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Future challenges for nuclear energy in Europe

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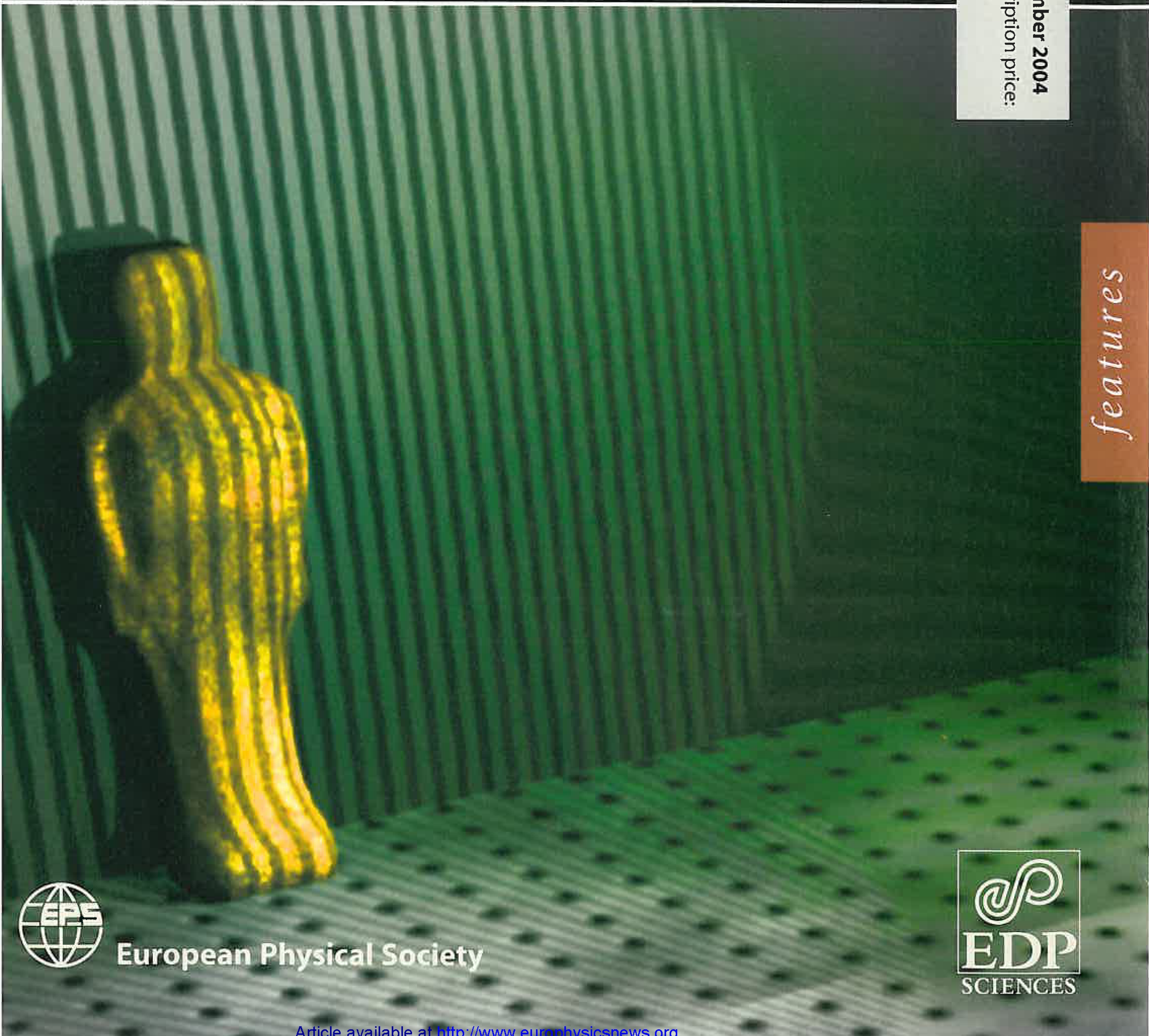

European Physical Society

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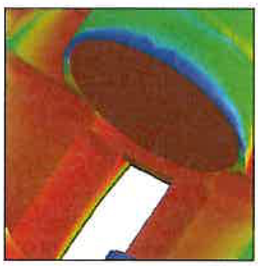
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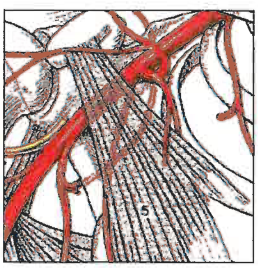
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Editor .... **David Lee** EMAIL: d.lee@uha.fr

Science Editor .... **George Morrison** EMAIL: g.c.morrison@bham.ac.uk

Designer .... **Paul Stearn** EMAIL: p.stearn@uha.fr

Directeur de la publication .... **Jean-Marc Quilbé,** EDP Sciences

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Production and Advertising

Agnes Henri

Address EDP Sciences,
17 avenue du Hoggar, BP 112,
PA de Courtabœuf,
F-91944 Les Ulis Cedex A, France
Tel +33 169 18 75 75
Fax +33 169 28 84 91

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EPS Executive Committee

EPS Secretariat

Address EPS, 6 rue des Frères Lumière,
BP 2136, F-68060 Mulhouse Cedex, France
Tel +33 389 32 94 40 **Fax** +33 389 32 94 49
Web www.eps.org

The Secretariat is open 08.00–17.00 CET except weekends and French public holidays.

EDP Sciences

Managing Director Jean-Marc Quilbé

Address EDP Sciences, 17 avenue du Hoggar, BP 112, PA de Courtabœuf, F-91944 Les Ulis Cedex A, France
Tel +33 169 18 75 75 **Fax** +33 169 28 84 91
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From physics to the marketplace: Special issue overview

François Bourgeois,
Special issue editor, chairman EPS Technology Group

Basic Science does not usually have immediate benefits for industry or the economic world in general, and delays in visible return are often difficult to reconcile with the short-term expectations of market driven activities.

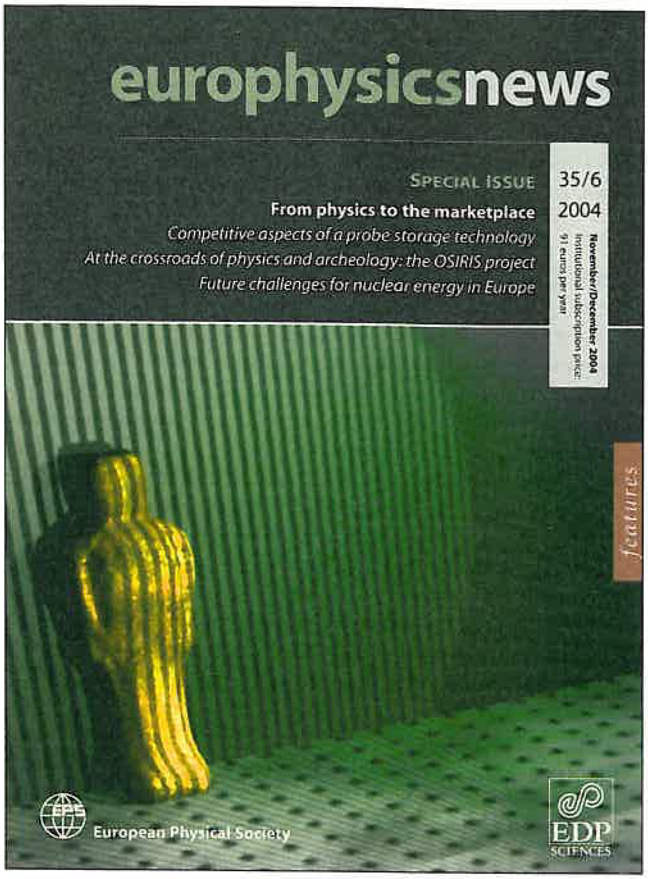
Times have changed and there is nowadays a justified need for a closer connection and an improved exchange of knowledge between academia and industry. Society at large also supports the view that basic science findings should be put to use where appropriate and without delay. During the last twenty years the jobs that have been generated by new ventures have injected extra liquidity into the labour market. Since the early 1970s, academic institutes and their Technology Transfer structure schemes (Technology Exploitation Office, Incubator, Science and Technology Park, etc.) have been supporting young entrepreneurs. If this is very much the case for biomedical and pharmaceutical research, physicists have shown some reluctance to foster a widespread entrepreneurial attitude throughout their community. The reasons are twofold:

1. The linear model of transfer from basic science to technology very seldom applies for physics;

2. Physicists still see the patent system as impairing the free exchange of knowledge they have enjoyed ever since universities were created.

Technology bridges the gap between academia and industry and it is often intimately mixed with basic science and education. Technologists have in general a better literacy in Intellectual Property Rights (IPR) for they are more exposed to the free market economy. In addition, the patent system nowadays is less regarded by scientists as a tool to disclose trivial inventions such as "better mouse traps" or new types of barbed wire, and market prone developments are no longer readily published without analysing their market potential. It is better accepted that a "patent or perish culture" does not necessarily affect the open and free exchange of information in basic science. The proof of this can be found in the USA, where universities have long practiced proactive IPR policies without impairing communication with other academic and R&D institutes in the world.

...the patent system nowadays is less regarded by scientists as a tool to disclose trivial inventions...



With this special issue of EPN, the European Physical Society aims to trigger more reports on the application of physics related technologies in the market. The contributions appearing in this issue have been selected to give an overview of technology transfer methods and processes in physics. If the first contribution shows how, 150 years ago, Lord Kelvin fruitfully bridged the needs of science and industry, all other papers present recent cases and are practical examples of the formal presentation appearing on the Technology Group web site http://www.eps.org/divisions/techgroup.html. The paper on the application of biomechanics to the design of a new mouse, somewhat remote from us, was chosen on purpose to illustrate an example of a "spill-over" process.

It remains that competition in the search for private sources of funding can significantly divert the scientific community from its basic mission. I am convinced that basic science should not be market-driven and that scientific policy makers should fund it adequately. This dilemma is clearly implied by the last paper in this issue that discusses the problems society, science and industry will face with energy production in the coming decades.

To conclude, I would like to hope that this issue will contribute at its level to the shortening of the time elapsed from the moment when a relevant research result is found and established, until it is actually applied in the marketplace. To this end, industry should be better informed of the latest achievements in physics, and of those instruments and procedures that are likely to find an application in the development of products for the marketplace.

Lord Cable

Bruce J. Hunt,
Associate Professor, Department of History, University of Texas at Austin, USA

Sir William Thomson (1824 – 1907), better known to later generations as Lord Kelvin, was the quintessential Victorian physicist. Today most of us would probably place him a little below his younger and shorter-lived contemporary James Clerk Maxwell (1831 – 1879), but in his own day, Thomson was invariably ranked at the top. Appointed Professor of Natural Philosophy at the University of Glasgow at age 22, he made fundamental contributions in many areas of physics: with Rudolf Clausius, he was the first to state the Second Law of Thermodynamics; he originated the absolute temperature scale, now known as the Kelvin scale; he did pioneering work in electrical theory; and he devised important instruments for precision electrical measurement. He was also active on the technological side, particularly in submarine telegraphy. In 1867 he was knighted for his work on the first Atlantic cables, and by the 1870s he was earning a large income as a consultant to cable companies and through his patents on telegraphic instruments – enough to buy a yacht and build a large country house. In fame and fortune, and in the personal satisfaction that comes from doing important and interesting work, physics paid off handsomely for Thomson.

In January 1892, Thomson was raised to the peerage and, as a newly minted baron, had to pick a new name for himself, since "Lord Thomson" was already taken. He soon settled on "Kelvin," after a small river that ran near his Glasgow laboratory, but only after friends had half-jokingly suggested that he call himself "Lord Cable." It would have been an apt choice, reflecting not only the chief source of his wealth and fame, but also the inspiration for some of his best scientific work. We might find it odd now to think of quoting absolute temperatures on the "Cable" scale, but if Thomson had chosen that name, it would continually remind us just how closely science and technology were intertwined in his career.

The first successful submarine cable was laid across the English Channel in 1851. Most early cables consisted of one or more copper wires insulated with a few millimeters of gutta percha, a rubber-like tree gum from Malaya, and protected by an outer layer of iron wires. In the early 1850s telegraphers noticed that sharply defined signals sent into one end of such a cable emerged at the other slightly delayed and greatly distorted, so that signals sent in rapid succession blurred together and became unreadable. Michael Faraday looked into such "retardation" phenomena in 1853 and soon identified capacitance as the source of the problem. When a telegraph key is pressed and the wire is connected to the battery, he said, a steady current cannot flow until the wire first acquires its full electrostatic charge. Since most land lines were simply bare wires strung from poles, they could store so little charge that the whole process occurred almost instantaneously, producing little or no retardation. Submarine cables, by contrast, were practically long tubular capacitors; they could store enormous amounts of charge, and the resulting retardation severely limited signalling rates along them. Reducing retardation became the great goal of cable telegraphers.

Thomson took up the problem in 1854, analyzing it using equations drawn from Fourier's theory of heat flow. He showed that when resistance and capacitance dominate, as they generally do, electrical signals diffuse along a cable much like pulses of heat passing down an iron rod – though of course far more quickly. The time lag before the current at the far end rises to a detectable level is proportional to both the total resistance and total capacitance of the cable, and so to the square of its length. Retardation on a really long cable could thus become very bad indeed.

