Irish Academy of Engineering - Intel® Labs Europe

Lecture Series on

Engineering Research and Innovation

October 2011 to May 2012

The Irish Academy of Engineering

The Irish Academy of Engineering is an all-Ireland body, concerned with long-term issues where the engineering profession can make a unique contribution to economic, social and technological development.

Its members are Irish engineers of distinction, drawn from a wide range of disciplines and membership currently stands at approximately 140.

Drawing on the experience and knowledge of its distinguished members, the Academy works to facilitate communication and dialogue on engineering-related matters. It publishes reports and analyses, some jointly with other learned and professional bodies.

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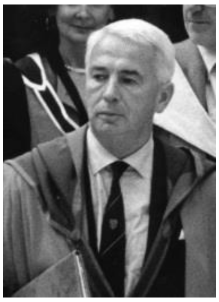

The lecture series presented here is a programme of the Irish Academy of Engineering in partnership with Euro-CASE, the European association of engineering academies, and with the support of the Intel Labs Europe.

The Academy's Standing Committee on Engineering Research established as its prime mission in 2010, to create a critical awareness in the Irish universities, Government and industries of the need for major changes in the philosophy and practices of engineering education and research which will result in a new dynamic in the contribution of engineering education and research to innovation in Ireland. The starting point for such an agenda was to establish the precise current status of engineering research in the Irish university and higher education institutions.

The results of this study are reported in the committee's paper "***Engineering Research & Irish Economic Development***" and may be seen in the Academy's website www.iae.ie where it is reproduced in full. The situation was seen to be clearly far from optimum when it was discovered that, though the research that was being conducted in the Irish third level engineering schools was of the highest international standard, that over the previous five years, only 8% of the total Government's funding for research was allocated to engineering, with some 85% going to the sciences. Furthermore, the bridge which could provide the route for translating the findings of engineering research to industrial innovation was seen to be weak and sorely in need of major structural changes. The reasons for these situations were analysed and the actions necessary to correct them were identified and presented in the committee's paper.

It was decided by the Academy that for the greater promotion of the Committee's findings and recommendations, to invite four distinguished engineers who have made their names in the international world of engineering innovation, to participate in this lecture series on the topic of Engineering Research & Innovation. The Academy has been greatly honoured, and our Irish society greatly enlightened, to have the following participate in this lecture series:

- Mr. Justin Rattner, Chief Technical Officer of the Intel Corporation USA
- Professor Michael Kelly, Prince Philip Professor of Technology at the University of Cambridge
- Professor John V. McCanny, Director of the Institute of Electronics Communications and Information Technology (ECIT), Queen's University Belfast
- Professor Henning Kagermann, President of National Academy of Science and Engineering (acatech)

This lecture series was launched by the Minister for Education and Skills, Ruairi Quinn, T.D. in University College Dublin in October 2011 and the lectures were delivered at university venues in Belfast and in Dublin over the academic year 2011/2012. The Academy believes that they merit a wider audience than they had in Ireland, great indeed though it was, and accordingly, it is pleased to launch them on the World Wide Web for the benefit of the international audiences which these lectures deserve and where they will be appreciated.

John Kelly

Foreword by Dr Tony Barry, President of the Irish Academy of Engineering

It gives me great pleasure as President of the Irish Academy of Engineering to welcome the publication of this outstanding series of lectures. A central part of the mission of the Academy is to contribute to the economic development of the country through the deliberations of its members on a wide range of issues in which the profession is involved and in which they bring a very high level of expertise. This lecture series is a very important contribution to these efforts.

This particular publication focusses on the vital role of research in industrial innovation and identifies the specific contributions which the various sectors make:

1. *Government* through its fundamental strategies and its agencies.
2. *Industry* with its interaction with the research programmes of engineering schools.
3. The *engineering schools* which promote the innovation of undergraduate courses and in their research topics.
4. The *speakers*, each of whom is of the highest international standards and who came to Ireland to give these lectures and share their views with us.

Above all we must thank Intel Labs Europe who sponsored this series so effectively and actively.

Opening speech by Minister Ruairi Quinn, Minister for Education and Skills at launch of Series on October 11th 2011

Ladies and gentlemen,

I would like to thank the IAE for inviting me to formally launch their Intel Lecture Series-Research and Innovation.

The Academy, in association with the European association of engineering academies and with the support of Intel Ireland are to be congratulated on this initiative and in highlighting the contribution that engineering can make to research and innovation in Ireland. The line-up of speakers over the coming months, representing both the academic and industry wide view, will provide for a very robust examination of the role that engineering can play in economic development.

I know I don't need to convince anyone here that Irelands future prosperity lies in a knowledge-based economy. Regaining economic stability and developing future growth will rely on our ability to foster a culture of ideas and innovation. The development of a strong research and innovation ecosystem, spanning both the public and private sector, is at the heart of this strategy.

Research investments have already had a very positive impact on our industrial development and highlights how research, development and innovation can contribute significantly to job creation and economic prosperity. After ten years of investment, we are beginning to see clear indicators on the benefits of this investment.

- The number of research papers published has grown significantly in recent years but more importantly is the impact/quality of that research
- We are now ranked in the top 20 countries in terms of citations per paper across all fields, up 16 places from 2003. Our position in these ranking is very important in marketing Ireland as a destination for quality research
- IDA Ireland continues to attract more research related investments, generating high end job opportunities around the country. Boston Scientifics €26 million investment in an R&D facility in Clonmel is one of the most recent wins in this area
- Irelands continued improvement in the world innovation rankings, up from 19th in 2010 to 13th in the 2011 Global Innovation Index.

While our institutions have developed a strong base of research activity, the focus of our systems development must be on our ability to maximise the impact of our research in terms of the commercialisation of that research and its conversion into real sustainable jobs. Engagement and collaboration with industry is essential in this regard.

We have built up a considerable base of research across the broad spectrum of higher education and it is important that we maintain this base. But we must also augment it with targeted investment in specific strategic areas of national opportunity. The ongoing national prioritisation exercise, chaired by Jim O'Hara, aims to identify these areas of potential and Forfás has undertaken detailed consultation with both industry and academia as part of this process. I believe that engineering research will have a strong role to play in developing many areas of strength identified.

As an architect, I have a keen awareness of the impact that the engineering profession has made on Irelands development to date. I have no doubt of the fundamental role it will continue to make to our future prosperity.

Engineering can be defined as 'the application of scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines processes and systems'. I think the key words here are 'application' and 'practical'. Engineers make ideas happen, in nearly every facet of modern society, and will be essential in ensuring we realise our vision for an innovation economy.

The key traits of engineering – problem solving and innovation – are vital characteristics that we are trying to instil in students throughout the education continuum. Since taking up my position as Minister earlier this year, promoting STEM literacy has been one of the areas that I have prioritised. We need to convince students, parents and wider society of the benefits of having an aptitude in these subjects, and of the wide variety of career opportunities that are available. I hope that measures we are taking through curriculum reform and teacher training will have a significant impact on the level of interest and take-up of these subjects in both second and third level.

I have read with interest the Academy's recently published report '***Engineering Research in Irish Economic Development***'. The paper points to the untapped potential nationally in the area of engineering research.

Having research-active innovative engineering schools will be vital in improving the attractiveness of pursuing an engineering qualification. Like in all other disciplines, engineering departments across our higher education institutions must work collaboratively to develop research strengths. The development of inter-institutional initiatives or national platforms is to be welcomed. Engineering research also has a key underpinning role to play in so many other academic areas and the development of trans-disciplinary initiatives offers great potential.

Greater collaboration with industry should also be a key target in terms of both undergraduate provision and research activities. I recognise that much progress has been made in recent years, especially in terms of collaborative research projects but I believe there is still much more that can be gained. We are lucky in Ireland to have many of the world's leading companies operating here, and we need to take advantage of this.

Let me conclude by assuring you that the Government is committed to Research and Innovation as the stimulus for driving economic growth and will continue to ensure that Ireland is an extremely attractive place in which businesses can carry out R&D.

I would like to again offer my congratulations to the Academy for organising this series of lectures and to wish them every success.

Lecture 1

Mr Justin Rattner

Corporate Vice President and Director of Intel Labs

Engineering Research and Innovation: Transforming the World in the 21st Century

October 11th 2011

Mr. Justin R. Rattner

Justin Rattner is a corporate vice president and the chief technology officer (CTO) of Intel Corporation. He is also an Intel Senior Fellow and head of Intel Labs where he directs Intel's global research efforts in processors, programming, systems, security, communications and, most recently, user experience and interaction. As part of Intel Labs, he is also responsible for funding academic research worldwide through its Science and Technology Centers, international research institutes, and individual faculty awards.

In 1989, Justin was named Scientist of the Year by R&D Magazine for his leadership in parallel and distributed computer architecture. In December 1996, he was featured as Person of the Week by ABC World News for his visionary work on the Department of Energy ASCI Red System, the first computer to sustain one trillion operations per second (one teraFLOPS) and the fastest computer in the world between 1996 and 2000. In 1997, Justin was honoured as one of the Computing 200, the 200 individuals having the greatest impact on the U.S. computer industry today, and subsequently profiled in the book Wizards and Their Wonders from ACM Press.

Justin is a member of the Department of Defense/Department of Homeland Security Enduring Security Framework and serves as a member of its Operations Group. He is a trustee of the Anita Borg Institute for Women and Technology and serves as Intel's executive sponsor for Cornell University where he is a member of the External Advisory Board for the School of Engineering.

Justin joined Intel in 1973. He was named its first Principal Engineer in 1979 and its fourth Intel Fellow in 1988. Prior to joining Intel, he held positions with Hewlett-Packard Company and Xerox Corporation. He holds B.S. and M.S. degrees from Cornell University in electrical engineering and computer science.

Engineering Research and Innovation: Transforming the World in the 21st Century

Justin Rattner

Introductory Remarks

Good evening. I want to start by thanking Minister Quinn and the Academy of Engineering for inviting me to speak to you tonight. It's truly an honour and privilege to be here. As some of you may know, this is Intel Technology Week in Europe. We've scheduled a number of our annual European research meetings and events, both internal and external, and are hosting them at the Intel complex in Leixlip. The largest event this week is our annual European Research and Innovation Conference (ERIC), which brings together our academic, industry, and government partners from across Europe to discuss progress and opportunities in tackling societal challenges by asking the key research questions.

At Intel we pride ourselves in continually pushing the boundaries of research and innovation. And that very much includes our engineering activities here in Ireland and throughout Europe. To bring a greater sense of a European identity to these efforts, we created a network organization known as Intel Labs Europe. ILE now connects over 25 research, development, and innovation labs which span the region from Barcelona to Belfast. Its mission is to strengthen Intel's commitment to and alignment with European R&D. ILE is headed, I should note, by my good friend and Ireland's own, Dr. Martin Curley.

