programme. Their mission is to steer European research in embedded systems and develop embedded platforms that can be leveraged by its members for rapid product development. The majority of the 100 members are European-based multinationals like Nokia, Ericsson, Siemens, ABB, Airbus etc. At NICTA, we have joined this initiative with the intention of providing a pathway to global embedded platforms for Australian technology. We will be supporting Australian involvement in Artemis on many levels as a part of our strategy to grow a market-driven national core competency in Embedded Systems.

CONCLUSION

I would like to end by listing some guiding principles for leading a team in the process of innovation. I have done my best to incorporate them in my leadership approach. I would like to offer them to you from a position of respect - as a colleague on a path of learning - and not with any authority.

1. Identify your customers (internal and external) and make sure they are satisfied with your products and services. This is a fundamental rule that everyone knows. It goes without saying that engineers would never say anything like *"the folks in marketing are a pack of idiots"* or *"the customer hasn't got a clue"*. Because truly customer-focused engineers would not even think such things.

2. Have the courage to hire people who are better than you. This is a really confronting thing to do. At Bell Labs, we looked for education (tertiary qualifications), talent and cultural fit. We never did skills-based job matching.

3. Train and task individuals so that they are self motivated to drive their own performance. This includes empowering them with the belief and the responsibility to make decisions on ***how*** they do things. They should feel accountable for their decisions and deliverables.

4. Motivate the team to a central cause. At Bell Labs Australia it was National Benefit. It is important for people to participate in something that is greater than themselves. It gives work immense purpose!

5. You cannot have loyal customers without loyal employees. The employees provide the service to the customer so keep them satisfied. Go a step further and be grateful for them: *Every day, my employees would say good bye to their loved ones and come to the office to spend a significant amount of their day with me. For this, I was grateful, and it was my duty to ensure that they had something worthwhile to do and that every day was rewarding for both them and the organisation.*

6. Spouses are called *"significant other"* for a reason. They have significant influence. When someone is travelling, or on a conference call at midnight, there is usually a spouse who is feeling under-appreciated. Extend the notion of *"team"* to include them. Include them in your cause, your communication and reward them in your success. This is important when employees are required to defeat time zone barriers. It is all part of work-family balance.

7. Positioning. It is better to be different than it is to be better. Our strategy was to deliver to a value proposition that contains a unique selling position for R&D in Australia. Rather than asking *"Why do we have a centre in Australia"*, we wanted executives in overseas boardrooms to ask *"How come we don't have more centres like that one in Australia?"* (If they did, we would have to change our value proposition to remain unique).

8. Continually change - and self-inject change - especially when it feels like it is not needed. ***"When you are green you grow, when you are ripe you rot."*** So we must change, to make sure we are always on a path of growth - and to avoid becoming ripe. Opportunity lies on the boundary of order and chaos. Too much of either and growth is diminished. Complacency will kill you and if you succeed at everything you do, you might consider taking on greater risk.

9. The last - is one that my wife taught me: *At the end of the day, when you have done your best - await the results in peace.* To await the results *"in peace"* is incredibly difficult to do. It takes self-discipline - but worrying about stuff benefits no-one and probably makes you ill.

With that I encourage you all to take a moment and reflect on the life of Richard Newton - who guided Bill Gate's philanthropy, who launched CITRIS Centre for Information Technology Research in the Interest of Society and the ICT for Billions (ICT4B) project to develop low cost ICT systems for developing regions. May we all live up to the example set by Professor Newton and other great Australians like him...

... and may everything you touch put a little magic into other people's lives.

Thank you,

Chris Nicol

APPENDIX

1. *Mervin Kelly, a manager at Bell Labs who had built a career doing research into vacuum tubes, established the Solid State Device lab in 1936. He assembled a team and challenged them to create solid state devices to replace the vacuum tube. Even after the team was disbanded during the war, Kelly re-assembled the team in 1946 to continue the research that ultimately led to the discovery of the transistor action and the first working prototype in November 1947 by John Bardeen and Walter Brittain. Although it was largely ignored by the media, Kelly appreciated the magnitude of the discovery and continued to invest in the research. William Shockley then added much of the theory of the Bipolar Junction Transistor and minority carrier injection to describe how the transistor worked and the first junction transistor was created in 1951. The three scientists were awarded the Nobel Prize in 1956. In 1952, the invention was licensed to several companies for a fee of $25,000 including Tokyo Tsushin Kenkyujo who launched the transistor radio in 1955 under the brand of Sony. The integrated circuit was then invented at Texas Instruments, the microprocessor invented at Intel and today's trillion dollar semiconductor industry emerged.*

2. *The MIMD DSP chip contained four 64-bit processing elements PE's interconnected by a 128-b pipelined split transaction bus with separately managed address and data buses processing multiple outstanding memory requests. Each processor contained the 32-b RISC core and a 64-b SIMD vector co-processor for speeding up Digital Signal Processing operations typically found in modems, speech processing and multi-media algorithms. The processors were connected to the bus through re-configurable dual-ported snooping Level 1 cache memories that supported shared memory multiprocessing using a modified-MESI data coherency protocol. High-bandwidth data transfers between system memory and on-chip caches were managed in a pipelined memory controller that supports multiple outstanding transactions. This means the processors can keep running - even while they are waiting for data or instructions to be obtained from the off-chip memory. Furthermore, the data coming back into the chip was allowed to arrive in a different order to the order in which the processors requested it to allow the controller to optimize its accesses to suit the architecture of the external memory. An embedded real-time operating system was written that dynamically scheduled multiple tasks onto each of the processors using an earliest deadline first scheduling algorithm. The programs on each processor could be synchronized using cached semaphores. When n L1 cache banks were configured as a cache (either Instruction or Data), they behaved as an n-way set-associative cache with a Least Recently Used cache line replacement algorithm. The data, tag and state memories were all dual-ported to enable bus transactions (like those required for data coherency) to be processed without interrupting the processor.*

3. *Our filters utilized a time-multiplexed architecture with neighbouring filter taps applied to a single multiplier. Given that adjacent taps in the tails of a raised cosine filter tend to change sign, we were looking at a worst-case operating power scenario in each of the 64 multipliers on the chip. Several patented techniques, low power symposium papers and painful months later, two of us developed what we believed was the lowest possible power consumption for a digital filter. As soon as we sent the chip to be manufactured, we invented several other techniques that could have reduced the power even further - one of the joys of the research process.*

4. *Bell Labs had about 24,000 employees globally. 1,800 worked in research, the remaining 22,000 worked in product development. Australia already had a sizeable Bell Labs development organization - creating software products for business communications systems. This group was created by Scott Coles in 1994. Scott advised me throughout the process of setting up Bell Labs Research in Australia. The group he founded still exists and is now the Avaya Labs team in North Ryde. The most-valuable lesson that Scott taught me was that diversification reduces risk. Diversify angels (executives in head office that support your team), funding, reporting line and product areas. When things go wrong, you have several political levers at your disposal to obtain the support you need.*

Disclaimer

The ideas and assertions put forward in this handbook are from the presentation of the 2007 Warren Centre Innovation Lecture, a Warren Centre event held at:

- the PricewaterhouseCoopers building in Melbourne on 5 June 2007
- the Powerhouse Museum in Sydney on 6 June 2007
- the PricewaterhouseCoopers building in Brisbane on 10 July 2007 and
- the National Wine Centre, Gallery Room in Adelaide on 11 July 2007.

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