This was bad news for the ambitious promoters of a cable across the Atlantic. A telegraphic link between London and New York (via Ireland and Newfoundland) held the promise of enormous profits, but if Thomson was right, retardation would evidently prevent such a long cable from being able to carry enough traffic to pay for itself. At this point Wildman Whitehouse, an English surgeon turned electrical experimenter, announced that his tests on cables contradicted Thomson's "law of squares"; the law was "a fiction of the schools," Whitehouse declared, and retardation posed no real obstacle to the success of an Atlantic cable. The delighted promoters of the Atlantic Telegraph Company made Whitehouse their official "electrician" in October 1856 and put him in charge of all electrical arrangements for the planned cable. Thomson stood by his theory, and Whitehouse eventually conceded its validity "as theory," while Thomson agreed that with proper handling, it might be possible to reduce the effects of retardation enough to make an Atlantic cable a paying proposition.

At the end of 1856, Glasgow investors elected Thomson to the board of directors of the Atlantic Telegraph Company, and he threw himself into the cable project. While Whitehouse was being paid enormous sums for his own patented signalling instruments, Thomson worked privately to devise the mirror galvanometer, an exquisitely sensitive instrument that used a wieghtless beam of reflected light as its "pointer," enabling it to respond to even very weak currents. Thomson's little instrument would be used in cable testing rooms and electrical laboratories for decades to come.

When ill health kept Whitehouse from sailing with the cable-laying expeditions, Thomson volunteered to take his place, supervising shipboard electrical arrangements on the abortive first attempt in August 1857, when the cable snapped after only a few hundred miles had been laid, and on the repeated attempts in 1858, culminating in the successful completion of the cable from Ireland to Newfoundland on August 5.

The first Atlantic cable was greeted as the wonder of the age; one celebration in New York became so spirited that City Hall caught fire and nearly burned down. Unfortunately, the cable had been hurriedly made and roughly handled; moreover, when the Irish end was handed over to Whitehouse, he set aside Thomson's mirror galvanometer and subjected the cable to jolts of current from his own equipment – including an induction coil five feet long – that further damaged its already fragile insulation. Exasperated by Whitehouse's inability to send or receive readable signals, the company removed him in mid-August and put Thomson in charge. Using battery currents and his mirror galvanometer, Thomson managed to send and receive a significant number of messages, but the damage had already been done, and within a few weeks, the cable was dead.

The first Atlantic cable was a spectacular failure whose collapse tainted the reputation of ocean telegraphy as a whole. While Whitehouse was saddled with much of the blame, Thomson drew almost universal praise, with the implication that if his scientific advice had been followed more closely, the cable might have succeeded. An official inquiry in 1861 nearly said as much, and as the Atlantic Telegraph Company regrouped to try again, it pledged to build its new cable to scientific specifications. In the meantime, Thomson pushed for adoption of measures to ensure that such specifications could be followed and enforced. It was largely at his urging that the British Association for the Advancement of Science formed its Committee on Electrical Units in 1861, and he played a leading role as the committee proceeded to produce essentially the system of ohms, amps, and volts still used today.

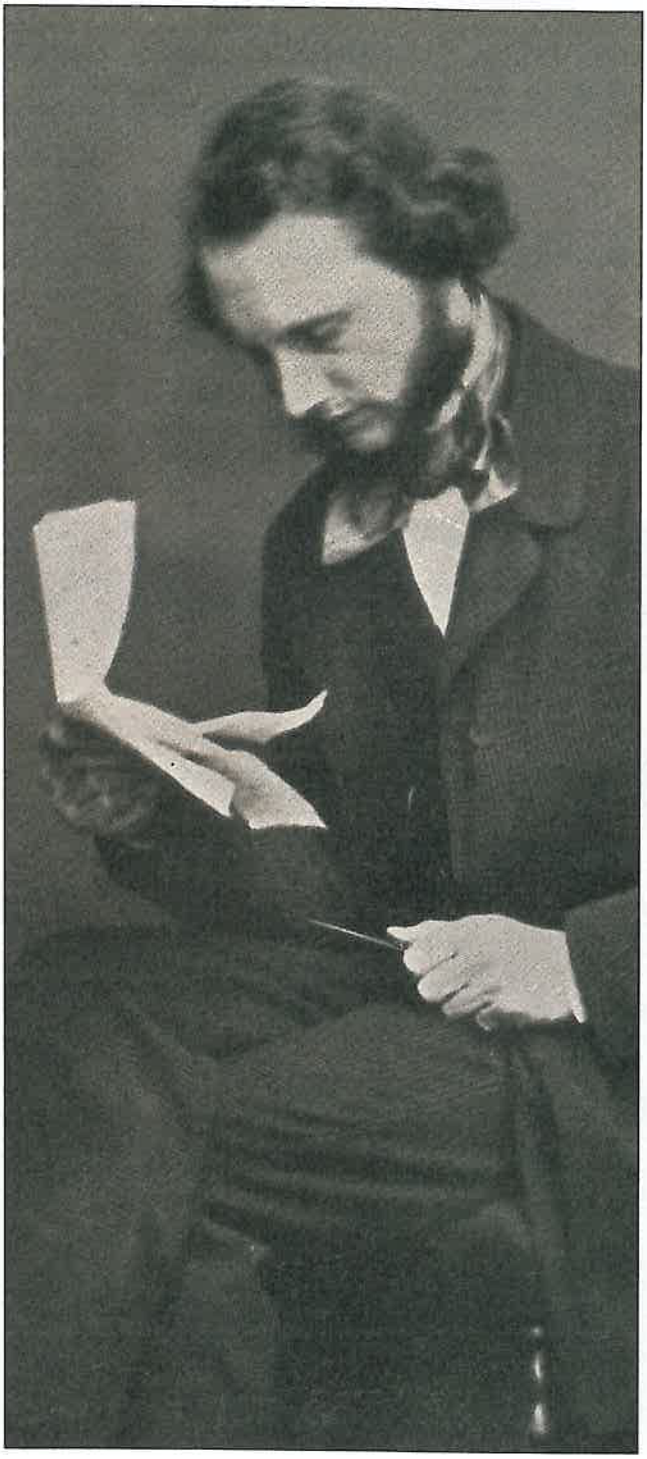
By 1865 the Atlantic Telegraph Company was ready to try again, using a new and thicker cable. Thomson again sailed with the expedition, this time on the *Great Eastern*, but two-thirds of the way across, the cable snapped and sank. Undaunted, the backers raised more money, ordered another cable, and set out yet again the next year. This time everything went smoothly and the cable was landed at Heart's Content, Newfoundland, on 27 July 1866. The *Great Eastern* then returned to where the cable had parted the year before, grappled it up from the bottom of the ocean, spliced on a new length, and completed it to Newfoundland on September 7. The Atlantic was thus spanned by two working cables, and Europe and North America have been in direct telegraphic contact ever since.

In the 1860s Thomson formed a partnership with two cable engineers, Fleeming Jenkin and C. F. Varley, and within a few years, each was bringing in several thousand pounds a year in consulting fees and patent royalties – this at a time when a few hundred pounds a year was a good academic salary. Thomson followed up his mirror galvanometer with the siphon recorder, an "ink jet" device that used a delicate pivoted glass tube to paint a wavy line on a moving paper tape, recording messages in the bumps and dips of Morse code. By the mid-1870s, as big British firms rapidly laid cables to India, Australia, the Far East, and South America, as well as new lines across the North Atlantic, Thomson could boast that all long distance cable traffic was handled by instruments he had invented.

Even as his telegraphic work grew in the 1870s, Thomson continued to publish prolifically on electromagnetism, hydrodynamics, the age of the earth, the design of navigational gear, and other topics both scientific and technological. As he rose to the top of the scientific world, serving as president of the Royal Society, the British Association, the Institution of Electrical Engineers, and other organizations, he began to fall behind the advancing frontier of research. Except for a few years after 1888, when he was caught up in the excitement surrounding Heinrich Hertz's discovery of electromagnetic waves, Thomson never took up Maxwell's field theory, and it was left to others, particularly Oliver Heaviside, to show how the theory could be applied to telegraphic propagation problems.

When Thomson was born in 1824, the fastest means of travel were the sailing ship and the horse drawn coach, and a message could travel no faster than the messenger who carried it. By the time he died in 1907, steamships were plowing the seas, railways crisscrossed the continents, and the first airplanes were taking to the skies. The global network of telegraph lines and submarine cables had rendered communications almost instantaneous, and the first systems of wireless telegraphy were reaching out into what was still known as the ether. In less than a century, the world had been transformed, not least through the work of Thomson himself.

Throughout the nineteenth century, Thomson and other scientists were repeatedly drawn into disputes about the relative value of practice versus theory, as "practical men" they claimed that their own experience, not scientific theories, gave the best guide to technological progress. From the time of his controversy with Whitehouse, Thomson always preached the "harmony" of



▸ Fig. 1: An early photograph of William Thomson, later Lord Kelvin, reading a letter in 1859 from his your engineering protege Fleeming Jenkin on submarine telegraph experiments. Thomson had played a leading role in the effort to lay the first telegraph cable across the Atlantic the year before, and after it failed after only a month of fitful service, he worked hard to ensure that future efforts would succeed. *From: Agnes Gardner King, Kelvin the Man: A biographical sketch by his niece (London: Hodder and Stoughton, 1925).*

features

science and technology, proclaiming that when properly pursued, each served to advance the other. Scientific knowledge had been vital to the eventual success of cable telegraphy, Thomson said, while the growth of the cable industry had produced a demand for knowledge and opportunities for acquiring it – notably in the confrontation with retardation phenomena – that had led to great advances in the scientific understanding of electromagnetism.

Thomson exemplified this fruitful interaction in his own research and in his Glasgow laboratory, the first physics teaching laboratory in any British university. There he set his advanced students to work on problems arising from cable projects, often as direct as having them measure the resistance of samples of wire, and trained many of them for careers as cable engineers. Beginning in the 1870s, Thomson even used part of his cable earnings to endow physics scholarships at the university, thus not just reinvesting in the scientific and technological enterprise that had paid off so well for him, but contributing to what, in his characteristic Victorian fashion, he saw as the best path to the larger progress of the world as a whole. For Thomson, that path led from the physics laboratory into the market place, but also from the market place back into the laboratory.

About the author

Bruce J. Hunt is an associate professsor in the History Department at the University of Texas at Austin. He initially studied physics before moving into the history of science. His book *The Maxwellians* was published by Cornell University Press in 1991, and he is now working on a study of the relationship between telegraphy and electrical science in Victorian Britain.

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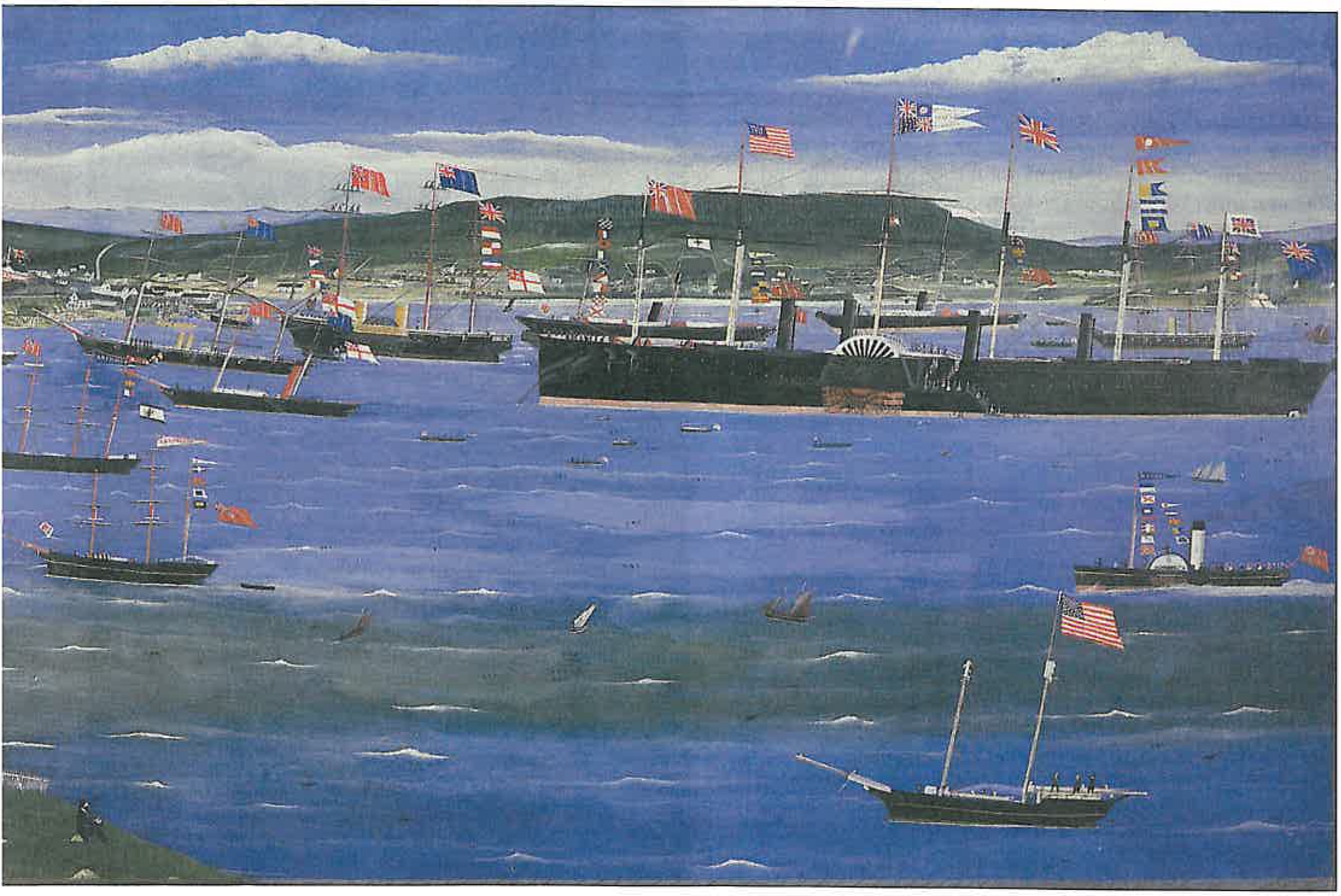
For more on the life and work of William Thomson (Lord Kelvin), see Crosbie W. Smith and M. Norton Wise, Energy and Empire: A Biographical Study of Lord Kelvin (Cambridge: Cambridge University Press, 1989).