How Intel and Steve Jobs Transformed the World

Steve Jobs' recent death has caused much of the world to stop and reflect on his extraordinary ability to use engineering innovation to create products we never knew we needed, but were indispensable at the very moment they came to market. It seems only appropriate that I reflect a bit on how Intel and Apple worked together for the last six years of Steve's life to make just a few of his powerful visions come to life.

Few people know how many times Apple came close to moving to Intel Architecture. It had happened so many times, that the Intel-specific changes to the Mac OS were well documented by Intel's OS engineering teams. Each time Apple thought it might be time to switch from IBM's PowerPC architecture to Intel, they'd dust of the source code and prepare to engage. Each time, of course, they were left at the altar, but never feeling jilted, they re-archived what they'd done and waited for Apple to call again. It was Intel's Centrino platform architecture that really got Apple thinking it was time to switch. IBM and Motorola simply couldn't match Intel's processor performance and energy efficiency. By the middle of the last decade, the gap between Intel and IBM microprocessors was too great for Apple to ignore. A team was quickly assembled to bring the Apple product line to Intel Architecture. I'll never forget the day Steve came to Intel to share the secret with Intel's top 100 leaders. His very presence in a small auditorium in Santa Clara had the crowd buzzing with excitement. When Steve told us that the deed was done, and Apple computers would henceforth be powered by Intel, it was a breath-taking moment in our history.

But it was what Steve said about working with Intel that made us feel very special. He said the Apple engineers had expected their Intel counterparts to be very corporate, very inflexible in their approach to product design. To their surprise and great delight, the Intel engineers shared the same passion, the same technical zeal to make the new Intel-based Macs the best they could possibly be. It was Steve's ability to understand what drove engineers to greatness that made him so exceptional. He understood that despite our discipline and training in mathematics and science, we love what we do, and we do it not for the money, but for the sheer pleasure in seeing the fruits of our labour make the world a better place to live.

Those early Intel Macs led to many more collaborations. The MacBook Air is one such example. The folks in Cupertino wanted to build by far the thinnest notebook computer ever seen, but their work was frustrated by the thickness of the processor package. Fortunately, Apple's requests finally reached our Assembly and Test Technology Development (ATTD) team in Arizona where they had invented a very thin package, but couldn't get Intel's own product planners to embrace it. Suddenly, ATTD had a customer who saw their ultra-thin package as the basis for a new class of notebook computer. The MacBook Air was suddenly off the back burner and headed to market. The latest bit of Intel magic to make its way into Apple's product family is called Thunderbolt. If you've bought any new Macintosh recently, you have a Thunderbolt connector somewhere on the case. What makes Thunderbolt unique for Intel is the fact that it's the first technology to go straight from Intel Labs, the research team I lead at Intel, directly to product. Once Apple learned we had a cheap and versatile 10 gigabit per second I/O technology, they made it their number one priority. Even my boss, Intel's CEO Paul Otellini, was stunned when Steve said Thunderbolt was their top technology request of Intel in 2009. Steve honoured us at the product launch last year by not only mentioning the Intel contribution to Thunderbolt, but by giving the technology its official name: Thunderbolt by Intel, courtesy of Steve Jobs and Team Apple. Thanks, Steve. We'll truly miss you.

Intel Labs: A 21st Century Industrial Research Lab

Over much of the period I've just discussed, research at Intel was undergoing some extraordinary changes as well. To understand the challenges we faced, I need to explain a little bit of history that began even before Intel was founded. In the 1960s, one of the hottest technology companies around was Fairchild Semiconductor. It was headed by the legendary Robert Noyce, the inventor of the planar integrated circuit. Running its research lab was another chip industry legend, Gordon Moore, the father of the famous "law" that governs the advancement of semiconductor technology. Gordon's lab was famous for inventing all kinds of breakthrough chip technologies, but Fairchild Semiconductor, as a company, struggled to move those great ideas from the research lab and into the factory.

When the time came to found Intel, Noyce and Moore, along with another chip industry legend, Andy Grove, agreed that there would be no research at Intel. New chip technology would be developed right on the factory floor. Intel was thus born with an anti-research sentiment, and it stayed that way for a least its first 15 years. The anti-research attitude was broken in the mid-80s, when a small research team was formed under John Caruthers to look a bit further out in time. Components Research, as it was called, was chartered to work on processes and devices two technology generations (or nodes) ahead of current production. It still exists today, employs a little more than 100 or so people, but is responsible for most of the recent semiconductor breakthroughs you've read about, including strained silicon, high-K, metal gate transistors, and most recently, the tri-gate or 3D transistor we're just about to put into production at 22 nanometers. Intel did not form the equivalent of Components Research for microprocessors for another ten years, but the Microprocessor Research Lab did not get off to a very good start. When I took charge of it in late 2000, not one major microprocessor feature had been invented in MRL. Much of what it had created was being licensed to companies outside of Intel. I put an immediate stop to that and insisted that we plan for success in any new research. If there wasn't an obvious landing zone inside of Intel for a new technology, we shouldn't even start the research. That realization led to a transformation in our thinking about many aspects of non-semiconductor research at Intel. It launched a process that we'd later understand as a fundamental rethink of what it meant to do research in the industrial setting.

When I took charge of Intel Labs in late 2005, the timing could not have been more perfect. Early the following year, Intel had launched an effort called SET for Structure and Efficiency Taskforce. It was a classic corporate re-engineering effort aided by one of those highly-paid business consulting companies. Fortunately, part of SET was a study of how to improve the transfer efficiency or "hit rate" of new technologies coming out of Intel Labs.

After much debate we came to understand that the low hit rate problem was due to timing differences between research and product development. Too often a research project would reach proof of concept, but the development teams would be tied up getting a new product out the door. After months of waiting, the research team would move on to other work and the motivation to transfer the previous results would fade. Similarly, when a development team would come looking for new ideas for their next product, the researchers were busy with other work and had little interest in returning to what they viewed as old work. We came to refer to this problem as the "valley of death" given its remarkable ability to kill perfectly good technologies before their time. The solution to the problem as it turned out was right under our noses. Of particular relevance was the way our Components Research and semiconductor Technology Development teams go about creating the next generation semiconductor technology using a process they call pathfinding. The key to their pathfinding process was assembling a team made up of both researchers and developers for a sufficient period of time, typically 12-18 months to affect the technology transfer.

Our challenge was to scale out the pathfinding process to cover the literally dozens of new technologies coming out of Intel Labs. Despite our fears, adapting pathfinding to the broad areas of research we pursue in Intel Labs has been a remarkable success. The process is so successful that today the product groups literally fight over the pathfinding slots. It's also not unusual for more developers to be assigned to a pathfinding project than researchers. At any moment, we have over 50 distinct joint pathfinding projects between Intel Labs and the various product development teams. We also raised the bar by which we define successful pathfinding from simply transferring the technology to actually impacting the product roadmaps. We even included a joint pathfinding objective in our employee bonus program.

While roadmap impact is certainly a critical part of being a 21st century industrial research lab, it is not the whole story. To better understand what works and what doesn't work in modern industrial research and how it differs from academic research or government research, we initiated a benchmarking effort with various multi-national, industrial research labs around the world. Included

in the study were all your favourite labs including IBM Research, Microsoft Research, Google Research (a misnomer, by the way), and GE Global Research. We looked at about a dozen different labs in all. One thing we learned was the importance of balancing research directed at existing product lines and research aimed at exploring technologies that had no immediate business relevance. This 50-50 split has been in place for the last four years and has worked remarkably well.
While it would be easy to argue for a much higher spend on the business-directed side, we feel we create much more long-term value for Intel by keeping exploratory research in equal proportion.
Another thing we learned was the role research plays in reducing longterm development costs. Product failures in our business are extremely expensive. A typical mainstream microprocessor may cost 500 million Euros to develop. That cost is on top of the billions of Euros it costs to build the factories to manufacture such a microprocessor. Intel can ill afford a mistake of that scale, yet they can and do happen, more often than you might suspect. What a research lab can do is test out those new ideas before they become part of a product, validate the good ones and weed out the bad ones. This is called "failing fast" and it's something we do with great pride. So crucial are these validations prior to product development that we even have an award for it. We call it the "First Penguin" prize. It comes from the observation that it always takes that one penguin to jump off the ice floe for the rest to follow. Our penguins willingly make that sacrifice and we are delighted to recognize their risk taking. One consequence of having a substantial amount of exploratory research taking place is the need to find other avenues for these technologies to reach the marketplace. One such outlet is open source software. One of our great successes has been our Open Computer Vision library. OpenCV has become the de facto standard toolset for doing computer vision research and building actual applications. We even made a little money by delivering a set of optimized software libraries for the kernel vision functions. Most recently, we released a new tool called Parallel JavaScript into open source. It allows Web programmers to harness the power of multi- and many-core processors within the browser. The initial version for the Mozilla Firefox browser had over a 1000 downloads in the first few weeks it was available. Versions for other browsers are in development.

For other technologies we have recently established a venturing practice within Intel Labs. While few technologies represent compelling venture opportunities, those that do usually require substantial financial investment before they can be brought to market. Just to calibrate you on the size of such investments, significant research efforts for us represent an annual investment in the range of 1 to 10 million Euros per year. Taking just one of those technologies to product requires an investment of from 10 to 100 million Euros per year. Given that fact, we look for opportunities to enter markets where the total available market will reach 1 billion Euros within three years. There aren't many such ventures, but the ones we are pursuing are truly compelling.

In addition to venturing and validating there is one more role for the 21st century industrial research lab and that's the one we call visioning. Thanks to people like Steve Jobs it is no longer sufficient to put a bunch of technical ideas together and call it a competitive product. The days of "data sheet" product design are quickly fading in the IT industry. To either be Apple after Steve or to compete with Apple after Steve, products and product lines need to spring from a vision of what the user needs to be more productive, to have more fun, and to be more social. Technology has reached the point where we as users shouldn't settle for anything less. We call this experience-driven design, and it's really reshaping the way we think about and plan new products at Intel. Unfortunately, experience-driven design is not something they teach you in engineering school with perhaps one or two exceptions. In fact the disciplines that are critical to experience-driven design aren't even taught in engineering school. You find the experts in the field coming out of anthropology and the social sciences. Disciplines such as ethnographic research and behavioural economics, along with human interface design are what it takes to compete here. To create these visions for future products based on experience-driven design, we added a new research division to Intel Labs a little over a year ago. It is headed by an ethnographer named Genevieve Bell who is also an Intel Fellow. She leads a team of about 100 researchers who are charged with creating these visions, prototyping these visions, and formally testing these visions. They then take each vision into pathfinding with a particular product group to turn that vision into reality. Our health care products, our Classmate family of educational PCs, and our Smart TV products are all a result of this methodology. And, we expect most if not all of Intel's products will benefit from it in the future.