For an interesting perspective on Thomson, see Denis Weaire's Cecil Powell Memorial Lecture, "The Value of Useless Studies," Europhysics News (2002) Vol. 33.

On the general topic of the interaction between physics and technology in the nineteenth century, see my forthcoming book, Power and Light: Physics and Technology from James Watt to Albert Einstein (Baltimore: Johns Hopkins University Press).

▼ Fig. 2: A painting by C. Lewis showing the Great Eastern and its accompanying flotilla of ships landing the first enduringly successful Atlantic telegraph cable at Heart's Content, Newfoundland, in July 1866. The ships then returned to mid-ocean, grappled up a cable that had snapped during laying the year before, and completed it to Heart's Content in September 1866, establishing a second working link across the ocean. William Thomson accompanied both expeditions and later that year was knighted for his cable work, becoming Sir William.
From: Cable & Wireless Archive, Porthcurno Museum of Submarine Telegraphy, Porthcurno, UK.



Technology Transfer at the EPFL

André Catana and Hervé Lebret,
EPFL Industry Relation Office, Lausanne, Switzerland

Technology Transfer has become a new "buzz word" in the academic world. Everywhere in Europe, research institutions look at their American counterparts with envy or respect. Stanford University is known to generate about $40M per year in royalties from its Office of Technology Licensing [1], but MIT, Columbia, Caltech, Harvard and many others also generate significant revenues through licensing of their technology [2]. With the exception of the UK universities, Europe is far behind in royalty generation. Cambridge, Oxford mention figures of a few million dollars per year; on the continent, most universities do not publish any number. The figures 1 and 2 show some key data on technology transfer at the Ecole Polytechnique Fédérale de Lausanne (EPFL), including the yearly number of inventions, patents, licenses and start-ups created.

It is however worth demystifying Technology Transfer: as the Stanford revenues show, royalties will never be able to replace the traditional funding of research[1]. Even the growing role of industry in the funding of research is no guarantee of the success of technology transfer. So this new fame has to have other roots. As Prof. Aebischer, President of EPFL said: "Which researcher would not be satisfied to see the results of his research used for the well-being of the society?" [3] If the goals of research are first to explore new frontiers, it has become clear that its industrial applications have recently contributed as much to the fame of the inventors. And when they become founders of successful start-ups, these inventors are sometimes more famous than Nobel Prize winners in their university. It would not be surprising if Stanford students know more about Jerry Yang, Larry Page or Mark Horowitz than Robert Laughlin or Martin Perl.

Even if we will not see for a long time the hundred of start-ups being funded every year in the late nineties, it seems the entrepreneur mindset finally exists in Europe. It will certainly take years, maybe decades before we catch up with the US but the important element is that some early success stories will push academics with business or entrepreneurial vocations to try to catch up. It does not mean every person in academia should try and even in the US, the academic entrepreneur remains a very rare species and it should remain so.

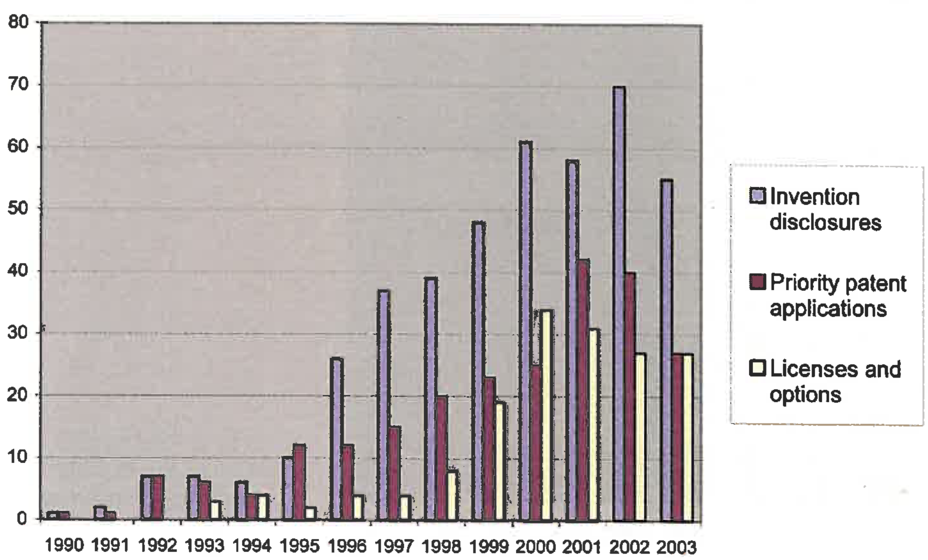
Whereas many universities in Europe do not have and even do not wish to have technology transfer offices, EPFL launched its first effort more than ten years ago. The well-known Graetzel photovoltaic cells have been already talked about a lot and are among the most promising EPFL technologies being licensed, but the reader may be surprised that the computer mouse sold by Logitech was also developed at EPFL [4]. They should not be considered as exceptions. More than one hundred technologies have been licensed in the last couple of years. The EPFL scientific park [5] counts more than 60 young start-ups (figure 3).

One element which is seldom mentioned in technology licensing is the role of inventors in enabling a technology transfer. Very seldom will an established company be interested in a technology if it cannot collaborate with the research team which developed it. Very seldom will a start-up be created if the inventor, either a professor or a student, is not involved in the company creation.

In late 2000, Eli Kapon, a professor of Physics at EPFL travelled all over Europe to convince investors to back his project of creating a start-up to develop long wavelength VCSELs. After a few months of discussions, BeamExpress was founded in July 2001 with $3.75M. A team of six EPFL scientists moved to the start-up and further developed the technology. In mid 2003, the company raised another $7.5M. Eli is still a scientific consultant with the company even if he has kept his position as a professor at EPFL and the founding team of scientists is still on board.

If the team is a crucial element, time is another. There was a very strange period, in the late 90's, certainly unique in the business world, when a company could be created in a few days, raise tens of millions of dollars in a few months and go public less

[1] Whereas royalty generation at Stanford University is in the tens of millions of dollars, its overall budget is around two billion dollars and sponsored research (e.g. through corporations and agencies such as NSF, NIH, Darpa) are in the hundreds of millions of dollars.



◄ **Fig. 1:** Number of inventions, patents filed (priority filings only) and licenses granted per year than two years after its creation. Needless to say most of these companies do not exist anymore. BeamExpress will not go public next month as it takes time from the creation of a company to its first revenues, it takes time to build a full organization, it takes time to transform a technology into products sold to customers.

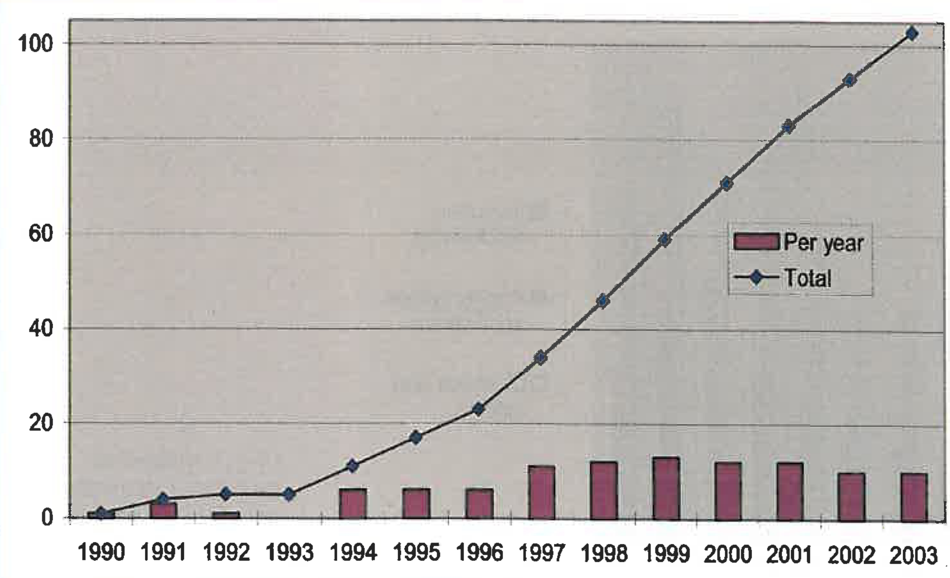
It also takes time just to create a company. Pierre Fazan, a professor in the Electronics Lab of EPFL became famous in late 2001 when the semiconductor community heard about his invention of a single transistor, capacitor-less DRAM (Dynamic Random Access Memory). Like Eli, he met with venture capitalists in 2002, again in 2003. He had to explain his technology, but also its benefits, its applications, the market and who would be his customers. He had to show he had a sound intellectual property through patents filed by the Industry Relations Office of EPFL. Finally, he raised $6M for Innovative Silicon in late 2003 when the start-ups "shooting stars" had disappeared, when too many people complained about the difficulty of creating a start-up. The situation is just as it was before the "bubble years": it will always be challenging to be an entrepreneur, but one with a serious and sound project will be funded if he believes in it enough to convince partners. Pierre is now the CEO of Innovative Silicon and his research team has followed him in the adventure.

Neither BeamExpress nor Innovative Silicon are guaranteed successes. The path to glory, either being acquired by a bigger company for a nice amount of money or staying as a profitable standalone company like Logitech, is a very long one. Venture capitalists will tell you it takes five to seven years to build a successful company.

Whereas Innovative Silicon and BeamExpress are venture capital driven start-ups, there are others where the founders decide to preserve independence from venture capital and to follow a more conventional "organic" growth. Naturally, this can only happen when alternative ways to capital or to early stage earnings are available. Family and friends, business angels or bank loans could be such capital providers whereas earnings could be generated by early clients or licensees.

A continual search for opportunities and a strong ability to convince are absolute skills of a young entrepreneur. Hubert Lorenz, the founder and CEO of Mimotec SA would certainly not deny that. In 1996, while he was working on his PhD at EPFL on a novel micro-moulding technology, he met Victor Bruzzo, the manager of Indtec, one of the leading companies for the production of components for the watch industry. Victor strongly encouraged Hubert to start his own business. Two years later, Hubert and his friend Nicolas Fahrni, founded Mimotec SA to exploit the technology they developed at EPFL: "we invested all our money and also asked the families to contribute; 200,000 Swiss francs could be raised this way". Matching funds from a business angel and from Indtec's Victor Bruzzo helped double the founders' contribution and allowed the company to lift off the ground. But Mimotec's take off would not have been successful without obtaining from EPFL the transfer of intellectual property rights on the patent that was protecting the technology developed by Hubert during his thesis and without Indtec, the first client. Indeed, for the first 18 months, Indtec was covering about 90% of Mimotec's orders. So, Hubert got the "big five" ingredients for the successful launch of a start-up: novel technology, intellectual property rights, seed money, team and first client. He has no regret refusing offers from investors. "At the time when our turn-over was hardly reaching one million Swiss francs, some investors were proposing to invest up to 10 million Swiss francs in the company" says Hubert. In 2003, Mimotec had 15 employees and its turn-over reached about 3 million Swiss francs. Next step: enhancing the market extension beyond the watch market and developing the business in the US.

Having early clients is one means that helps to succeed without venture capital, and Mimotec is a nice example; another way is early licensing. And this is the way that Diagnoswiss' Fréderic Reymond and Joël Rossier followed. Diagnoswiss SA is a life science company founded by Fréderic and Joël in 1999 to develop a new generation of biochips that integrate novel methodologies for high-throughput protein analysis. These are essential for the diagnostic and drug discovery markets, and in particular for the fast growing fields of genomics and proteomics. Being active in such an emerging field without clear major players creates a large number of business opportunities for Diagnoswiss. The business idea is quite simple: acquiring and developing patented technologies and devices, bridging the gap between laboratory demonstrations and industrial prototypes, validating the use of novel technologies, developing partnerships and licensing or sublicensing intellectual property rights in well-defined market segments so as to finance proprietary development, and commercialisation of



◄ Fig. 2: Total number of start-ups as well as number of start-ups founded per year from EFPL

▶ **Fig. 3:** The campus of the Swiss Federal Institute of Technology in Lausanne (EPFL) with its scientific park (PSE) on the right.

the company's technology in other segments. So, the company developed a strong patent portfolio largely based on technologies developed by the founders during their PhDs at EPFL. These technologies have been exclusively licensed by EPFL to the company. Among them is the so called Off-Gel electrophoresis which is expected to lead to high performance protein fractionation and purification. In 2001, Diagnoswiss entered into a collaboration and license agreement with Agilent Technologies Inc. to further develop this technology.

There are other ways to transfer technology. Creating a company may simply not be realistic when the technology is only a small brick of a much bigger system. Or the team may not have the entrepreneurial mindset and once again, there is nothing wrong with that. Licensing the technology to an established company is another option. Coming back to the Graetzel cells [6], EPFL has an interesting example of a multi-license model. More than 10 companies based in Europe, in the United States, in Japan and in Australia have licensed the technology and are working with EPFL's Laboratory of Photonics and Interfaces (LPI) to put the technology into production. A lot of work remains to be done, but without the collaboration between industry and EPFL, the technology would not have been developed to the current stage.

Collaborative research with industry is another rich ground for innovation and enhances the development of technologies issued from universities and their transformation into products. EPFL has had from its very first years strong links with industry and is actively promoting such interactions. It is within such an industrial collaboration founded by the Swedish chemical company Perstorp AB that Prof. Jan-Anders Manson and Louis Boogh from EPFL developed uniquely high surface interactions between hyper-branched polymers and their surrounding materials, which allows the tailoring of their properties for a large variety of applications. A real breakthrough! Perstorp extended this one year long exploratory project for three more years which brought to the lab about 1.5 million Swiss francs. The company filed several patents on the results of this work and set up a manufacturing infrastructure shortly after the end of the project. Perstorp is now one of the leading companies worldwide for the manufacture of hyper-branched polymers on a large scale and EPFL is proud to have contributed to it. But not only that: the knowledge generated within this collaboration helped the Laboratory of Composite and Polymer Technology of EPFL to become the world leading laboratory in macro-molecular engineering based on hyper-branched polymers for use in functional and structural applications; at the same time it greatly increased its attractiveness for industrial collaborations in this field.

Technology transfer is multiform. Start-ups have been the favourite model in recent years, but direct licensing with established companies or collaborative research with industry are other clear options. There are however at least two common points in any transfer: first it takes time, a long time, often much longer than what was originally envisaged and many inventors will tell you they may not have jumped into the adventure if they had known it. Second, it takes a high involvement of the inventors without whom a successful collaboration between the industry and the university is very unlikely. But all inventors will tell you that they will never regret the experience they have gained from taking the risk.

About the author

André Catana graduated from the Swiss Federal Institute of Technology, Zürich (electrical engineering) in 1985 and obtained a PhD in the field of semiconductor physics at EPFL in 1990. He worked for two years at IBM Research Laboratory in Rüschlikon in the field of laser science and superconductors before joining EPFL in 1992 where, he strongly contributed to the creation and development of EPFL technology transfer office and manages many of the EPFL inventions, patents and licenses

Hervé Lebret graduated from Ecole Polytechnique (France) in 1987, SupAero (Toulouse) in 1989 and obtained an MS from Stanford University in 1990, then his PhD in electrical engineering from Université de Rennes in 1994. In 1997, he left academics to begin a career in venture capital at Index Ventures in Geneva where he invested in Information Technology start-ups in Europe, Israel and the United States. He joined EPFL in 2004.

features

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Exploiting technology in the commercial world

Charlotte Forrester and Nicola Maguire,
Bird & Bird, PLC Counsel 3000 Global 50 law firm,
London, United Kingdom

In this article the authors explain the stages involved in the creation of a company and in obtaining external investment to commercialise technology developed in the laboratory. Some of the steps are illustrated by reference to a recent transaction on which they have worked, Southside Thermal Sciences Limited (STS).

Early Stages

Increasingly universities are becoming aware of their vast, untapped intellectual property resources with the potential to commercialise them and raise real value, not just for the university but also for the academic inventors. Academics are being encouraged to identify intellectual property in their laboratories that may have commercial value. Once the potential technology has been identified, how is the technology put into the marketplace?

Traditionally there are two ways that value can be achieved from an invention. The university may licence the technology and the academic will receive a payment under the university's awards to inventors scheme. Alternatively a company will be set up to commercialise the technology. This article focuses on the second route, which was the way chosen to exploit the technology now owned by STS.

What are the initial tasks that will need to be undertaken in order to get started? First you will need to prepare a business plan. This will explain to potential investors what your technology is all about, how you propose to transform the technology into a marketable product, fund your company and get your product to market. There are people you can turn to for help in this regard, from fellow academics, technology transfer departments and colleagues in business schools, to professionals who will write the plan for a fee.

Southside Thermal Sciences

STS is a company spun-out from Imperial College, London in the UK. STS was set up to commercialise a sensor coating for gas turbines which was developed by Dr Andy Heyes and Dr Jörg Feist. Udo Dengel was appointed to manage the commercial activities of the company. Their ceramic coating allows wear on the turbine blades to be monitored without having to shut down the engines to check whether the blades are deteriorating, thus improving fuel economics and maintenance costs for gas turbines [see refs.]. The company secured initial seed investment from NPI Ventures Limited (part of the Nikko group) and from the Imperial College University Challenge Fund in October 2003. It is currently looking for further investment and seeking industrial partners to collaborate on the development of its technology.

◄ **Fig. 1:** Drs Feist and Heyes receiving the European Technology Innovations Award from the editor of the Wall Street Journal Europe

There are business plan competitions you can enter which will help to raise your profile and the prize could help fund your company. STS successfully raised its profile by winning the Imperial Entrepreneurs' Challenge, Eurowards, the European Award for Entrepreneurs and the Wall Street Journal Europe 2002 Technology Innovation Award. These competitions gave STS lots of publicity that helped when it came to raising finance.

Instructing professional advisers

An initial step is to instruct professional advisers who will guide the company through the incorporation process. These will include lawyers, patent agents and accountants. Advisers will, of course, need to be paid for their services. These costs are always a burden for start-up companies and a concern for inventors wanting to commercialise their products. In choosing your advisers, seek recommendations from your institution, your colleagues and other early stage start-ups. Making a poor choice will be detrimental to your business in the long run.

Your choice of lawyers is particularly important. You may feel that the costs associated with instructing quality lawyers with experience in your sector are simply not justified. In fact, when you instruct lawyers, you are setting up what should be a genuinely beneficial relationship with your chosen firm. They should provide more than just legal advice, such as giving you the benefit of their insights into how other clients in similar sectors operate; what are good commercial terms for the types of deals you plan to enter into; the pitfalls you should look out for in certain types of deals; contacts with investors, and so on. Many professionals will offer discounts to their standard rates for start up companies, so check whether there are any arrangements from which you can benefit. STS used Bird & Bird as they have significant experience acting for start up companies; in particular they have acted for a large number of the companies spun-out from Imperial College, London.

Incorporating a company

You will need to incorporate a company and transfer the technology to it. In most European countries companies can be quickly and cheaply set up by a lawyer, company formation agent or yourself. In the UK the Companies' Registry provides helpful guidance at www.companieshouse.com. Your lawyers may include this service at a reduced rate as part of a fee package.

Intellectual property rights are likely to be your Company's core assets and therefore you must ensure that they are properly transferred or licensed to your company. The method of transfer will depend on whether technology is patented or not. If the technology is not patented you should be wary about disclosing details of it to third parties because you will destroy your ability to obtain patent protection. This will affect the drafting of your business plan and the way in which you present your business to investors. Always make sure you get a signed non-disclosure agreement before handing over any confidential information and if in doubt, seek professional advice. Again, your lawyer may provide a standard draft agreement as part of their fee deal.

Contacting investors

Presentation to investors may involve your participation at technology transfer investment events or touting for opportunities to pitch at relevant conferences and angel networks. The technology transfer department at your university, your colleagues, friends and family and your lawyers may be able to help you with introductions. There are also brokers but this is a less common approach for finding initial funding of a start-up, partly due to the additional costs involved.

Protecting Intellectual Property

You must also consider how best to protect your intellectual property. If the technology is patentable you should consider making an application. A patent agent who is an expert in the relevant technology will usually be instructed to do this by the owner of the intellectual property, often the inventor's employer. Understanding who owns intellectual property is not always straightforward but your lawyers will advise you on this point.

The owner of the intellectual property will either assign the rights to the spin-out company in exchange for shares or will licence the rights in exchange for shares in the company and/or the payment of royalties. The terms are likely to need careful negotiation to ensure that the company gets a fair deal. In STS's case the relevant patents were assigned to the company.

Obtaining funding

The essential factor in a successful spin-out is obtaining funding. Without funds the company will not be able to develop its technology and grow. A good business plan and talking with investors who have experience of investing in companies using similar technology and at a similar stage of development, should help you secure that investment. Investors will see the management team as critical to the success of the venture. Many spin-out companies employ a professional manager who is experienced in the relevant sector to seek funding for them. Since the company will have no funding, the manager can be paid by being issued with shares and, as a further incentive can be granted options to acquire further shares on achievement of certain milestones, for example obtaining specified levels of funding. The length of time that it takes to obtain funding should never be underestimated. It took STS nearly a year to raise its initial investment and this is not unusual.

Once a party is interested in investing you will need to agree the investment terms. This may involve entering into heads of terms, a document in which the company, the investor and the founders of the company agree the key terms of the investment. The investor will also want to carry out some due diligence regarding the company's technology and proposed business before entering into an investment agreement. If you have not protected your ideas and intellectual property properly this will affect the value of your company and the investor's decision as to whether or not to invest. The high profile achieved by STS at an early stage through their participation in business plan competitions doubtless assisted STS in raising investment.

Prepare Business Plan	Stage 1: Initial Phase
↓ Appoint Professional Advisers	
↓ Incorporate Company	
↓ Assignment or Licence of Intellectual Property	Stage 2: Seek Investment
↓ Raise Profile	
↓ Seek Investors	
↓ Agree Heads of Terms of Investment	Stage 3: Confirming the Investment
↓ Due Diligence carried out by Investors	
↓ Complete Investment: agree and sign Subscription and Shareholders Agreement and adopt new Articles/By laws	Stage 4: Where do I Sign?
↓ In Business!	Stage 5: Operational

▸ Fig. 2: Receiving the European Award for Entrepreneurs at the Brussels Stock Exchange

Documentation

The documentation required to implement an investment will normally comprise: a subscription and shareholders agreement; articles of association (the by-laws or rules setting out how the company is operated); share option schemes (allocating a pool of shares to reward employees and management team members); assignments and licences of intellectual property (if not already entered into); intellectual property pipeline agreements (which allow the company to take an assignment or licence of intellectual property created by the founders in the future whilst continuing to work in the university laboratory); and founders' employment or consultancy agreements.

The main document is the subscription and shareholders agreement. This sets out the terms upon which the investor will obtain shares in the company including the amount that will be paid for the shares and how many shares, and when and how the money will be paid to the company. It also includes the terms on which existing shareholders of the company (usually the investor, and the founders) will hold the shares and the way in which the company will be managed including the decision-making processes. In the case of STS the investors required a slightly more complicated document known as a convertible loan. The investment was lent to the company and the investors have rights to subscribe for shares in the company at any time or to require repayment of their loan.

Conclusion

Providing you identify the technology you wish to exploit and understand the steps involved, a spin-out is an effective model for the exploitation of technology. The key stages are developing the business plan, transferring the technology, finding investment and creating a business which has a good commercial basis. Expert professional advice, should be sought at each stage and is critical to getting it right. However, as with any new business, the time and effort required should not be underestimated.

About the authors

Nicola Maguire is a partner and Charlotte Forrester is an assistant in the Corporate Department at law firm Bird & Bird. They have acted for STS and many start-up companies including a large number for Imperial College, London. They provide advice on both corporate and commercial law issues including advising on the exploitation of intellectual property through licensing, start up and joint venture companies. They also advise investors and companies on all levels of funding and on private and public acquisitions and disposals and joint ventures, many involving an international perspective.

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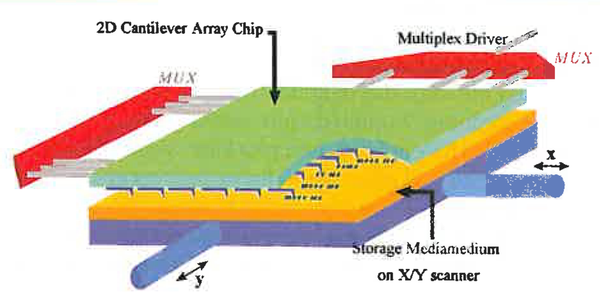
Competitive aspects of a probe storage technology

Eric Ruetsche,
IBM Zurich Research, Rueschlikon, Switzerland

Probe storage technology has been pioneered by Gerd Binnig and Peter Vettiger who developed the concept based on AFM activities in IBM Zurich Research. The basic concept uses a matrix of micro-machined cantilevers to write and read indentations in a polymer material [1]. The cantilevers are bonded to a CMOS chip that holds an analogue sensing unit per cantilever and a multiplexer that transfers the data to the main sensor and control component. A magnetically actuated x/y scanner moves the storage media cantilevers relative to the cantilevers (see Figure 1). A mass-balanced design protects the media from shock in the x/y direction. In a single-lever test system the thermo-mechanical read/write mechanism has demonstrated a storage density of 641Gbit/in2 at raw bit-error rates of 10-4 [2,3]. Raw error rates of this order of magnitude are typical for magnetic recording. Standard error correction schemes can be used to get to the error rates required for today's applications. The system architecture, control and error correction codes are currently being developed to demonstrate a fully functional storage system. MEMS components have been fabricated and assembled and are incorporated into a first small-scale prototype that serves as a test platform for the channel and control electronics built on a dedicated printed circuit board. In parallel to the technical developments a commercial evaluation is performed to validate the competitiveness and market attractiveness of the technology against the most successful non-volatile memory technologies today: magnetic hard disc drive (HDD) and Flash. (We will use the term storage for any non-volatile memory)

Assessing a technology

The attractiveness of a technology can only be analysed by looking at the attractiveness of derived products for particular applications and markets. In a commercial enterprise the business case will be analysed to evaluate the attractiveness of any



▲ Fig. 1: Probe storage concept based on an array of cantilevers.

investment in a new product. This analysis addresses the product, its cost and potential on the market but is driven by the strategic objectives of the organization and its capabilities such as the marketing and sales channels, the manufacturing expertise and capacity, and financial resources.

The basic analysis of the competitiveness of the technology can however be assessed to a large extent without addressing the company-specific issues. Figure 2 gives an overview of the key factors that drive this process. Application requirements are derived from the needs and wants of the end user. Video and still picture cameras, and mobile phones are the high volume applications in today's consumer electronics. Audio players and USB drives are emerging applications with important growth rates. Each one of these applications has its particular set of requirements on a storage device that are addressed in the market by various products: Flash cards and small HDDs are the two most important technologies that enable products for these applications.