These three dimensions; visioning, validating, and venturing, in our minds form the core of 21st century industrial research. While Bell Labs may have been the model of 20th century industrial research, and there are still a number of cases of companies chasing that vision, it is increasingly dated and out of step with today's fast moving information and communications technologies. We are trying to set a new course for the 21st century and we hope many other companies will join us in the endeavour.

Lecture 2

Professor Michael Kelly

Prince Philip Professor of Technology at the University of Cambridge

Engineering Research for Economic Growth

December 8th 2011

Professor Michael J Kelly

Professor Michael Kelly is the Prince Philip Professor of Technology in the University of Cambridge since 2002, and a Professorial Fellow at Trinity Hall. He is also a Non-Executive Director of the Laird plc.

He studied Maths and Physics to MSc level at Victoria University of Wellington in New Zealand until 1971 and obtained his PhD at Cambridge in 1974 in solid state theory.

His career history includes:

- GEC Hirst Research Centre 1981-92: developed new families of microwave devices that are still in production with E2V Technologies at Lincoln.
- University of Surrey 1992-2002 including a term as Head of the School of Electronics and Physical Sciences.
- Executive Director of the Cambridge-MIT Institute, 2003-5. Chief Scientific Adviser to the Department for Communities and Local Government 2006-9.

Michael is a Fellow of the Royal Society of London, the Royal Academy of Engineering and Honorary Fellow of the Royal Society of New Zealand. He is also a Member of the Academia Europaea and a Fellow (and former Vice-President) of the Institute of Physics and Fellow of the Institution of Engineering and Technology.

Engineering Research for Economic Growth

Michael J. Kelly

Abstract

In the continuum from basic, to applied, to developmental research on to production and sales, there is a great attrition rate, as few ideas from basic research make it successfully to the market place. In good economic times, much resource is devoted to basic research, on the basis of 'let a thousand flowers bloom'. I suggest in difficult economic times it is the engineering research that needs to be centre stage, as we focus more closely on demand led research. The traditional serendipitous developments out of CERN or the space race are a little too indirect in hard times. For this strategy to work, the onus is on established industry to be open and confident about its own future intent, and for a system to be put in place that allows new players to come to the market.

Innovation Today

Industrial research as we know it today was an invention of the late 19th century, starting with the chemical industry in Germany. In the first part of the 20th century, there was a steady growth of industrial research laboratories in Europe and the US. The big expansion came after World War II, grateful nations sent the boffins who played a major role in winning the war back to their universities and industrial laboratories to win the peace. Vanaveer Bush, the presidential advisor from MIT, described a linear model of progress where ideas from universities were developed into products by industry. There was also a rise in basic research in industry in the US and in the UK in aerospace and pharmaceuticals. This latter activity was curtailed in the 1980s and 1990s, as competitive pressures from loss of monopoly status and new entrants from low-cost economies showed the return on investment in basic industrial research to be unattractive: there was a renewed focus on product engineering and development which continues to this day. A compact between society and higher education over the last 50 years has overseen a great expansion of the latter in the expectation of enhanced local and national economic growth. The greater capacity of universities are to be deployed, in part, in helping industry – nowhere is that more exemplified in the great research universities, of which MIT is the leading exemplar. The successful economies have strong and effective two-way links between universities and industry. The 1980 Bayh-Dohl act in the USA gave the universities the duty to exploit any new intellectual property arising from research undertaken on campus.

Today we have a rich tapestry of innovation. Silicon Valley and Route 66 in the USA, the Cambridge phenomenon in IT, biotechnology and now green technologies, are international examples of economic success. The research parks in many universities, exemplified by the University of Surrey in Guildford – placed halfway between Heathrow and Gatwick – are major venues of economic growth. In the UK, there are many cities where the university and its science park represents the largest single local employer, and when the infrastructure around the local health service is added in, they together account for as much as 25% of local employment.

We live in the middle of major economic turmoil brought about by unregulated financial speculation, not least around the domestic housing sector in Ireland and the US. We have the rise of low-wage, high capacity, and well-educated economies such as China, India, and Brazil who will manufacture most of what we need at costs too low for us to compete. Where do we turn?

Applicable Research

I want to begin by looking more closely at why we do research. I would argue that 90% of the research undertaken in universities is funded by the taxpayer in the clear expectation, delivered over recent decades, that they will be able to live better, healthier and less environmentally damaging lives by exploiting the outcomes of that research. They would also support 10% of funding because we are civilised and curious peoples: we want to know more about our universe, history and cultures. The taxpayer would expect whatever benefits from the latter to be pursued in economic terms if that is appropriate. This is a message that needs constant reinforcing in universities, as the mantra of 'blue skies' research is put on a pedestal. I once heard a research council leader argue that that motivation for research in universities should be 10:90 the other way!

Donald Stokes in his 1997 book 'Pasteur's Quadrant' went beyond the linear model of research outlined above. He pointed out that in addition to pursuing new ideas in a quest for fundamental understanding, one could independently pursue new ideas with a consideration of use, or in many cases pursue both simultaneously. He contrasted Neils Bohr's interest in the theory of the atom, and lack of interest in applications in materials science, with Thomas Edison's pursuit of light and electricity without stopping to dig deeply into the theory of these phenomena. He pointed out that Louis Pasteur was driven both by the desire to improve the health of Parisians in terms of removing diseases that came to them from the water, beer and milk they drank, and by a curiosity about the life and workings of microbes that he was sure lay at the heart of the problem. I want to suggest that after five decades where basic research (particularly the Bohr type) has been on a pedestal in societal and academic and even government terms, it is time to give the Edisons of this day a little more support and publicity. Engineering research that either turns a good idea into a new product (technology push) or creates a product to serve a societal demand (market pull) needs to be centre stage, at least until we can afford to be generous to basic research again.

There are five experiences that have led to this suggestion. During the period 1981-1992, I worked as a researcher at GEC plc, developing two families of new generation microwave diodes, one of which is still in production for automobile radar. I had the excitement of doing intrinsically exciting research that was directly aligned with the company aims. I spent 10 years at the University of Surrey, where I saw the real benefits of sizeable teams of academics working together to produce outputs of significance and real-world impact that was beyond the capability of those academics working independently. I will say more below about my work on the link between Cambridge and MIT, where I saw the real benefits of putting the end-users in the driving seat of research projects. As a part-time scientific adviser to a Government Department, I have seen the sorry consequences of the absence of serious project delivery capability, an essential part of successful engineering, in the formation of policy. Finally as a non-executive director of Laird plc, I have seen how internationally competitive industry is led from the top.

End-User Led Research

A Bank of Boston report in about 1998 had a subtitle indicating that over 4000 companies, employing >1M American citizens and turning over $238B per annum had been formed by MIT alumni. Gordon Brown read this while on holiday, and contacted MIT from the beach. From that start the Cambridge-MIT Institute (CMI) (2000-6) was born. I had the privilege to lead the UK end during 2003-5. I will not rehearse the difficulties of getting the project off the ground, but they were considerable, but rather focus on the ideas and achievements[1]. It was a 50:50 venture between the two universities, with two strategic business partners, BT and BP, and the Gatsby Trust provided funds to allow for student and academic staff experiences to be paid for, so that in the end it spent £80M, of which £65M came from Government. The mission of CMI was simply stated: *To enhance the competitiveness, productivity and entrepreneurship of the UK economy by improving the effectiveness of* ***knowledge exchange*** *between university and industry, educating leaders, creating new ideas, and developing programmes for change in universities, industry and government, using an enduring partnership of Cambridge and MIT, and an extended network of participants*. All our outcomes were encapsulated in three meta-models: (i) education for innovation, (ii) knowledge integration around research, and (iii) engagement with industry around knowledge exchange.

Education for innovation

Having interviewed many entrepreneurs and successful people in business and industry who were alumni of Cambridge and MIT, we encapsulated our education for innovation as having three key elements. The interviewees attributed their success to having (i) acquired a deep conceptual understanding of one or more disciplines or inter-disciplines, rather than being wide generalists, as their innovation was generally deeply thought through; (ii) they had developed the personal and interpersonal skills to build teams and deliver successful innovation on time and to budget, and (iii) they had a level of self-confidence from having completed realistic projects while at University. Interestingly we thought Cambridge did the first better, MIT the second better, and we both struggle to find realistic projects that can be completed in the time and budget constraints of an academic semester. As a result of our analysis, we developed new curricula, projects to bring out team skills, mixed technical-business Masters programmes, and an undergraduate exchange between Cambridge and MIT that continues to this day for engineers.

Knowledge integration around research

Our knowledge integration around research was one of our key innovations, now widely emulated in the UK and EU. We wanted to be sure that we were developing fundamental new ideas developed with a consideration of use (so we were always in the Pasteur quadrant). The whole research programme had to exhibit an awareness of the needs of society and industry, and we developed an integrated community of stakeholders from the academics (researchers and project students), industry (the primary exploiters of the outcomes), the public sector and the regulators to ensure that progress went seamlessly and with the grain of societal development, not across it. We launched major projects in the areas of emerging technologies in aviation, drug discovery, future communications, technology management, and quantum computing. We helped others start up similar programmes in the financial sector, future healthcare systems, energy reliability, future cities, and the creative industries. The most successful of these was the Silent Aircraft Initiative involving Boeing, Rolls Royce, airlines, airport operators, the Air Traffic controllers etc. We even had a

[1] For more details than can be covered here, I refer you to a 2009 report compiled two years after the completion of the CMI programme:
http://www.technopolis-group.com/cms.cgi/site/group/uk_group/uk_project_sheets/902_CMI.htm

thousand schools following the project via a web-page that the Science Museum hosted for two years with new material provided by the young researchers on a monthly basis. Just after it ended, I had 20% of my interviewees at College for an engineering place in Cambridge wanting to get closer to the Silent Aircraft Initiative! It designed and modeled an aircraft with a 97% reduction in today's level of sound energy during the landing stage! This new model is firmly on the books of the civil aviation sector.

Engagement with industry around knowledge exchange

Our work in engaging industry with knowledge exchange had three elements. We were interested in being proactive in engaging on a prolonged interaction. We were concerned with education and empowering those agents at the interface to engage in effective knowledge exchange, and we tried to promote a new culture in universities and industry for university involvement in the problems of industry and society. Here we developed a systematic dialogue with whole industry sectors through sector interest groups, e.g. ground transport, construction, retail, leisure, to focus on the longer term development of these sectors and the role that universities could play in accelerating progress. These were modeled on the successful international motor vehicle federation hosted at MIT.

The Technopolis Report[1] shows that there are now 300 students on the family of MPhil courses in 2011 (mainly overseas students!). The Silent Aircraft has been adopted by NASA as the N+2 airframe for civil aviation. CMI papers had higher citations than either CU or MIT papers. The report confirmed that CMI met the objective that Ed Crawley (my MIT opposite number) and I had set for ourselves, namely that the output metrics of CMI would exceed that of either Cambridge or MIT on its own, and that the Government got more out of the money than deploying it through more conventional routes. Among the many successful research programmes were (i) E-stack – software for architects to design more energy efficient buildings, (ii) Fibretech – light-weight metal sheets – exploited by existing companies, (iii) Orthomimetics – artificial ligaments – spun out and acquired, and (iv) Ferroelectric nanotubes – spun out and acquired. The international calling card did wonders, and it gave us much power to convene. Many of the new processes have become embedded in Cambridge practice. The Technopolis report concluded that CMI achieved its objectives in broad measure. It delivered (i) a programme of excellent research with good innovation potential; (ii) some measurable economic impacts; and (iii) a programme of educational innovations, which have led to institutional learning and equipped students, faculty and technology transfer professionals with new knowledge and skills. It also managed to share at least some of this insight and learning with the wider academic community. Overall, CMI financed a large and impressive body of educational development work that has more than satisfied the general objectives set for it. A stronger focus on technology transfer transactions has helped Cambridge Enterprise improve its reputation with its CU customers and its connections to the business community.

The Cambridge Phenomenon

There was some initial reluctance within Cambridge at the approach of the UK Treasury and MIT for the CMI partnership, on the grounds that there was already a strong local trend in commercial exploitation going back to the Science Park movement in the 1970s. MIT were adamant they wanted to interact only with Cambridge under the proposed initiative of Gordon Brown. Cambridge provides an excellent environment and community for early stage science and technology based ideas, and University people and ideas are at the core of many new technology ventures. There are over 1,000 innovation based companies, with >500 in IT and >200 in Life Sciences, the most rapidly expanded sector, and a greentech sector is starting to emerge. The whole region has been nicknamed 'Silicon Fen'. In 2006, the Cambridge cluster was fourth in Europe for total European institutional investment. In addition to several science parks there are two incubation centres, the St John Innovation Centre and the Broers Building in the Hauser Forum (Hermann Hauser being dubbed the father of Silicon Fen). These provide a supportive environment within which the start of the commercialisation of new ideas can take place.

There are many ways in which existing industry interacts with the University, with relationships individually tailored to optimise the productivity of the link in terms of the corporate strategy and requirements. The standard relationships include the funding of doctoral and post-doctoral researchers to carry out work of relevance to the company. There are a plethora of collaborative research projects, from the bilateral to the consortium-based. There are framework agreements with individual tasks being called off as required. Some companies have endowed a professorship to work in the area germane to the company's interests, and we also have embedded laboratories, where the company has set up its own presence within the University. These latter are usually established at the end of a trust-building exercise that has previously delivered value to both parties.

Yet another version is exemplified by the electrical engineering division of the Department of Engineering in Cambridge, where I belong. The Centre for Advanced Photonics and Electronics (CAPE) is based around world-leading facilities and expertise at the University of Cambridge. It is a Partnership with a small group of global strategic industrial investors, operating across the supply chain of the electronics and photonics industries. CAPE provides a new form of joint university-industry research that is leading edge, vertically integrated and commercially relevant. The second five-year phase has just started. Partners include Alps Electronics, Dow Corning, Disney Research and Jaguar Land-rover, and have included Nokia, Ericsson and others in the past. These companies embed researchers, and fund a range of short, medium and long term projects. The mission of CAPE is to (i) invent and develop, through multidisciplinary research, materials, processes, components and systems, (ii) define the future strategy and market implementation and (iii) set the industry agendas for the convergence of photonic and electronic technology platforms. My own work is in two areas, trying to master the manufacturing processes of ultra-thin semiconductor layers to exploit quantum mechanical tunnelling in real-world products, and in trying to define the boundary in nanotechnology between that which is, and which is not capable of low cost, high volume manufacture.

Recent technical highlights from CAPE include (i) a new radio over fibre system for tracking assets with an early deployment handling baggage at airports, (ii) the prototype for the now ubiquitous laser mouse, (iii) a graphene transistor gated with an electrolyte, (iv) a demonstration of fibre-coupled multi-wavelength liquid crystal laser, (v) nanotubes acting as optical tweezers detecting 8 femto-newton forces, and (vi) ferroelectric random access memory technology transferred to industry for production. Over the last decade, there have been at least eight spinouts.

What now for the UK and Ireland?

The growth of China as the world's manufacturer and India as the world's back office is a central feature of change in the modern global economy. We will live for at least this decade in an era of financial stringency as a result of banking crisis and building boom. We will need to see a renewed focus on design and hi-tech manufacture, supported by public policy and not ignored by it. We should be driving the mass customisation agenda which cannot be easily off-shored. Finally we need a more tightly coupled national innovation system – understanding the feed-backs and the feed-forward processes[2]. This will involve (i) bringing the research funding much closer to the end-user aspirations (ii) coping with existing companies and building new ones, (iii) putting engineering research on the pedestal where blue-skies has been and (iv) empowering engineering researchers as the new focal point of the economy.

In this respect I have no hesitation in endorsing in full the Irish Academy of Engineering Report 'Engineering Research in Irish Economic Development', and its general and specific recommendations. The one area I would have beefed up is to throw down the challenge to the existing industry in Ireland, to be clearer and more confident about where it is going, and to share the relevant insights and aspirations with university researchers, in a process of continued contact and interaction. In that case, the university researchers can be drawn in and be expected to deliver on their own aspirations to be working for the good of the country. Where industries have complained in the past about the lack of interest from academics, it is often their own fault. The challenge of working ever more closely together brings with it a prize of economic success, and when that success comes, due recognition of the role of academics researchers in that success will be a prerequisite for continued second generation successes.

Wherein does Ireland have an unfair advantage that it can exploit across the globe? You can best answer that. Where do I see important technology-enabled transformations of society in the coming two decades? Just as the internet, which is now pervasive, was embryonic in 1990, I think that the widespread deployment of smart wireless control systems will enable a much more efficient use to be made of all resources, and energy in particular. The same systems will be deployed to monitor health away from medical centres. It might be used to maintain an autonomous electrically powered transport for city centres, and to allow electricity demand to be load balanced in much more effective ways than is possible at present. That is my instinct, and you will have your own.

In summary, the end-users need to be clearer about their own intentions and to be able to articulate them to those up the supply chain. Success will be down to those who interact very successfully at the interfaces of the supply chain that extends from concept to sales of products. The establishment of an effective route to manufacture, i.e. engineering research, is the pivotal stage for the next few years at least.

[2] Crawley, E., Greenwald, S., "Creating A Ten-Year Science and Innovation Framework for the UK: A Perspective Based on US Experience", Journal of Industry and Higher Education, June, 2006

Lecture 3

Professor John V. McCanny

Director of the Institute of Electronics Communications and Information Technology (ECIT), Queen's University Belfast

Research and Innovation – Successful Models for Economic Impact

February 21st 2012

Professor John V McCanny

Professor John V McCanny is the Director of the Institute of Electronics Communications and Information Technology (ECIT), Queen's University Belfast, Northern Ireland Science Park. He is an international authority on special purpose silicon architectures for Digital Signal and Video Processing and Cryptography. He has published 5 research books, 360 peer reviewed research papers and holds over 20 patents.

He is a Member of the Royal Irish Academy and a Fellow of the Royal Society, the Royal Academy of Engineering, the Irish Academy of Engineering, the Institute of Electrical and Electronic Engineers (IEEE), the Institution of Engineering and Technology (IET), the Institute of Physics and Engineers Ireland. His many honours and awards include a CBE (2002), a UK Royal Academy of Engineering Silver Medal (1996), an IEEE Millennium Medal, the Royal Dublin Society/Irish Times Boyle medal (2004), the IET's Faraday medal (2006) and the Royal Irish Academy's Cunningham medal (2011).

He has co-founded two successful high technology companies based the work of his research teams, Amphion Semiconductor Ltd. – later acquired by Conexant, then NXP, then Entropic - and Audio Processing Technology Ltd - acquired in 2011 by Cambridge Silicon Radio.

He was responsible, within Queen's University, for developing the vision that led to the creation of the Northern Ireland Science Park and the creation of its £37M ECIT research flagship (www.ecit.qub.ac.uk) for which he is currently Director. He also led the recent initiative that created the £30M UK Centre for Secure Information Technology (CSI) (www.csit.qub.ac.uk) which is based at ECIT.

He is currently a Member of Council of the Royal Irish Academy, was a Member of Council of the Royal Academy of Engineering between 2009 and 2012 and has been a member of the EPSRC's Strategic Advisory Team on Information and Communication Technology. He has served on numerous Royal Society committees including its Sectional Committee 4 that elects Fellows in Engineering and Materials Science and chaired this during 2005 and 2006. He was a member of the international advisory board of the German Excellence Centre on "Ultra-High-Speed Mobile Information and Communication" based at the University of Aachen from 2007 to 2012 and was a Member of member of the board of Ireland's Tyndall National Institute between 2004 and 2011.

Professor McCanny holds a Bachelor's degree in Physics from the University of Manchester, a PhD in Physics from the University of Ulster and was awarded a DSc in 1998 in Electrical and Electronics Engineering by Queen's University Belfast.

Research and Innovation – Successful Models for Economic Impact

John V McCanny

Introduction

A nation or a region's ability to remain competitive in a global economy is highly dependent on its ability to innovate and create new products and new services. A key aspect of this is the quality of its research. However, what is also critical is the environment and mechanisms to rapidly translate the outcomes of this research into wider economic impact and benefit. These issues and the challenges are now high on the agenda of many developed countries, not least the UK and Ireland. It is this core theme that forms the backdrop to this paper and one that resonates strongly with the recent Irish Academy of Engineering report: "Engineering Research in Irish Economic Development".

In the previous lectures in this series Justin Ratner, CTO of Intel, talked about innovation processes within that global company. Professor Mike Kelly from Cambridge, in the second lecture talked about the linkages between Cambridge and MIT – the Cambridge-MIT Institute. This was established to enhance the competitiveness, productivity and entrepreneurship of the UK economy by improving the effectiveness of knowledge exchange between university and industry. In this lecture I wish to talk about things closer to home. These are the research activities we have been involved with at Queen's University Belfast through the creation of the Institute of Electronics Communications and Information Technology (ECIT) and its role as the research flagship of the Northern Ireland Science Park (NISP).