The success of a storage product in the marketplace depends primarily on its fitness for a specific application. If multiple products are perceived to match the requirements of an application then the price is the most important buying criteria: the price per capacity ($/Gbyte) and price per unit. In the price sensitive consumer electronics market the maximum storage capacity of a device is often driven by the price of storage unit that must not be over a certain percentage of the overall cost of the device.

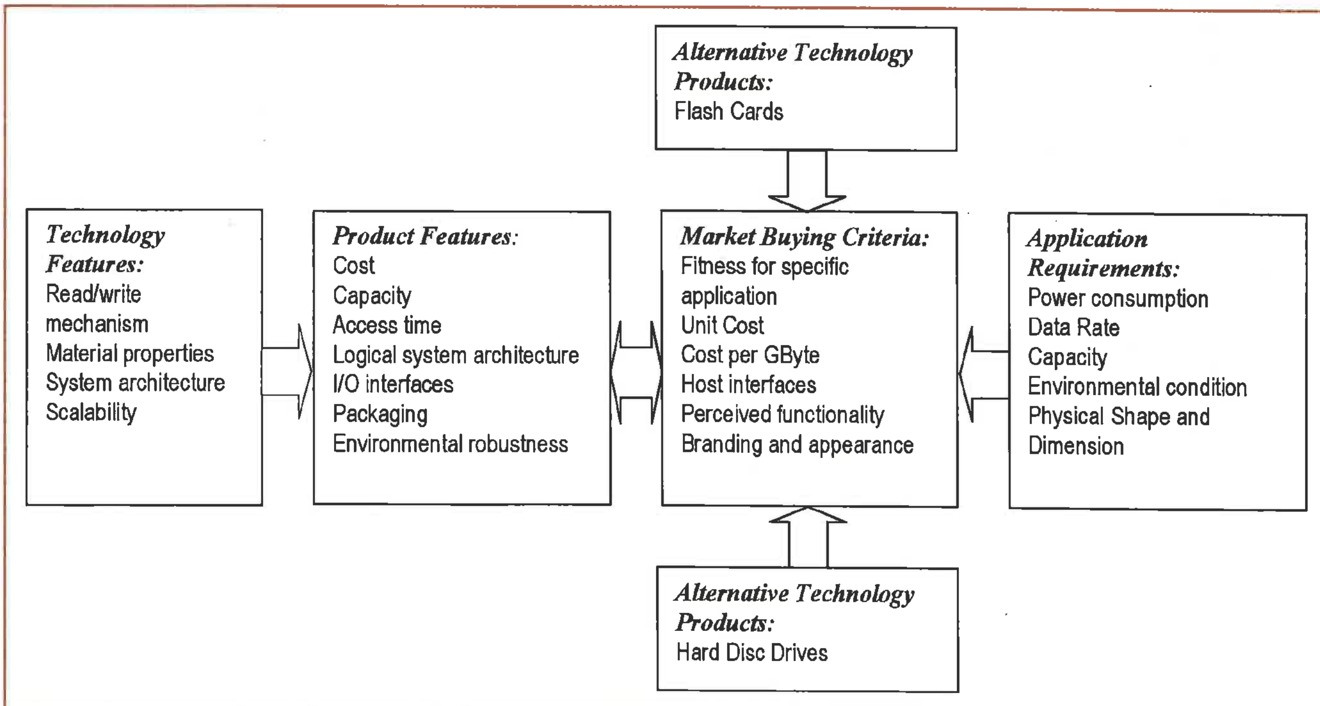
Flash vs Hard disc vs Probe storage

Flash is a semiconductor device that follows the scaling rules of this technology. Increasing densities provide lower cost per storage bit. The cost per bit is however relatively high because of the overhead of a sensor per bit. A high demand and consequently high investments in Flash drive the progress of the technology and decrease cost.

Magnetic storage in HDD takes advantage of a single but expensive sensor that is addressing a magnetic disc and provides low cost per bit. The unit costs are high because of the system overhead of the electronics and sensitive mechanics imposes a limit to the downscaling of the cost. In the next few years it is unlikely that another technology will compete with HDD in cost per GByte at high capacities, i.e. larger than 40GByte. However Flash products have the advantage of the best unit price for small and moderate storage capacity, i.e. <1GByte (see Table 1).

In the near future probe storage cannot compete with the high volume products in HDD and Flash. Even if there might be some technical challenges in the further development of these technologies over the next 5 years, it is likely that they will be overcome by the combined investment of these multibillion industries. Probe storage must therefore target niches not optimally addressed by Flash and HDD. One niche we have identified is mobile storage at capacities that are very costly for Flash and for HDD, between 5 and 40 GByte. The mobile storage market is attractive because of the high growth of mobile devices that are demanding ever increasing storage capacity. Analysts studies by Webfeet and IDC predict around 15B$ revenue in this market for Flash cards and 1B$ for small HDD (Microdrive or competing 1" devices) in 2006.

In mobile applications the environmental stress on a device is an important challenge. The most important factors are an operating temperature over a wide range (e.g. -20C to 85C) and shock resistance (e.g. 1 m drop of a host device on concrete). A permanent loss of data is not acceptable. Semiconductor storage has distinct advantages for these requirements. Probe storage due to the low mass of the MEMS components has a good potential to be advantageous over HDD devices that are very sensitive and are using accelerators to sense a fall and take preemptive measures to protect sensor head and magnetic disc. A detailed analysis with the developers, marketers, and users of the



▲ Fig. 2: Market situation for a new storage technology.

applications is required to identify additional usability requirements. An example of such a requirement, specific to mobile application, is the extreme low power requirement at moderate data rates when a device is used on battery power versus a high data rate and virtually no power limitations if a device is connected to the line-powered host. Differentiating factors that provide the user a noticeable advantage can help to position a product in a market niche beyond a price comparison.

Investment and Risk Management

The most effective allocation of resources is one of the imperatives of any business. Hence we must assess the technology also on the necessary investment and the associated risk.

Manufacturing investment: The downscaling of the feature size is a huge challenge to current semiconductor technologies. Current and future cost will be dominated by very expensive mask technologies and lithography tools. While the cost for mask sets will be several hundred thousand to millions of dollars, lithography tools will cost more than 10 million dollars per tool. Our current probe storage prototypes and potential future product do not require the latest lithography but can rely on established MEMS and CMOS manufacturing facilities. The initial manufacturing investment will therefore be significantly lower than for a new semiconductor generation. Unknown factors are in the yield of assembly and packaging of the components that require nanometer precision. This issue is however not directly related to a high one-off investment but can be addressed in a carefully planned engineering effort.

Scalability: Even though the investment in a product line must be amortized over a few years the opportunity costs could limit the attractiveness of a product investment if it cannot be demonstrated that the technology is competitive over multiple generations of products. The scalability of the technology becomes therefore another important parameter to be analyzed. It seems that the fundamental limitations of probe storage are reached if the indentations approach molecular dimensions. In current tests indentations are in a distance of around 30nm. Higher densities have been demonstrated and indicate room for further scaling. Improved coding and increasing storage area are additional means to develop multiple product generations with ever increasing storage capacity.

Summary

Thermo-mechanical probe storage has demonstrated record density. The technical and commercial feasibility of a product is currently being investigated. The viability of a technology must be analysed on specific products. We have identified mobile mass storage at capacities between 5 and 10GBytes as a potential first niche market. For a successful product the cost per unit and cost per GByte must be attractive. However, ideally additional parameters provide a perceived benefit for a user beyond price. An investment decision must take into account the mix of upfront investment for tooling and of controllable investment for development and engineering efforts. Scalability of a technology over generations of products provides the opportunity to amortize the investment over the longer term. In thermo-mechanical probe storage, potential physical limitations allow for multiple product generations that appropriate engineering efforts could bring to realisation.

Acknowledgements

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About the author

Erich Ruetsche, holds a PhD in electrical engineering (ETH Zurich) and an MBA (Ashridge Management College, UK). He is responsible for Business Development and Relations in the IBM Zurich Research Laboratory. Before joining IBM he worked as a technology and strategy consultant to international technology and financial organizations and managed high-tech businesses in Switzerland.

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Hard Disc Drive	Flash (NAND)	Probe Storage
Magnetic	Electronic	Thermo mechanic
Rotating magnetic media	Semiconductor chip	Polymer substrate
High system overhead: Mechanical structure, servo, sensor, channel electronics low cost per bit	Low system overhead But high cost per bit cell	High system overhead: MEMS components and assembly, electronics Low cost per bit
high unit cost low $/MB wins at high end (high capacity > 40 GByte	low unit cost high $/MB wins at low end (low capacity < 1 GByte)	moderate unit cost moderate $/MB potentially attractive at moderate capacities
Sensitive to shock due to the moving parts and sensitivity of head and magnetic disc	Low shock sensitivity, no moving parts	Low shock sensitivity due to low masses

Table 1: Comparison HDD – Flash – Probe Storage

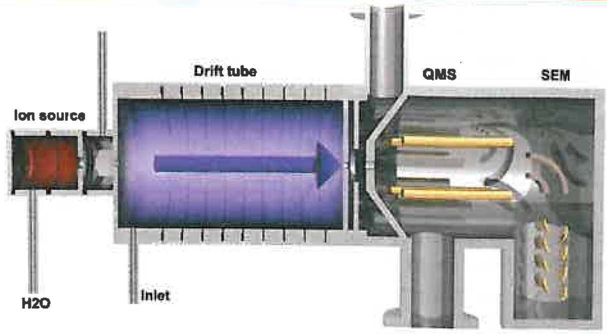
Proton Transfer Mass Spectrometer

Armin Hansel, Associate Professor at the Institut für Ionenphysik, University of Innsbruck, Austria

The first Proton Transfer Reaction Mass Spectrometer (PTR-MS) instrument was built ten years ago in our laboratories at the Institute of Ion Physics of the University of Innsbruck. In PTR-MS we use H_3O^+ ions to ionise volatile organic compounds (VOC) present in gaseous media, e.g. in air. This technique enables a variety of organic species in complex matrices to be monitored in real-time, with detection limits as low as a few parts per trillion, volume (pptv). In 1998 we founded the spin-off company Ionicon Analytik GmbH to provide this technique to a growing user community. Today we manufacture and sell PTR-MS instruments throughout the world. Our customers include noted multinational companies and renowned research institutions in the fields of environmental and food technology. This review covers the main principles of PTR-MS and shows key academic and commercial application areas in the market place.

Why PTR-MS?

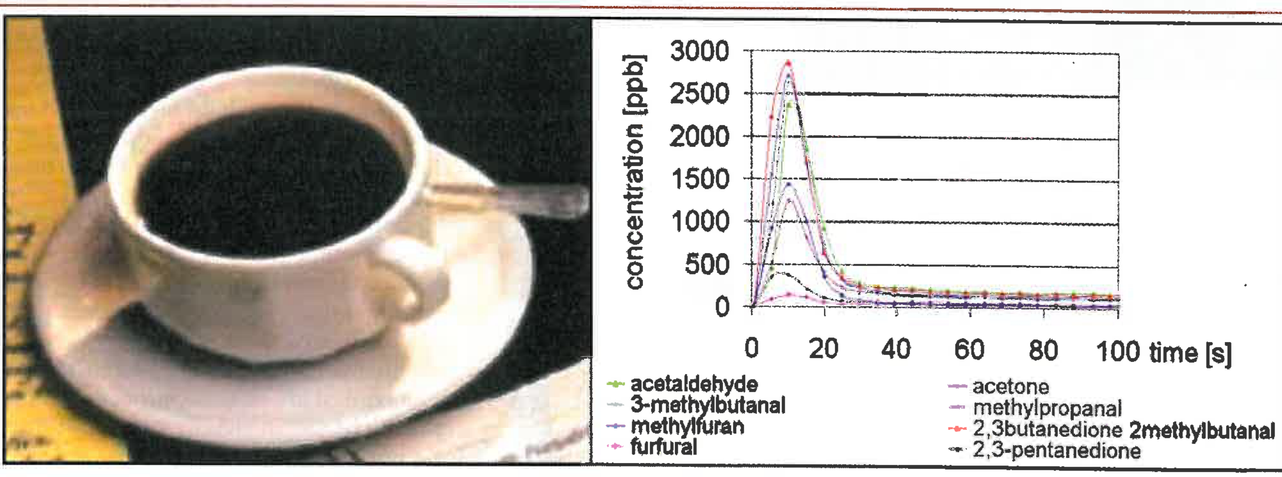
Conventional mass spectrometry (MS) is a well proven and highly sensitive technique for the identification and detection of organic pollutants. In simple terms, it works by separating organic molecules on the basis of their molecular masses. Molecules entering the mass spectrometer are ionised, usually by electron impact, and are then subjected to electromagnetic fields under whose influence ions with different mass/charge ratios will move in different trajectories. Thus the ionised molecules can be separated and individual molecules can be identified. That is the theory. Unfortunately, instead of forming a single ionised species, many molecules break down into smaller fragments, each of which is detected separately. This can result in one compound giving rise to a complex "mass spectrum". With a mixture of compounds entering the MS detector simultaneously, the final mass spectrum may be so complex that interpretation and quantification become difficult, if not impossible. The traditional solution to this problem has been to separate the compounds with a gas chromatograph (GC) before they are sent to a mass spectrometer. Unfortunately, GCs are inherently slow – a typical separation of just one sample could take 30 minutes – so while GC-MS is fine for analysing discrete samples or monitoring slowly changing situations, it cannot usually be regarded as a "real time" or on-line technique. PTR-MS can make the GC step unnecessary for many typical VOC analyses and achieve a response time measured in milliseconds. This opens a whole new range of possibilities in environmental monitoring, food science, odour analysis and medical applications.



▲ Fig. 1: Schematic representation of the PTR-MS instrument (QMS: quadrupole mass spectrometer; SEM: secondary electron multiplier)

How does it work?