In 2002 what is now the Northern Ireland Science Park was a derelict "brown field" site at the top end of the former Harland and Wolff shipyard on Queen's Island in Belfast. Today it accommodates 118 companies, ranging from small and growing start-up companies to well-known multi-nationals, such as IBM, SAP and Cambridge Silicon Radio. These companies have since created 2100 new high technology jobs generating over £100M per annum in salaries alone for the local economy. The main focus in this paper is to provide an overview of the activities of the ECIT Institute and to describe the models we are using to accelerate the translation of innovative research into business opportunity and application. A major motivation in creating ECIT was to take research out of the "ivory tower" and bring it into much closer proximity to business and industry. ECIT was opened in September 2004 with 70 people, with £37m funding over the first 5 years. Today it has 175 people and continues to grow.

Original Objectives

Our original motivation was to recognise the role that university engineering research could play in facilitating the growth of hi-technology business and employment within the wider economy. This followed a period where numerous university staff had created successful high technology businesses from their research. A key initial objective was to create an environment that had a critical mass of staff engaged in internationally leading research. This meant building on our existing expertise, whilst recruiting very high calibre people from all over the world to further enhance this.

In doing so, it was very important to recognise and identify our key areas of expertise and focus on activities where we could genuinely claim to be internationally leading, rather than spread our efforts too thinly.

We also, from the outset, set out to engage industry much more closely and at a much earlier stage than is the norm in a conventional academic environment. The objective was to strongly enhance the coupling between research and industry's longer term requirements. All too often research is done in isolation from actual need. Researchers produce wonderful solutions to complex problems only to often find from industrial colleagues, much too late in the day, that these were not the major challenges that needed to be addressed.

We also sought to create more "spin-out" companies from our research base and also to help facilitate externally created "spin-in" companies. In our terminology "spin-ins" refers to new high technology companies created externally from the University, usually in the areas of electronics and software that can benefit strongly by being immersed in a similar environment to our "spin-out" companies, at least at the early stages of their development. To date ECIT has created eight "spin-out" companies and has facilitated over 25 "spin-in" companies in a number of ways.

The conventional thinking is that research, development and innovation is a linear process where you engage in one aspect then the other and so on, moving through so-called "Technology Readiness Levels" i.e. TRLS. However, if one looks at places such as Silicon Valley then this is very often not the case. Rather it is more often likely to be the serendipitous interaction between entrepreneurs seeking new business/market opportunities, venture capitalists and technology innovators that help to create new products and services, often previously not envisioned. We have therefore created space within our Institute and through the Science Park to promote much stronger interaction between these types of people to strongly encourage and support the creation and growth of new high technology businesses in their very early stages. The term "incubation" is often used to describe this. However, what we are seeking to encourage precedes this – more a case of "germination" before "incubation". The environment actively seeks to help these early-stage businesses, that often tend to have relatively little funding, to overcome practical problems such as finding space and avoiding having to sign long term leases. In other words, it aims to de-risk some of the challenges faced by these fledgling companies and to give them a level of support to encourage their successful growth through these early stages.

Another important aspect and one we engage in on almost a daily basis, is to facilitate organisations such as InvestNI and UKTI in the successful attraction of Foreign Direct Investment (FDI). Thus ECIT has a constant stream of overseas visitors from major international companies seeking to assess the suitability of investing in the region. Being university based, another key role we fulfil is the training of young people with the education and skills needed to avail of the jobs opportunities that may ensue. This also resonates strongly with the findings of the Academy report, not least exposing our brightest people to a highly stimulating research environment where business awareness and entrepreneurship is also a core element.

Research and Innovation

Much is written about research and innovation. Again there seems to be a common misconception that one is a direct extension of the other, that these are related in a linear way and that increasing the funding of basic research will inevitably lead to more of the latter. This is not a view that we subscribe to at ECIT. Rather, whilst recognising that there is an important interrelationship, we also recognise that these are somewhat different activities requiring different levels of experience, skills sets, motivations and often people with different personality profiles. Thus we have created within an established university structure a novel "Open Innovation" environment that seeks to couple leading-edge research and innovation in a much more effective way, bridging the well-known "valley-of -death" that tends to impede the uptake of research for wider economic benefit.

An important aspect of this has been to seek to integrate the leading edge academic research environment with the type of infrastructure that is more common in a high-technology company, but in a manner that does not in any way compromise the international quality or speculative "blue-skies" thinking that can lead to exciting, new and disruptive opportunities. This has been achieved by the juxtaposing of engineering staff that, typically, have many years industrial experience, with academic researchers. These staff play very active roles in industry engagement. These roles are many and varied, but include the creation of new "proof-of-concept" prototype systems to demonstrate new product or business opportunities, to work on technology transfer programmes with companies large and small, nationally and internationally and, if appropriate, help to create new spin-out companies from the research base. Such staff speak the same language as that of businesses and can take on long-term or shorter term projects as these arise, being more agile in this regard when compared with typical multi-year year projects that tend to characterise the more traditional academic environment. They are also supported by a contract which is much more aligned with that used in high technology industry, rather than academia, with a well-defined career and promotion path.

This environment is supported by a Commercial Director and several Business Development Managers who continually seek new business opportunities for the research and new ideas being created, as well as seeking opportunities for new research funding from national and international sources (e.g. research councils, EU), and from industry.

A key aspect for a major research institute is to seek to be internationally leading. However, it is not possible to be such in all areas of technology and thus in establishing ECIT we set out to look for exciting and emerging technology markets that align well with our areas of research and expertise, seeking where appropriate to marry these. It is not our job to do or re-do what industry does well. Rather, what we seek to do is to work closely with our industrial partners, within the professional constraints of business confidentially, and derive five to ten year road-maps aimed at creating new disruptive technologies that potentially have widespread economic impact. All the time we have sought not to compromise the academic integrity or quality of our research. This is reflected in the many strong international linkages and collaborations that we have with major universities and research labs in the UK, Ireland, Europe, the US and SE Asia. It is also reflected in the many awards and medals received by and the prestigious fellowships held by our Academic and research staff.

"Mission-led" Approach

Traditionally university research starts by looking at often rather specific problems and then drills deeper and deeper, often over a period of many years. Our approach is to try and look at things from the other perspective i.e. trying to identify with our partners ambitious "mission-led" challenges that cannot be solved on their own by a few individuals, but rather require a strong team orientated approach. In this approach, a spectrum of research expertise and skills is brought together to address these challenges with our experienced engineering staff playing a vital role. This "Open Innovation" environment is designed to strongly promote the in-flow and out-flow of knowledge between our researchers and our industrial collaborators to strongly accelerate the innovation process.

Centre for Secure Information Technology - Membership Model

The original objectives of ECIT were significantly enhanced in 2009 through the creation at ECIT of the Centre for Secure Information Technology – CSIT. This is, with 80 people, is the UK's largest academic research centre in Cyber Security, with initial five year funding of £30M. CSIT is a UK "Innovation and Knowledge Centre" and is funded by the Engineering and Physical Sciences Research Council (EPSRC), the UK Technology Strategy Board (TSB), by InvestNI, by industry and by Queen's University Belfast.

CSIT has taken the ECIT experience to a new level through the creation of a US style membership model where companies pay an annual fee to join an industrial advisory board. This board works closely with the Centre in helping to shape and prioritise major research and innovation programmes. Current membership includes Cisco, IBM (Q1Labs), McAfee (Intel), Thales, BAE Systems, Qinetiq, Altera, Infosys and Roke Research. The membership board also includes important government organisations with major interests in this area.

Membership also provides early sight of our on-going research and allows companies and other organisations to use this for their own internal R&D purposes. This, in effect, provides a mechanism to "try before you buy" with full licence agreements being drawn up in cases where CSIT IP is scaled up and used in commercial products. This provides a mechanism to accelerate the uptake and exploitation of research results and is designed to short-circuit the tortuous IP negotiations that all too often characterise university-business technology transfer.

CSIT's overall activities are summarised in Figure 1. It has a number of "mission-led" themes. The first of these one is "Security in a Hyperconnected World". This is a very important and rapidly growing area which is a consequence of proliferation of devices connected via the Internet. The generation, storage and distribution of data by electronic means is now core to the way public and private sector organisations communicate internally and externally. This research is therefore studying threats to and vulnerabilities of systems and has led to the creation of new and advanced technologies for network monitoring and network forensics. This is creating new approaches to network and information security, information assurance and privacy. This includes technologies for securing wire-line, wireless and mobile networks, new authentication technologies and content protection.

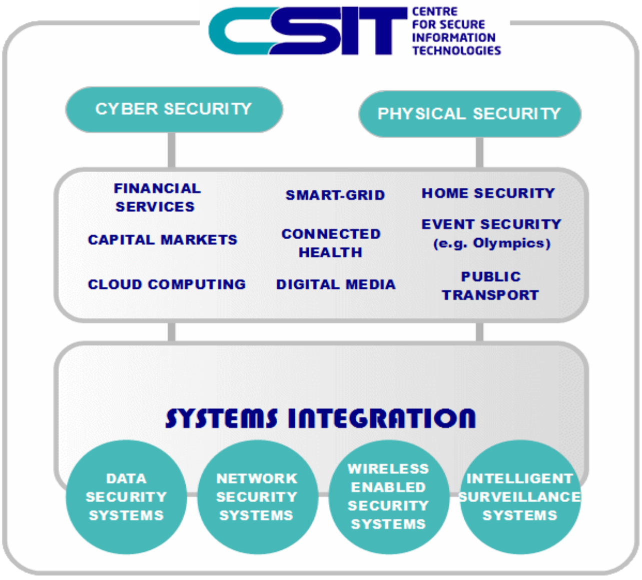

Figure 1 Centre for Secure Information Technologies – summary of its activities

Another inter-related theme is Financial Services. As the volume and value of online financial transactions continues to grow, the requirement to protect consumers and financial institutions from attack is also growing. Attackers are increasingly committing more and more resource in attempts to infiltrate systems through fraud and malware. There is therefore a strong industry need for innovative technology that will detect and prevent attacks from happening. CSIT therefore, in conjunction with financial institutions, is undertaking research and developing new solutions in a number of interrelated areas. These include Internet Traffic Analysis, financial malware, techniques and trends, methods for detecting fraud, information forensics and malware reverse engineering. This is aimed at the tracing of on-line fraud and scamming behaviour. Related research is involved with developing new low cost silicon circuits for implementing cryptography on RFID cards as a method for detecting and prevention of counterfeit goods and products. It is also developing new mobile trusted architectures and protocols. Research on Physical Unclonable Function (PUF) silicon circuits will provide future smart cards and credit cards with unique digital fingerprints which make stolen cards much more difficult to clone.

The availability of secure corridors for the rapid transit of people and goods is essential for modern economies. However the security of passengers and staff is a major issue. Whilst the last decade has seen unprecedented investment in CCTV technology the impact on anti-social and criminal behaviour has been relatively small reflecting the fact most of the data analysis is not being done in real time. This major programme is creating a new event-centric computing paradigm which records and processes events captured using a heterogeneous sensor network of CCTV hardware and other physical security devices. This is currently being applied to two related scenarios (a) public transport and (b) airport departure lounges. The overall aim is to ensure the increased safety of passengers and involves a number of closely interrelated activities being undertaken in close liaison with industrial partners that is leading to a range of new technologies. This includes systems for tracking people over a heterogeneous sensor networks, the use of a multi-level framework for event management and managing the convergence of information and physical security.

Other Examples

These are just some examples of the type of work we do that relates to Secure Information Technology. ECIT also engages in other important areas of technology that reflects the Institute's other research strengths. An important example is High Frequency Electronics research that has led to the creation of new "Frequency Selective Surfaces" for use in space-borne applications for remote earth sensing. The work is being undertaken in collaboration with the European Space Agency and Astrium, with a number of these devices now being readied to be flown in working meteorological satellites, allowing significant reductions in cost and size of relevant measurement instruments.

Related research has resulted in another new technology that our researchers refer to as "Flish" or flat satellite dishes. It is the result of work undertaken over a period of about 10 years by Professor Vince Fusco and his colleagues on novel self-steered satellite antenna. A conventional satellite requires a dish that has to be pointed in the direction of the satellite with which it is communicating – a good example being the Sky dish on houses. This technology offers many exciting opportunities in that it allows access to fast satellite broadband from anywhere in the world whilst also on the move. Therefore it not only has the potential to replace clumsy satellite dishes on the roofs of houses, it also potentially also allows wireless accessibility to communications from places not normally available, for example, in remote or desert areas where there little or no communication is available.

Another is the work undertaken by Dr Paul Miller and his team in collaboration with Andor Ltd. Andor is a very successful local company that manufactures high performance scientific digital cameras for academic, industrial and government applications. This joint research is aimed at creating new products in the area of confocal microscopy that, for example, are used in the tracking of telomeres in the cell nucleus to provide new insights into cancer therapies and anti-aging. ECIT's contributions have led to the creation of increasingly sophisticated software related tools for the image analysis needed in these new products. This is part of a joint £2M programme supported by InvestNI.

Technology Transfer and Commercialisation

ECIT, and through it CSIT, employs a spectrum of methods to engage closely with industry and effect the rapid translation of research and research expertise for wider economic benefit. These are summarised in Figure 2 and include conventional approaches such as joint R&D programmes, EU Framework programmes, sponsored PhDs and contract R&D. Considerable thought and consideration is given as to how intellectual property (IP) generated is best exploited. In the case of contract research or research undertaken through major joint national and international programmes this is normally done via the IP agreements established at the outset of these engagements including clear definitions of background (i.e. pre-existing) and foreground IP. This is done through the university's Knowledge Exploitation Unit.

Figure 2 Commercialisation and Technology transfer at ECIT and CSIT

Considerable thought is also given as to the best routes for the commercialisation of new and internally generated IP, the two main options being the licencing of this to an established company or companies or the creation of a spin-out company. Numerous other mechanisms also exist to promote the translation of research based expertise and know-how to industry. These include the very successful Knowledge Transfer partnership programme run by the UK Technology Strategy Board and the Fusion programme run by Inter-Trade Ireland where an employed graduate works partly in the company and partly at ECIT on programmes jointly designed to transfer "know-how" both ways, typically new technology and research based expertise one way and business and market knowledge the other. This also has the benefit of training bright young people in an environment that combines both aspects. Related activities include our Innovation Programmes and a vouchers-for-small business problem solving programme, funded by InvestNI. ECIT and CSIT also work closely with organisations such as UKTI and InvestNI in supporting their activities to help promote the UK/Northern Ireland as an attractive region of inward investment particularly for companies seeking skills and expertise in a spectrum of electronics, ICT and communications areas.

Another important aspect of this environment is its close relationship with the Northern Ireland Science Park's NISP CONNECT, an independent, non-profit organisation that fosters entrepreneurship and early stage company growth. This is supported and endorsed by San Diego's CONNECT and Global CONNECT organisations. CONNECT played a major role in dramatically changing the economy of that region following the loss of major contracts at the end of the "Cold War". It does this by accelerating the growth of promising technologies and early stage companies through numerous programmes. These include mentorship/coaching services (Springboard), educational seminars and events geared at developing and encouraging and supporting entrepreneurs and entrepreneurial ideas (Frameworks), as well as developing talent and leadership (Evening Series). CONNECT also promotes entrepreneurship in academia through the £25k Award.

This is modelled on MIT's $50K award, where potential academic spin-outs compete for an initial seed-corn prize and a package of support. ECIT is also actively involved in the NISP CONNECT "Halo" programme (UK Business Angel Network of the year in 2010). Halo links with Javelin Ventures' Halo Business Angel EIS Fund providing connections with Angel investors, who provide invaluable skills and experience. Another example of partnership is a monthly "brown-bag" lunchtime session where industry leaders regularly share 'best practice' in promoting commercialisation.

Summary

The Irish Academy of Engineering report highlights the important contribution that engineering research can make to economic development. This paper presents an overview of the approach that we have adopted at Queen's University Belfast's Institute of Electronics Communications and Information Technology - the research flagship of the Northern Ireland Science Park. In creating ECIT and major centres within ECIT such as CSIT, we have created what we believe is a fairly unique "Open Innovation" model where there is much stronger coupling of academic and industrial research than is the norm, at least within the UK and Ireland. In doing so, we continually seek to develop a much stronger understanding of the longer term and broader context of our research and equally try to persuade senior people from industry to learn of our successes and breakthroughs at a much earlier stage than is usual. In doing so, we have worked hard to ensure that we do not compromise the quality or integrity of our research or compromise our ability to create disruptive and breakthrough ideas - the type that can lead to new and unforeseen economic opportunities.

We also very strongly recognise the major benefits of creating environments where business, industry and speculative research are all brought much more closely together to promote a strong and rapid in-flow and out-flow of ideas, to strongly accelerate the creation of new applications and new market opportunities - the sort of thing one observes in places like Silicon Valley in California.

In effect, we are challenging the standard ways that advanced technology research is undertaken, and asking whether traditional models of university research and indeed research funding are as efficient as they might be in coupling research and innovation. We believe that we need to be more creative in our thinking and look at research challenges from a much more holistic perspective, in terms of the problems we are trying to solve, including wider economic potential, social implications and so on. The ECIT environment recognises that a multidisiplinary and team based approach is needed to deliver pre-commercial innovation and as such ECIT employs leading research academics, industry experienced engineers and a commercial team focused on building links with industry and ensuring technology developments are industry informed and/or industry inspired. In contrast, the traditional academic environment tends to emphasise and measure individual contributions rather than arguably much more ambitious and team orientented achievements. It could therefore be argued that not only have we to be innovative in the research we do, we have to be innovative in the way we do research. Thus one has to query whether standard practices in our universities currently recognise, reward or indeed provide appropriate funding streams to meet these wider research and innovation challenges.

In this regard, many important issues come to the fore. The first group of these are clearly identified in the Irish Academy of Engineering's report. The second are the mechanisms and support to make this happen. It is easy to say much more needs to be done to create and develop research, particularly university engineering research, so that it has wider economic impact. Indeed this is something that is regularly highlighted at government level. However, whilst it is important to recognise and highlight these issues it is another to take the practical steps to actively make this happen.

Clearly, a critical mass of research activity in carefully selected areas is essential in order to compete strongly at an international level and that is of major importance to any modern nation. However, this in itself is not sufficient. Rather, as I believe our experiences to date with ECIT and its wider role in economic development demonstrates, this must be overlaid with an exciting entrepreneurial eco-system that strongly promotes and facilitates this, whilst all the time strongly supporting and encouraging speculative “blue skies” research of the highest calibre.

Lecture 4

Prof. Dr. Henning Kagermann

President of the German National Academy of Science and Engineering (acatech)

How the German National Academy of Science and Engineering contributes to Sustainable Growth through Research and Innovation

May 14th, 2012

Professor Henning Kagermann

Since 2009, Henning Kagermann has been co-sharing presidency of acatech –the German National Academy of Science and Engineering; drawing upon 30 years of wide academic and industrial experience.

He is member of the senates of Max-Planck-Gesellschaft and Fraunhofer-Gesellschaft and is an honorary senator of the Foundation Lindau Nobel Laureate Meetings at Lake Constance.

Professor Kagermann holds several national and international chairman positions including:

- EIT ICT Labs, i.e. European Institute of Innovation & Technology, the Knowledge and Innovation Community (KIC) for Information and Communication Technologies (ICT),
- since 2010 he has been chairman of the "Innovation Dialogue" between government, industry and science in Germany - a dialogue board for advising the Federal Government on research and innovation policy
- for the National Platform for Electromobility - a partnership between car makers, industry providers, technical organizations and research associations in Germany aiming to promote electric mobility in Germany.

Professor Kagermann received his diploma in Experimental Physics from the Ludwig-Maximilians-University Munich, Germany. He holds a doctorate and postdoctorate degree in Theoretical Physics from the Technische Universität Braunschweig, and was promoted to professor in 1985. He taught physics and computer science at TU Braunschweig and University of Mannheim, Germany between 1980-1992. Furthermore, Professor Kagermann received an honorary doctorate from the University of Magdeburg, Germany.

Between 1998 and 2009 Henning Kagermann was chairman of the Executive Board and Chief Executive Officer of SAP AG. Together with Hasso Plattner, co-founder of SAP, he was co-chairman of the SAP Executive Board and CEO From 1998 to 2003.

Currently Professor Kagermann is a member of the supervisory boards of BMW AG, Deutsche Bank AG, Deutsche Post AG, Munich RE, Nokia Corporation and Wipro Technologies.

How the German National Academy of Science and Engineering contributes to Sustainable Growth through Research and Innovation

Henning Kagermann

Abstract

acatech – the GERMAN NATIONAL ACADEMY OF SCIENCE AND ENGINEERING - represents the interests of the German scientific and technological communities, being the voice for science and engineering at national and international level. acatech aims to promote sustainable growth through research and innovation. Therefore by being a working academy, acatech supports policy-makers and society by providing qualified technical evaluations and forward-looking recommendations on future technology issues. acatech provides a strong and vital platform for exchanging excellence between science and business, and encourages the next generation of young scientists and engineers. The lecture will give you deep insights in our academy´s daily work. Current projects are exemplified: The "Innovation Dialogue" between the German Federal Government, business and science, initiated by Chancellor Angela Merkel; Germany´s "National Platform for Electromobility", a network with members from all societal parties; and the alignment of national ICT innovation programs with EIT ICT Labs, the knowledge and innovation community of the European Institute of Innovation and Technology (EIT).