The fundamental difference between a conventional MS and PTR-MS is the "soft ionisation" method used to ionise the organic molecules. PTR-MS uses chemical ionisation, in which the VOC molecules react with charged ions, in this case hydroxonium ions (H_3O^+) produced in an external ion source. The first PTR-MS instrument was developed at the University of Innsbruck [1-2] and is shown schematically in Figure 1. A glow discharge acts as an external ion source which produces H_3O^+ ions from pure water vapour. H_3O^+ primary ions enter the drift tube (DT), which is flushed continuously with ambient air, and undergo non-reactive



▲ Fig. 2: Release of flavour compounds in the head space air from freshly brewed coffee. With the PTR-MS technology you can see aroma as you taste it!

features

collisions with any of the common components in air (N_2, O_2, Ar, CO_2, ..). H_3O^+ ions transfer their proton exclusively to VOC molecules that have proton affinities higher than that of water, making reaction (1) exothermic, and forming VOCH+ ions with a collision efficiency of unity.

$$H_3O^+ + VOC \rightarrow VOCH^+ + H_2O \qquad (1)$$

The density of product ions [$VOCH^+$] in the DT follow pseudo first-order kinetics as expressed in equation (2), where t is the average reaction time the ions spend in the DT, and k is the reaction rate constant.

$$[VOCH^+] = [H_3O^+]_0(1 - e^{-k[VOC]t}) \approx [H_3O^+]_0\,[VOC]\,k\,t \qquad (2)$$

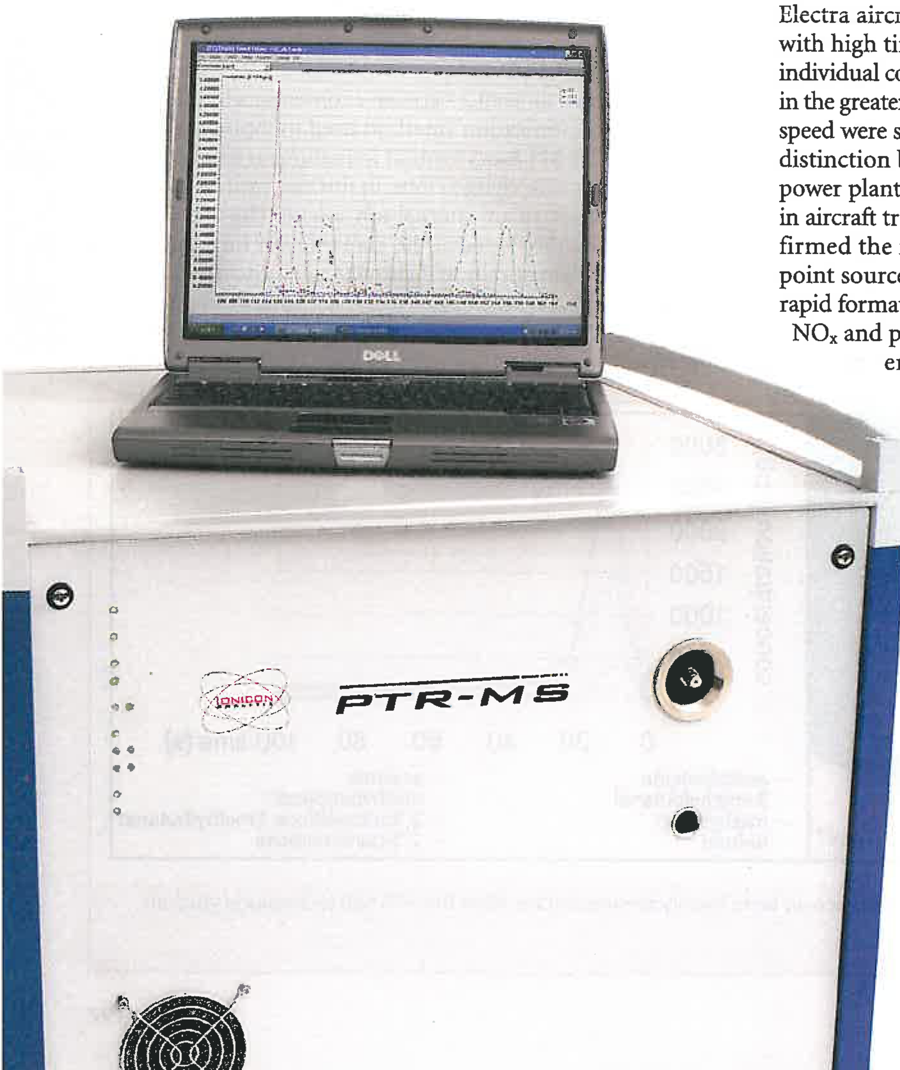
Primary and product ions are then detected by the MS in the usual way. The great advantage of this method, however, is that fragmentation of the product ions is very much reduced so the mass spectra produced are much easier to interpret and are more straightforward to quantify. This means that for many quantitative applications the preliminary GC separation becomes unnecessary.

Applications

The PTR-MS instrument has the key capability of being able to monitor and quantify complex mixtures of VOC in the gas phase such as alkenes, alcohols, aldehydes, aromatics, ketones, nitriles, sulphides and many others within seconds, with a detection limit of a few pptv. This means that one molecule out of 200 billion "air" molecules can be detected virtually in real time, without any time consuming work-up procedure. On the basis of these attributes it is possible to target a number of key academic and commercial application areas for exploitation of the technology. The most prominent amongst these are environmental, medical, and food/flavour applications. Fig. 2 shows an example from the food/flavour application; with PTR-MS you can visualise aroma in real time. In Fig. 2 you see the whole flavour release "film" and not just the fingerprint "snapshot" in the headspace air of freshly brewed coffee. With this technology a food flavourist can see the aroma as you taste it!

Over the last decade the PTR-MS technique has been used extensively in environmental sciences as a fast VOC sensor. Volatile organic compounds are emitted into the atmosphere from a wide variety of sources, both natural and anthropogenic. The photo-oxidation of VOC leads to ozone and aerosol formation, which are both major air pollutants, have adverse effects on health, and are significant factors for the Earth climate.

The Indian Ocean Experiment (INDOEX 1999) has offered the opportunity to study the influence of anthropogenic pollution in the tropical troposphere. In India and surrounding countries biofuel use and agricultural burning cause strong CO emissions. Ship and airborne PTR-MS measurements of organic trace gases in real time, over a broad spatial extent of the Indian Ocean, have turned out to be of great importance in detecting pollution outflow from India and in helping to quantify the relative amount of CO originating from biomass burning [3]. During the Texas Air Quality Study (TexAQS 2000) ambient air was analysed onboard the National Center for Atmospheric Research (NCAR) Electra aircraft. Molecular-level information of VOC obtained with high time resolution was essentially useful to characterise individual contributions of distinct sources for ozone production in the greater Houston area. On several flights, wind direction and speed were such that these airborne VOC measurements allowed distinction between anthropogenic petrochemical, urban, and power plant plumes. In-situ acetaldehyde measurements, taken in aircraft transects of the Houston metropolitan area, have confirmed the importance of propene emissions from localised point sources to the photochemical processing of NO_x and the rapid formation of ozone within short distances from co-located NO_x and propene emission sources. [4]. Supplementary references for further reading are available at www.uibk.ac.at/ionenphysik/umwelt.



History and development of IONICON ANALYTIK

Ten years ago we built the first Proton Transfer Reaction Mass Spectrometer instrument (PTR-MS) in Prof. Werner Lindinger's Laboratory at the Institute of Ion-Physics of the University of Innsbruck. In 1998 the key scientists involved in the development of the PTR-MS technology founded the company IONICON Analytik as a spin-off of the University of Innsbruck to provide this technique to a growing user community. Three years later in 2001, Prof. W. Lindinger died in a tragic accident. At the time of his death he was in Hawaii for the purpose of installing a PTR-MS instrument at the NOAA

◄ **Fig. 3:** Compact PTR-MS

Clean Air Baseline Station on the volcanic Mauna Loa mountain. Today the Ionicon Team (see www.ptrms.com) manufacture and sell PTR-MS instruments throughout the world. Now more than 70 instruments are used by many research groups and companies around the world, applying this technique in various fields. Our customers include noted multinational companies and renowned research institutions in the fields of environmental science and food technology.

Today, three different PTR-MS instruments are available. Besides the standard and high sensitive versions, the compact PTR-MS is the most recent development from Ionicon Analytik. The compact PTR-MS, the first commercially available configuration for more general applications, is pictured in Figure 3.

The future

In our business it is crucial to always be innovative. We therefore want to promote collaborative research between universities and industry. Ionicon Analytik is a partner in ISONET a Marie Curie Research and Training Network recently funded by the European Commission (http://imk-ifu.fzk.de/isonet). One objective of ISONET is to integrate an industrial partner to strengthen collaboration between industry and academia and to allow network trainees to use state-of-the-art and innovative facilities to carry out their research.

The goal of the 2nd International PTR-MS Conference next year (www.ptrms-conference.com) is to bring together active scientists and technologists involved in real-world mass spectrometric measurements of VOC from both academia and industry. The intent to found and organise such a biennial meeting was to promote discussion and stimulate the free exchange of ideas across disciplines, such as environmental sciences, food technology and medicine

About the author

Armin Hansel is Associate Professor in Physics at the University of Innsbruck. His research interests are ion-molecule-reactions and their application to trace gas analysis, which resulted in the development of the PTR-MS technique. In environmental physics he was involved in several international field programs. Armin is founding member of the academic spin-off company Ionicon Analytik GmbH.

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Materials characterisation service

Christophe Thessieu, Director, easyLabs Ltd, Egham, Surrey, United Kingdom

High-pressure is no longer a specialised tool. It has become vital to fields ranging from geophysics to optoelectronics, from polymers to the production of vaccines (see e.g. Dunstan and Scherrer, 1998). Take for example high-pressure biotechnology. This is an emerging technique initially applied for food processing and more recently in pharmaceutical and medical sciences. Here pressure enables enzymes to be stabilized and both their activity and specificity can be modulated as a function of pressure. High-pressure engineering of proteins may be used for enzyme-catalysed synthesis of fine chemicals, pharmaceuticals, and production of modified proteins of medical or pharmaceutical interest.

In essence, the strength of high-pressure studies rests it its ability to enable the tuning, in a controlled and reversible manner, of the volume of a sample and, therefore, the ensuing properties of that sample. The application of pressure can produce structural, electronic and other phase transitions, polymerisation of organic substances, and many other phenomena (Eremets 1996).

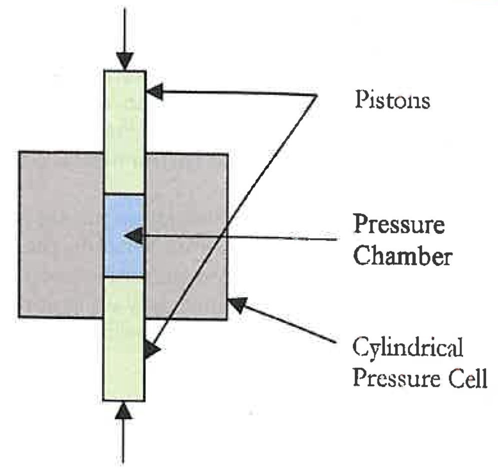
This expansion of fields benefiting from studies at high-pressures has inevitably led to the demystification of high-pressure techniques and equipment – a field notoriously dominated by experts. Thus, for example, the commercial development of miniature diamond anvil cells (which can generate pressures above 400 GPa or 400,000 ambient pressure) supplanted equipment weighing many tons, with essentially an instrument that could be held in the palm of the hand. These diamond anvil cells enable a variety of optical, x-rays and other measurements to be carried out at high and low temperatures and high magnetic fields in a safe and user-friendly fashion.

At easyLab we have commercially developed miniature piston-cylinder type cells. Although these cells are limited to the range of pressures up to above 3 GPa, they allow for much larger samples to be studied. Furthermore, our piston-cylinder cells make possible for different techniques to be used, such as electrical resistivity and magnetisation. In what follows we briefly discuss the technical aspects of achieving high-pressures (up to 3 GPa) with piston-cylinder cells. Then we present typical engineering and scientific results obtained with this type of equipment.

Technical Details

Piston-cylinder high-pressure cells are also referred to as hydrostatic cells. This is because pressure homogeneity has been shown to be very good with these devices. Of course, hydrostatic conditions are also obtained in diamond anvil cells, but piston cylinder remains one of the most obvious methods for pressure generation.

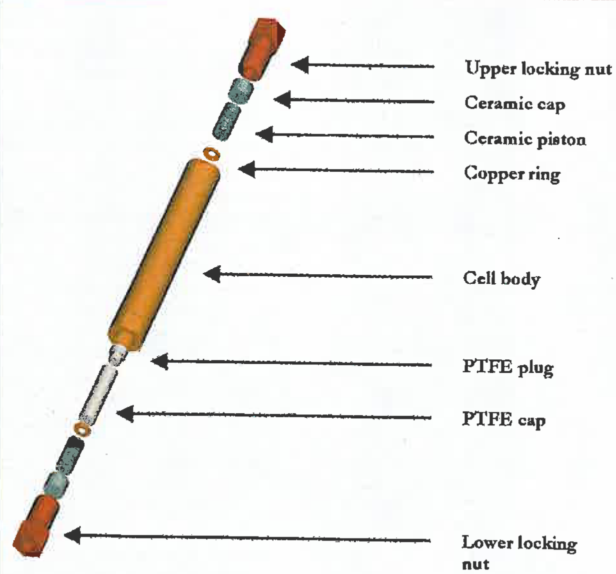
Fundamentally, a pressure-transmitting medium (within which the sample resides) is compressed, inside a relatively thick-walled cylinder, by pistons pushing in on either side (see Fig. 1). The main challenges faced in the optimisation of the performance of these cells are related to the choice of materials in general (but, in particular, for the cylinder and pistons), as well as, obtaining



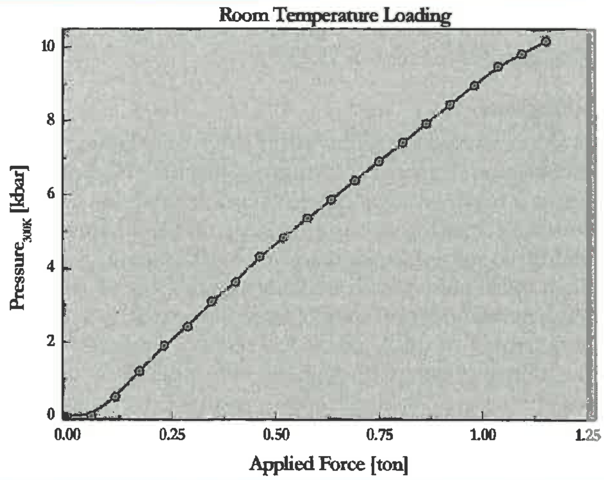
▲ Fig. 1: Basic principle of the piston-cylinder type pressure cell.

robust feedthroughs for wiring (if required). These must be allied, of course, to accurate design and precise engineering if such high-pressures are to be maintained whilst avoiding leaks.

In order to maximise working pressure one needs to look for materials with the highest tensile strengths, as well as, modifying the internal stress distribution of the cell. As far as materials are concerned, beryllium copper is one of the most widely used materials in the construction of cylinders for hydrostatic cells. It is relatively non-magnetic, and has an ultimate tensile strength of the order of 1.5 GPa. Matsumoto (2002) has compiled a useful list of other suitable materials. We have carefully chosen the materials for our cells depending on the maximum pressure to be achieved as well as the type of measurements that will be undertaken. Hence, for example, for our high-pressure cell for magnetisation, we have selected appropriate materials that, when combined in the cell, give a total low magnetic background. Figure 2 represents a 3D solid modelling exploded view and description of this cell.



▲ Fig. 2: 3D modelling exploded view of easyLab Mcell 10.



▲ **Fig. 3:** Typical loading curve of the easyLab Mcell 10 at room temperature.

Employing special techniques, such as, using short tapered plugs, using gaskets to support the plugs, etc, can modify internal stress distribution. However, in order to achieve the highest possible pressures with this construction, interference fit needs to be employed. Interference fit is achieved by the insertion of various cylindrical shells into each other. By force fitting an inner 'liner' inside an outer jacket, the zone close to the bore is put under compression, while the outer regions are put under tension. Hence a 'double-walled' piston-cylinder high-pressure cell that is prestressed in this way has a more favourable stress distribution when loaded than a conventional single-walled cylinder cell. This is because the outer regions carry a higher tensile load, thus pushing up its tensile limit. Thus, depending on the maximum pressure required for experimentation, our high-pressure cells employ these methods. Our cell for magnetisation is a single-walled cell, which achieves pressures in excess of 1 GPa. On the other hand our high-pressure cell for electrical measurements employs a double-walled construction.

The making of consistently reliable electrical feedthroughs is an art on its own. Although there are many known methods of introducing electrical leads into high-pressure cells, the most attractive involves the use of a tapered cone stopper (Eremets 1996). Wires are passed through the hole and glued into position by using, say, epoxy resin. Although this sounds trivial, extensive care needs to be applied when undertaking the preparation of such parts. The metal surfaces must be impeccably clean, dry and warm. The epoxy needs to be degassed prior to use. Any imperfections on the seal will translate into failure. We have developed our own techniques for obtaining reliable feedthroughs. Furthermore, our feedthroughs come already wired with the necessary (room and low temperature) resistive manometers.

Typical Results

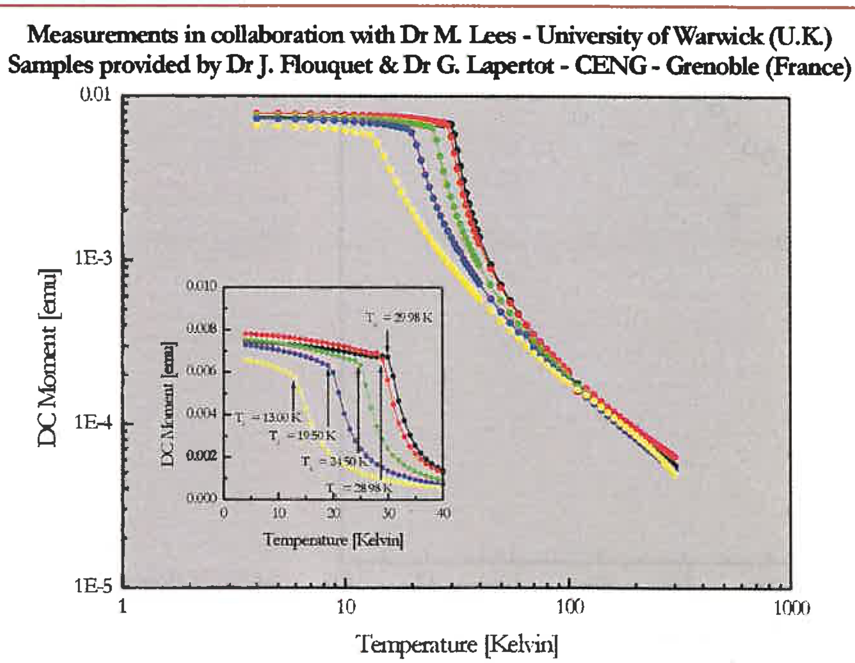
easyLab currently offers three different piston-cylinder pressure cell modules to the market:

easyLab Mcell 10 is a high-pressure cell module that was specifically engineered for magnetometry under high-pressures up to above 1 GPa. It is fully compatible with commercially available squid magnetometers.

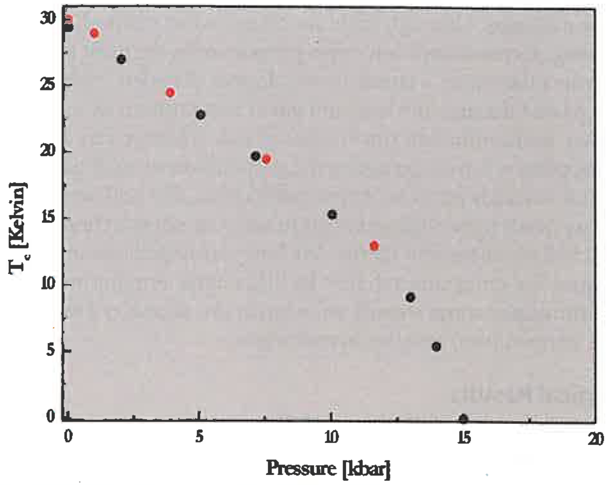
easyLab Pcell 15 and Pcell 30: these modules enable transport measurements up to 1.5 and 3 GPa, respectively. Although they were engineered to seamlessly integrate to Quantum Design's Physical Properties Measurement System platform, these modules may also be used in dilution refrigerators, 3He and 4He cryostats, as well as cryo-coolers or any other cryogenic platform

The concept behind these modules is to provide the novice as well as the advanced user with all the required tools to easily set-up, apply and release the pressure of the cell. We have engineered a range tools and accessories to facilitate these various steps. Thus, for example, the setting up time of the easyLab Mcell 10 is typically of around 30 minutes, including sample mounting, pressure cell setting up, pressurisation and mounting on the squid magnetometer. Figure 3 shows a typical pressurisation curve at room temperature for this cell.

As an example of the application and use of this high-pressure cell module we have measured the DC magnetisation of the itinerant ferromagnet MnSi in a squid magnetometer from Quantum



◄ **Fig. 4:** DC magnetisation of MnSi measured at 200 Oe for pressures 0, 0.99, 3.88, 7.56 & 11.63 kbar.



▲ Fig. 5: Magnetic phase diagram of MnSi as function of applied pressure.

Design, model MPMS-XL5.5. This work was carried out in collaboration with Prof. D. McPaul and Dr M. Lees from the University of Warwick (U.K.). The samples of MnSi were kindly provided to us by Dr J. Flouquet and Dr G. Lapertot from the CEN.G in Grenoble (France).

The graph in figure 4 shows our data. Pressure was regularly increased from ambient pressure to 11.6 kbar. The pressure effect is clearly observed in the data where the magnetic transition temperature is greatly reduced under pressure from 30 K to 13 K.

Based on these results, the magnetic phase diagram as function of pressure of MnSi can be compared with the published results, as shown in figure 5. The red points represent the results obtained with the easyLab Mcell 10, whereas the black points are previous results published by C. Thessieu et al. (1995).

Naturally we have also undertaken the same exercise with the modules of the Pcell range. Thus, for example, figure 6 shows the loading curve of the easyLab Pcell 30.

Conclusions

easyLab Ltd is based in Egham, Surrey (UK) at the Enterprise Hub, Royal Holloway, University of London. The prime objective of the company is to provide innovative solutions for materials characterisation. We do this by offering a 'materials characterisation' service for industrial and academic clients and by developing, in-house or through collaborations with academics, equipment which extends the current boundaries of measurement into extreme conditions.

In this paper we discussed the first series of products launched by the company: hydrostatic high-pressure modules for cryogenic and high magnetic field use. High-pressure is no longer a specialised tool. It has become vital to fields ranging from geophysics to optoelectronics, from polymers to the production of vaccines. Here we concentrated on the study of new materials, in particular, magnetism and superconductivity. We described some technical aspect of achieving high pressures (up to 3 GPa) and also presented some typical results that can be obtained with our modules, which demonstrate some of their capabilities. Please visit www.easy-Lab.co.uk for further details.

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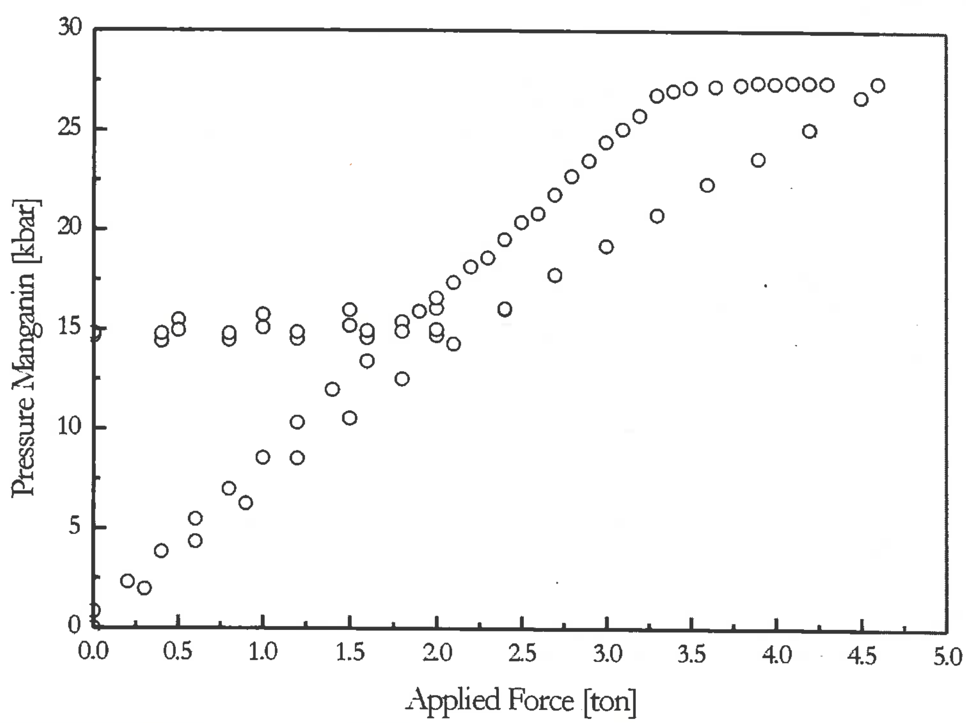


◄ Fig. 6: Room temperature characteristic loading curve of the easyLab Pcell 30.

Advanced electrochemical process research

Prof. Frank Gielen, Prof. Johan Deconinck, Dr. Leslie Bortels, Vrije Universiteit Brussel (VUB), Brussels, Belgium

Elsyca is a research based spin-off company of the Vrije Universiteit Brussel (VUB, Brussels). Elsyca combines 20 years of research and expertise in the domains of electrochemical transport processes and 3D fluid dynamics. The research has resulted in a number of software tools that allow a very fast and precise simulation of 3D electrochemical processes that are used in industrial applications: chemical reactor design, galvanics, electrochemical machining (MEMS) and electronics.

Elsyca's software products replace expensive "trial and error" testing, reduce design and material costs and improve the product & process quality.

Although Elsyca was founded in 1997 its history goes back to the seventies when the department of Electrotechnical Engineering (ETEC) of the VUB began modelling electrochemical cells. Jointed research work with the VKI (von Karman Institute for Fluid Dynamics) has extended existing knowledge with sophisticated models of mass and charge transfer. In 2003, Elsyca received a first round of venture capital financing from BI^3, the seedcapital fund of the VUB.

Scientific basis

In 1976, the ETEC research group of the VUB started to become involved in industrial consulting contracts related to electrochemical processing (i.e. anodising). One of the goals was to optimise the electrical parameters of the electrochemical reactor in order to obtain a homogenous deposition of material on the anode. This consulting work was the basis for the first computer simulation program that allows the optimal form of an electrochemical reactor to be calculated.

The first simulation models were based on the Potential model and are coupled with potential drops in electrodes and electrical networks such that they form closed electrical systems.