Overview

Let me start by saying I am very glad that John (Prof John Kelly) sent me the paper from the Irish Academy on 'Engineering Research in Irish Economic Development'. I liked this paper a lot because in a nutshell, what it says is to strengthen the innovation system here in Ireland and make a greater contribution to the economy. If I substitute Irish with German it is more or less what I would say what we are doing in **acatech** so therefore John we are very much aligned.

If you look back to the date acatech was founded (2002) you'll find that it is a very young academy compared to other countries (e.g. the Swedish academy is approximately 100 years old). Germany was very late in realising that engineering is different from science. This is something I in particular took from IAE's Engineering Research in Irish Economic Development paper because I strongly believe that science is about discovering and gaining knowledge, and about understanding. Engineering is different; we solve problems, we are about innovation, we want to shape the world, not just to understand the world; that is the big difference. If you are thinking about innovation then you must bear in mind, that it is not just about good ideas and good products; it is also about commercialisation, going to the market, financing innovation, managing the expectations of clients and investors etc. At acatech, along with our academic members, we also have a senate with CEO's from about 70 German companies and also from foreign companies (e.g. Intel, Google, IBM).

I want to give a brief introduction of how Germany advanced its national innovation system. In 2006, shortly after she was elected as Chancellor, Angela Merkel set up an 'Advisory group for innovation and growth'. This new government launched quite a lot of new strategies, many of which were successful and still exist today. It started with the High Tech Strategy (HTS) and then the question was how to execute those strategies, because "vision without execution is hallucination" (Edison). The Advisory group discussed the HTS and proposed setting up the Industry Science Research Alliance, a body of scientists and industrialists whose aim was to execute some of the ideas. Later the cluster program was launched at the IT Summit. In 2008, two academies were made national academies, acatech and Leopoldina, and acatech was asked to develop a new format which could substitute the advisory group. In 2010 we started the Innovation Dialogue with Chancellor Merkel which is organised by acatech.

At the end of my presentation I will talk about the EIT because it is one of the programs to coordinate innovation in Europe. Those initiatives are important because we are doing too many things in parallel. Last but not least I want to mention something which is unique in Germany and it might be a new instrument for innovation, it is called the National Platform for Electric Vehicles.

The High-Tech Strategy (HTS)

The High-Tech Strategy is the cornerstone of Germany´s innovation policy. Germany is pretty good at what is called mid-tech but not as strong in high tech e.g. biotechnology and ICT. The idea behind the High-Tech Strategy was to get stronger in these areas.

The aims of the HTS were to set new priorities and create lead markets, build bridges between industry and science and an improve framework for innovation in industry as shown in Figure 1.

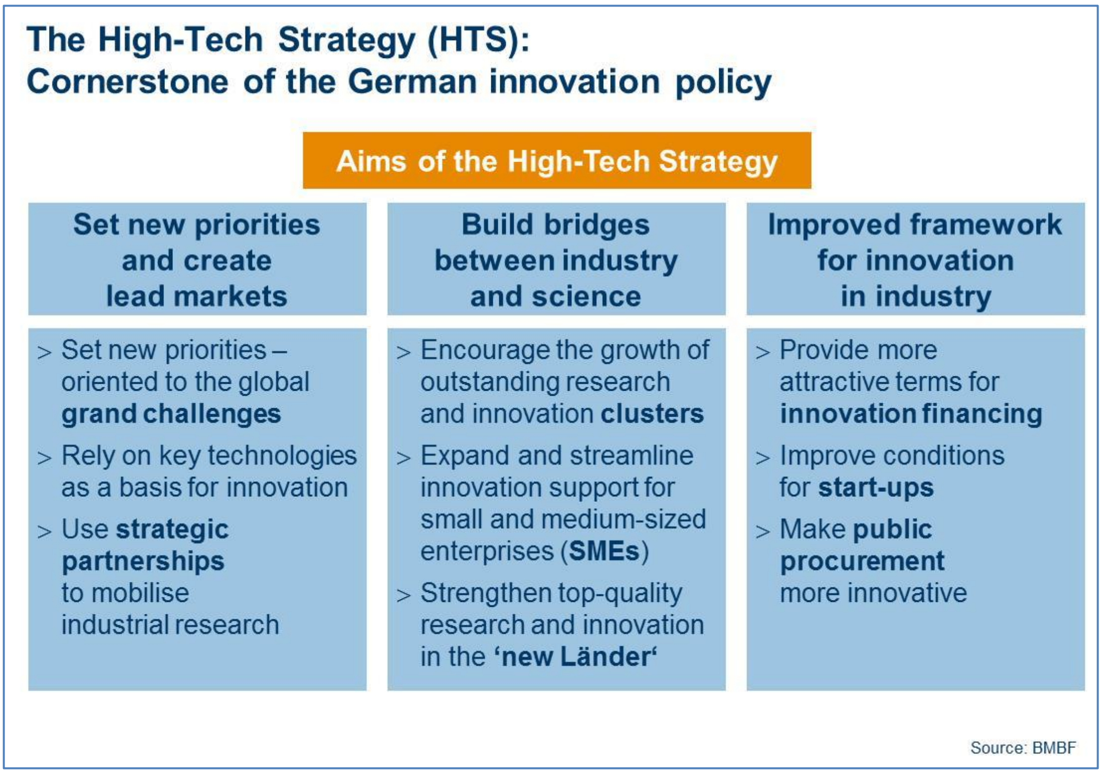

Figure 1: The High Tech Strategy

We orientated priorities to the global grand challenges and used strategic partnerships to mobilise industrial research. Recently we also created an *industry research campus* which is based on disruptive innovation. It is based on a private public partnership, with at least one business and one university and it must be located on campus. The financial support donated is not too much (1-2 million euro per year) but for a period of about 15 years. Roughly 100 hundred consortia applied for the funding.

The second aim was to build bridges and this obviously meant developing a cluster strategy,which I will come back to later. We have a good programme that supports cluster excellence and we believe this programme can serve as a best practise model for other European countries. SME's are the backbone of the German economic strengths and we always take care that they are appropriately represented in programmes supported by the government. They are usually more innovative and flexible, but we need the market access and scaling-ability of the big companies. Last but not least, the idea was to strengthen the new Länder. Frankly speaking that was not too successful because excellence is always the first criterium, when we select between competing consortia.

Improving the framework for innovation in industry is very much about financing and this is still a big topic because our tax system is not very innovation friendly. Germany is not very attractive for venture capitalists and to found a new company is more difficult than for example in the US and there are many other hurdles for entrepreneurs.

The idea of an Industry Science Research Alliance was to execute on the HTS with a focus on the five areas outlined in Figure 2. For the first 4 years, this body more or less carried out analytical research and produced recommendations. In the second round we were told to focus more on implementation and to identify a few so-called forward-looking projects that the government would support with significant funding. In the meantime, an official paper was published in which the government explained in detail the selected 10 projects below (Figure 2) and how much money they intend to allocate.

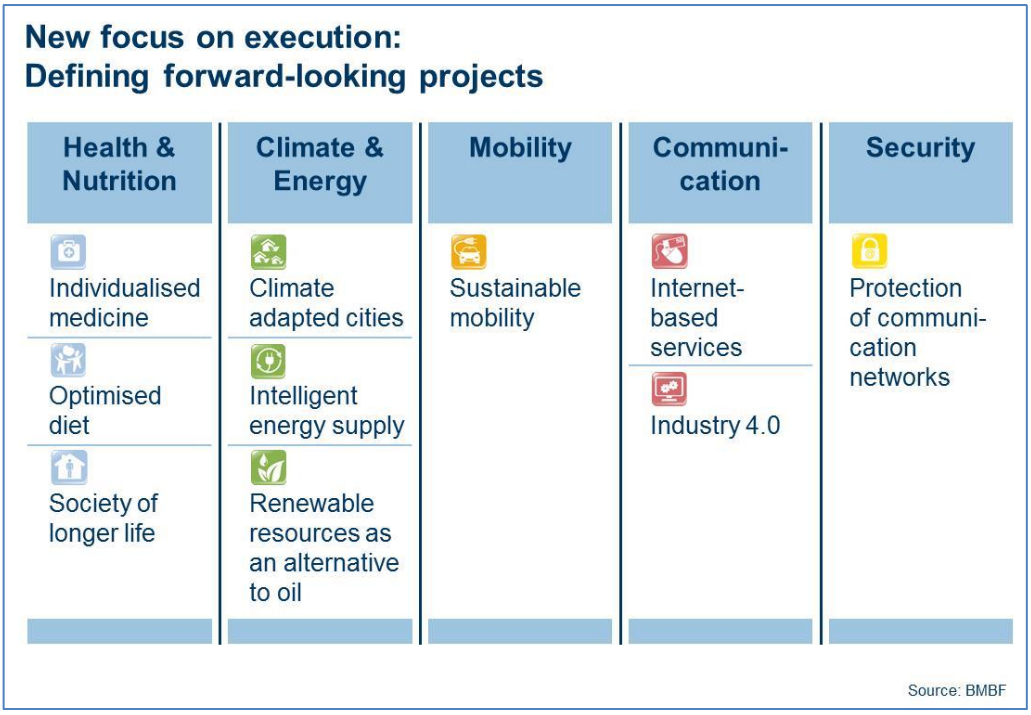

Figure 2: Industry Science Research Alliance

Each of the five areas was promoted by a few experts. I was nominated chairman of the group "communication" and we selected a topic where Germany has a lead: The manufacturing industry, embedded systems and automation engineering. We are convinced that the introduction of the "Internet of Things and Services" into the manufacturing environment is ushering in a next industrial revolution. In the future, businesses will establish global networks that incorporate their machinery, warehousing systems and production facilities in the shape of Cyber-Physical Systems. Smart factories allow a completely new approach to production; smart products know how to be manufactured and the role of employees will change significantly. As explained: In smart factories, humans, machines and resources communicate with each other as naturally as in a social network.

National German Cluster Strategy: Leading-Edge Cluster Competition

The National German Cluster Strategy was launched 2007 and runs every second year. Its aim is to take Germany to the top of the league of technologically advanced nations. Clusters are formed by business and science that enter into strategic partnerships. The total public funding is about €600 million (2007-2017) and decisions are made by an independent jury.

An example of one of these clusters is the Leading-Edge Cluster Forum on "Organic Electronics" which was the first SAP joined. The cluster consisted of three of the top 30 companies in Germany, eight international, a lot of mid-size, research institutes, a shared innovation lab and joint cluster management. This worked well especially for the small and mid-sized entities and universities to have access to a lab which they otherwise couldn´t afford. Every cluster is similar to this and has between 30 and 200 member organisations. It is not so much about breakthrough innovations but the cluster has to be established already and the question is always whether the donation of public money is necessary for developing the cluster into the top league globally.

German National IT-Summit

The National IT-Summit was established in 2006 to bundle all ICT-forces in Germany. Back then in my position of CEO of SAP I spoke to our Chancellor and it was decided that we had to improve our competencies in ICT. At that time, Germany was ranked number 16 globally and the advisory group for innovation and growth came up with the idea of an annual IT summit to bundle forces and increase public awareness. By 2011, Germanys ranking had improved to number eight. It is this strong involvement of the government that helps our industry a lot, in particular Chancellor Angela Merkel who always gives a key note speech. The preparation is done in six working groups; nearly all of them are headed by one Minister and one CEO of an ICT- company.

acatech, Germany´s national academy of engineering and science

acatech is not an academy of engineering like many others. It is independent, self-determined and supported by the Federal Government and all our 16 States. The institutional funding, however, only provides one third of our budget. So we have to look for two thirds of our budget ourselves through projects and donations from businesses. Our network has close to 400 members and we have nearly 100 senators, 70 from business (CEO´s and board members responsible for research and development) as well as representatives from civil society e.g. leaders of unions, key economic advisors, presidents of the major research institutions. Our mission is “sustainable growth through innovation”; our ambition is not to publish papers but to drive change.

The objective of acatech is to provide knowledge, guidance and support through:

- Scientific recommendations: acatech advises policy makers and the public on future technology issues
- Knowledge transfer: acatech offers a platform for exchange fostering cooperation between science and businesses
- Promotion of young scientists and engineers: acatech is committed to support young scientists and engineers
- Voice of science and engineering: acatech represents the interests of science and engineering on a national and international level

The topic networks covered by acatech are pretty broad; more or less everything in engineering is covered. However our three overall topics are **Energy Resources and Sustainability**, **Education and Communication** and **Key Technologies**. Our goal, as for any national academy, is to create value and employment. In order to give you a feel of how we work, I have selected one example from each of these areas.

Energy Resources and Sustainability

An integrated research programme on energy was published in 2009. A key recommendation was to keep all options open as we do not know what is down the road in 10-20 years’ time. Therefore we presented three scenarios, the nuclear, fossil and renewable one, and classified efficiency, storage etc as so called ‘no regret-activities’, which should be executed under any scenario.

These recommendations are still valid but last year (2011) Germany opted for the famous Energiewende (*energy turnaround)* with a strong focus on renewable energies and an accelerated withdrawal from nuclear energy supply. The academy published a paper on `Future energy grids` and some recommendations stated that if we go out of nuclear power it doesn't mean that we also stop research in nuclear science Now all academies are collaborating on a proposal on how we can manage this turnaround and how a future energy system should look like for the next 50 years.

Education and Communication

Education is another focus area for acatech. At the end of 2011, there was a shortage of skilled workers in Germany with 167,000 vacancies particularly in the fields of mathematics, computer science, natural and engineering sciences (Source: Institute for Economic Research 2011).

In 2009, acactech got involved in this area. We were concerned that companies were acting in the same way as they did 10 or 15 years ago when they would stop hiring, in particular engineers, which in turn had sent a message to young people that it is better to study economics than engineering. This was one reason why we see the current shortage of skilled and trained people.

During the current economic crisis the government implemented a policy of shorter working time for labour which resulted in over capacity in manpower, which we used for up-skilling. This is one of the success factors that meant Germany came out of the crisis better than most countries.

acatech recommended a holistic approach for the entire "education chain" starting at kindergarten. If you really want to encourage children to study engineering then you must target them between the ages of 6 and 14. That is the time, when they make up their minds. We also discovered that there are lots of initiatives to promote engineering and acatech recommended a more aligned and coordinated approach.

Key Technologies

For this topic, I picked the internet as an example which is the most important invention of mankind in these decades. Subjects and objects are connected in an unprecedented way. The internet is the mission-critical infrastructure of all infrastructures and it will have an impact on society more than anything else.

A key point is not only internet security but also privacy, particularly in our country. Therefore, we have launched a large project on internet privacy with a working combination which is pretty unique; we have professors from social sciences, ethical, legal science, economics, informatics and we also have some companies contributing to the project such as Google, Deutsche Post, Nokia and IBM. A powerful combination that, in the meantime, has published a set of recommendations, supported by all participants.

We have many distinguished members in our academy but no representatives of the young generation , in particular not the digital natives .To get their input we organised a contest with the title "Forgetting in the internet" together with the ministry of interior. Some of the questions asked were: how to create more awareness on issues like cyber mobbing, how to establish new rules of appropriate behaviour in the internet etc. The amazing result was that most of the awards were given to applicants between 12 and 16 years.

EIT ICT Labs

EIT ICT labs is put together in a European network of co-location centres (clusters) in six countries established to foster excellence in ICT. The local co-location centres are clusters with core members from science and business. From my experience as chairman it is an additional level of complexity and takes more time to get operational than originally anticipated. Our mission is: From idea to product, from lab to market and from student to entrepreneur. Our focus is to integrate the knowledge triangle of education, research and business. Deliveries are supporting modules for the Innovation Pipeline: Explore, mature, experiment and deploy, for example business modelling, access to finance, opportunity scouting, strategic coaching, master and doctoral schools.

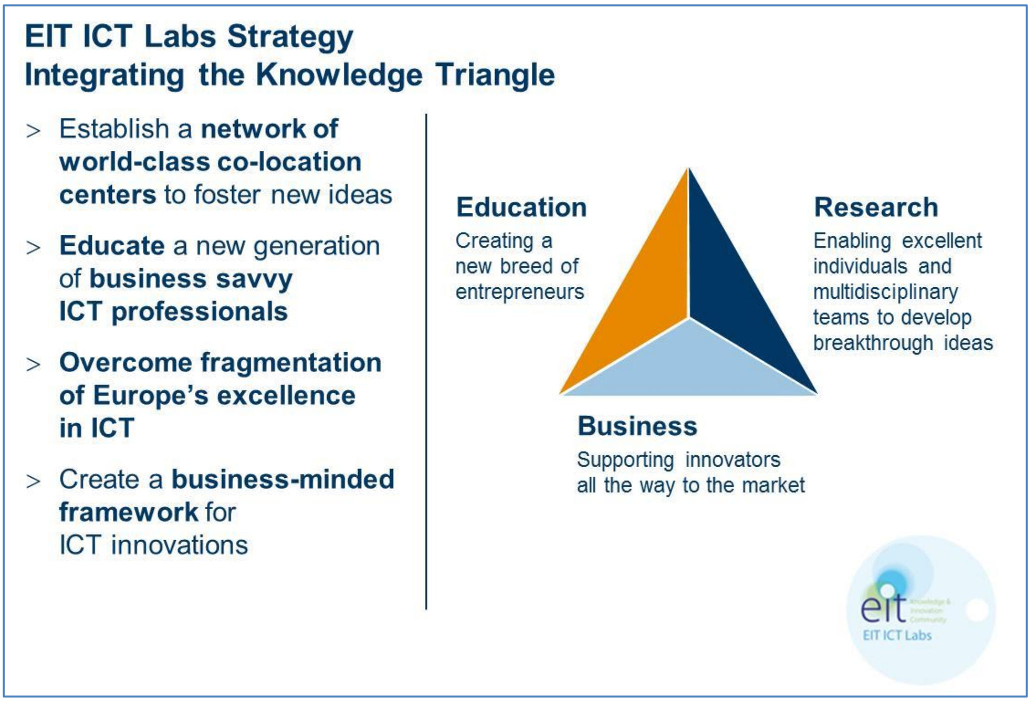

Figure 3: EIT ICT Labs Strategy

Cooperation of the German Academies of Sciences

Another challenge in Germany is how to incorporate the different academies as we have now three, representing science, engineering, and humanities. We have a standing committee which meets four times a year to ensure we are not working on the same subjects. I have to say that it was not easy but it is working very well now, which is very important because we have more impact speaking with one voice.

The Innovation Dialogue

The Innovation Dialogue steering committee consists of 15 members from business, science and society. Two Innovation Dialogues take place per year and in preparation for these acatech compiles thematic dossiers. The dialogue is based on facts, everybody has agreed upfront on the paper so we have the same facts but the opinions expressed during the dialogue are frank, open and sometimes provocative. Topics covered in recent Innovation Dialogues are given in Figure 4.

Topics of the Innovation Dialogues at a glance

Topic of Dialogue	Date
International benchmark innovation systems	13/09/2010
Financing innovative business start-ups **Cluster landscape analysis**	07/04/2011
Technology fields with great potential for added value and employment in Germany	27/02/2012
The international dimension of technology and science policy – using the example of Asia	22/10/2012

Figure 4: Topics of the Innovation Dialogue

A new innovation instrument: The National Platform for Electric Mobility (NPE)

As we move to more renewables and because there is direction from the EU that our CO_2 emissions have to be reduced significantly by 2020, in particular the German car industry has some challenges to meet these requirements. It is not so much an issue for Ireland but it is very important for Germany because the automotive industry is a key pillar of our economy. So it was obvious that we had to do something and we articulated our ambition to become a leading supplier and a leading market for electric vehicles by 2020.

To achieve that we brought together all our forces: about 150 representatives from the entire society (six industries, science, politics, unions, NGOs etc.). This group was not easy to manage and we approached it in a typical German way, very systemic. Our approach is also technology open and market oriented, that means we strive for a self-supporting market by 2020. The steering board is dominated by politics and business. It has 3 chairs; one from industry, that is me and the secretaries of state of two ministries. The work is done in seven groups each with about 20 representatives from various companies, science and other societal groups. We developed a complete program from education, R&D to instruments for market stimulation, supported by all participants. Progress is monitored and reported every year. In about hundred consortia multinationals from different industries and SME´s co-innovate with universities and research institutions.

Conclusion

To conclude; to drive innovation these days, networking is key as well as collaboration between science, business, politics and the civil society. That is also our approach at acatech. If we want to cope with the grand challenges and economic crises like the recent, we need substantial innovation. The world is more volatile and resilience is becoming a more important topic for companies and countries too. Many of the challenges like resource and energy efficiency are global and cannot be solved by one nation. That is why international cooperation and leveraging global knowledge resources is becoming more and more important. Others, for example the long-term transition to electric vehicles are too big to be managed by one company only; co-innovation amongst businesses that never worked together before must be initiated. Defining an appropriate level of privacy without limiting the enormous benefit of the internet requires not only the debate between all societal groups, but also a joint afford of scientific disciplines that haven´t talked much to each other. And finally, we have to experiment with new instruments and innovate innovation.

I strongly believe that academies can play a key role here. We are independent and self-determined. Our recommendations are fact-based and present alternative scenarios for decision makers. We can be trusted advisors for the society, but we have to earn the right for it. Therefore, it is all about the quality of our work, the quality of our communication and the impact of our recommendations.

Please note the above paper is a transcript of the lecture given by Professor Henning Kagermann

Engineering Research & Irish Economic Development