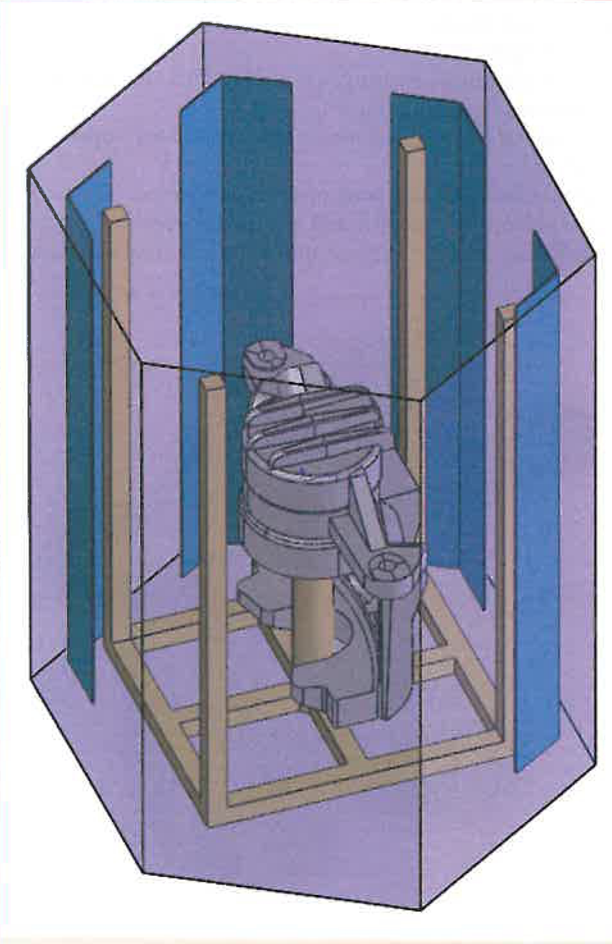
Further research and feedback from industry showed that the simulation results could be improved by taking into account other phenomena in addition to the electrical parameters. By 1985, the Ph.D research work of Johan Deconinck had demonstrated that electrode motion and the changing shape of the electrodes (due to the deposition of material) had a significant beneficial impact on the models. They were included in the simulation model and are continuously being improved in order to deal with time dependent processes such as electroforming, electrochemical machining and corrosion.

In the next phase of the research it became clear that the motion of ions in the liquid and the mass transport phenomena transport due to convection, diffusion and migration needed to be taken into account. Herman Deconinck, the brother of Johan and a professor at the VKI is an expert in numerical fluid mechanics. This was the ideal basis for a jointed multidisciplinary research project between VUB and VKI. From 1992 onwards, VUB and VKI were awarded research funding from consecutive European Brite-Euram programs. This resulted in the development of numerical solvers for laminar and turbulent fluid flows. Those solvers are needed in the multi-ion transport and reaction models where there is interaction between the electrochemistry and the fluid flow.

VUB/ETEC and VKI are continuinge their jointed research to improve their models for electrochemical processes. Some of the more recent research topics include electrochemical processes in electro-osmotic flow and gas-evolving electrochemical processes with two-phase flow.

From science to spin-off

Today universities are asked not only to play an active role in science and technology research but also in turning their research into innovative applications. To support this new role the VUB has created the appropriate context, structure and processes. The VUB R&D interface group actively manages the university's contract research and patent portfolio and it has developed the necessary mechanisms to support the creation of spin-off companies. VUB R&D promotes the support for collaborative research with industry and continuously raises the awareness of the young researchers towards technology transfer and knowledge exploitation. VUB R&D has also invested heavily in the creation of competencies and tools that are needed to turn research into potential commercial applications such as the development of



▲ Fig. 1: Elsyca's software visualizes a 3D model of a virtual chemical reactor.

business plans and access to seed capital with the creation of the BI³ fund in 2002.

In this environment the VUB/ETEC team had all the ingredients that are needed to create a successful venture: the many years of outstanding multidisciplinary scientific research that provide a solid basis for the development of industrial applications; while the long track record of collaborative research with many diverse partners from industry that has given the team a good insight into the types of industrial problems that they could solve with their technology. Add to that the ambition and drive of a motivated team and you have a new spin-off company: Elsyca was created in 1997. Under the impetus of the EC Value program and with the aid of the Value Relay Centre of the Flemish Government, a technology transfer contract has been agreed between the VUB, VKI and Elsyca.

Elsyca first started as a consulting company that offered simulation software and engineering solutions for electrochemical applications. Elsyca's industrial objectives consist in applying the technology of electrical, fluid flow and electrochemical modelling for:

- consultation in the field of cathodic protection and electrochemical engineering,
- provision of unique CAD integrated state-of-the-art simulation software and expert solutions that enhance the process design, the production tools (reactors) and the products for the electrochemical industry.

Applications are found in plating processes for micro technology, semiconductors, automotive, aerospace & aeronautics. Some examples are:

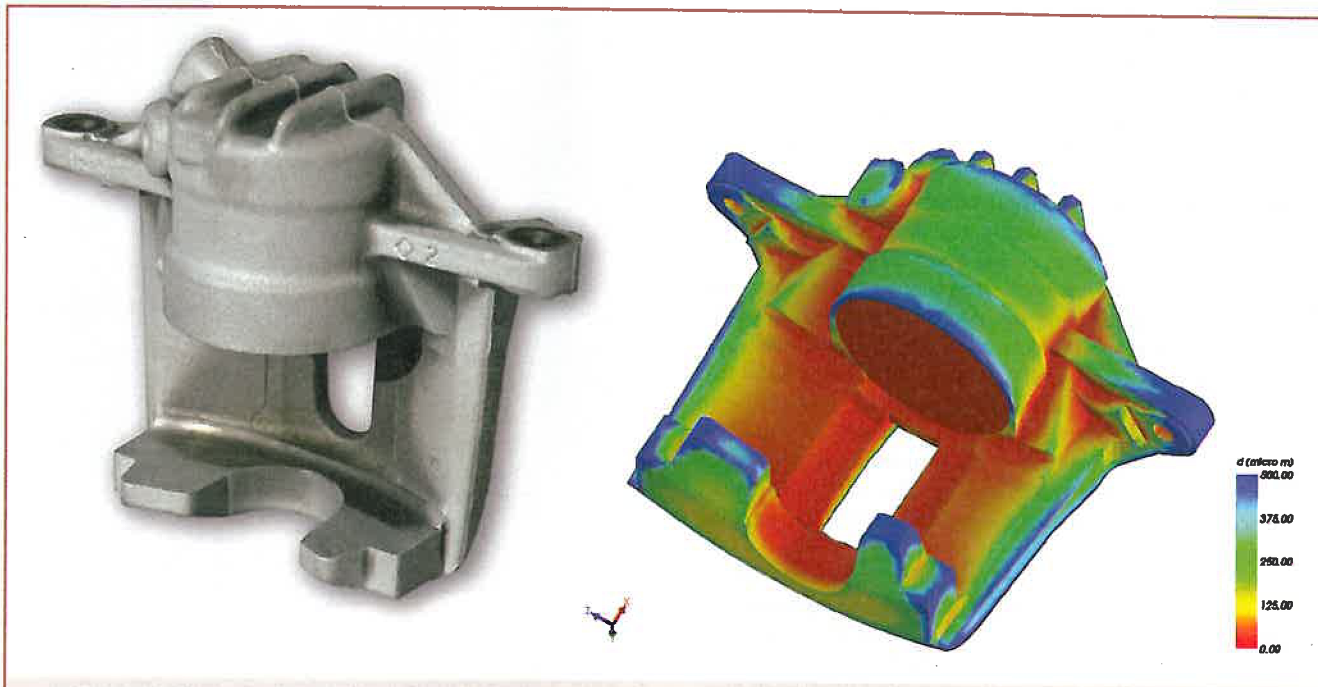
- Electrochemical etching, anodizing and electrochemical colouring of aluminium;
- Design of high speed plating processes for copper, zinc and tin;
- Electrochemical machining of steel work pieces;
- Electroforming of copper and nickel work pieces;
- Modelling of cathodic protection of buried pipes and tanks;

The high levels of qualifications of the team combined with diverse and extensive industrial experience provide the perfect resource mix needed to successfully tackle and solve real-life problems. As a result, Elsyca is able to perform high-level electrochemical consulting and electrochemical simulations (predictions/optimizations) that are very close to reality and in line with market requirements. The products and services of Elsyca create value for their customers at different levels:

- Faster time-to-market: No more need for numerous time-consuming trial-and-error lab experiments. ElSyca's software creates a virtual electrochemical reactor and simulates the effect of different combinations of parameter settings in minutes in stead of weeks. [Figure 1]
- Cost reduction: The customers spend less time in their laboratory and the improved process parameters allow faster production. There is no more post- processing to eliminate excess material deposits and in general less material is used in the improved electrochemical production process.
- Better quality: The optimization of the process parameters creates higher uniformity while the software tools allow to find higher quality process configurations to be found which would never be identified by using lengthy laboratory experiments.

Over the years, this knowledge and experience has earned Elsyca the business of many leading companies including Robert Bosch, Agfa, Corus, Bekaert, Philips, Andreas Stihl, CERN, EADS, Kohler Mira, Kogas, Gasunie and many others.

In 2002, the success of the consultation services made Elsyca decide that there was a need to transform the software tools used by the consultants and scientists into professional software packages that could be sold together with services to their customers. In order to grow their market and develop the professional software products, the company started to look for external financing. This financing was provided by BI³, the seed- capital fund of the university.



▲ Fig. 2: Simulation of material deposit on a brake caliper.

This has helped Elsyca to create a unique integrated- value proposition based on virtual design. Elsyca's approach allows customers to model their electrochemical reality, accounting for the physico-chemical parameters of the electrolyte bath, the complete geometry of the electrochemical cell, the electrode reactions and all process parameters ranging from flow rates to DC or pulse reverse parameters. This methodology is applied and encapsulated in all of Elsyca's engineering services and software solutions. Moreover, product development is highly application-oriented, led by customer requirements in several markets.

Elsyca has proven that... an academic spin-off can become a leader in a niche market.

In 2003, Elsyca reached the commercial and technical targets that were included in the business plan. For 2004, the revenues and growth rate are expected to exceed the business plan.

Conclusion

Elsyca has proven that despite the lack of size, resources and a new undiscovered market, an academic spin-off can become a leader in a niche market. The focus of the VUB/VKI research and the ability to identify meaningful applications are important success factors. However, equally or even more important is the fact that Elsyca started as a consulting company. This was not only a way to generate cash in the early days of the company but it has also put the engineers in direct contact with the market and the customers. Since Elsyca had (and still has) to create its own new market this is more valuable than any overpriced market-analysis report. Finally the team had the vision to hire commercial and business oriented people and to look for external financing at the right moment. Today Elsyca has the talent and the team to implement its vision and move to the next stage of their development: to become a global leader in electrochemical intelligence.

About the authors

Johan Deconinck received his M. Sc. Degree in Electromechanical Engineering from the VUB, in 1976 and the PhD degree in Applied Sciences in 1985. Since 1998 he is professor of Electrical Engineering and Electromagnetic Field Theory of the VUB and is head of a research group performing "numerical electrochemistry".

Leslie Bortels received his M.Sc. degree in electrical engineering from the VUB in 1992 and his Ph.D. degree in electrical engineering in 1996. He joined the Electrotechnics Department from Technical VUB in 1992. He is a NACE certified cathodic protection technician.

Frank Gielen received a Master degree in Telecommunication System Engineering from the Royal Military Academy in Brussels (1985) and has a Ph.D. in Computer Science from the VUB (1993). Since 2002 he is senior investment manager of BI3, the seed capital fund of the VUB, where he is responsible for dealflow generation, capital raising and hands-on interim VUB management activities for the newly created spin-offs.

At the crossroads of physics and archaeology: the OSIRIS Project

Y. Renotte[a], D. Laboury[b], B. Tilkens[a], V. Moreau[a], M. Morant[c]
[a] Hololab, Dept. of Physics, University of Liège, allée du 6 Août, 17, B-4000 Liège, Belgium
[b] Egyptological Dept. and European Center for Archaeometry of the University of Liège (ECA), University of Liège, quai Roosevelt, 1B, B-4000 Liège, Belgium
[c] Interface Entreprises-Université de Liège, quai Van Beneden, 25, B-4020 Liège, Belgium

Archaeology, as the Science which studies the material remains of human behaviour, naturally stands at one of the crossroads between the human Sciences and Science (physics, chemistry, biology, etc). This connection is precisely a way to define what nowadays it is customary to call Archaeometry, that is the combination of laboratory techniques with the traditional methodology of the historical and archaeological investigation to deepen the analysis, the knowledge and the interpretation of ancient works of art, monuments and archaeological objects. Archaeology is also permanently confronted with the problem of recording the objects of its study, since excavated relics of the past are always exposed to a progressive and often irremediable process of defacement, and, finally of annihilation. In order to find a solution to this important and still unresolved problem, the OSIRIS Project aims to develop one or several devices that allow by optoelectronic process-

▲ **Fig. 1:** Moiré effect on an Ancient Egyptian Relief *(copy of the relief Brussels MRAH E 2157)*

features

es an accurate, quick and easy to use, recording dedicated to the specific and demanding needs of archaeological research.

The traditional recording techniques in archaeology and art history [1-6]

The recordings needed by the different aspects of Archaeological research have a double aim: the creation of a medium that allows one to display in a more accurate way the object studied; and, even more importantly, the virtual conservation of this object, or, at least, the conservation of the historical information it reveals and preserves.

The conservation of archaeological objects is far from simply being a theoretical problem. Indeed, in its very process of revealing the relics of the past, Archaeology is by definition destructive: it always destroys the containment of the object it aims to reveal.

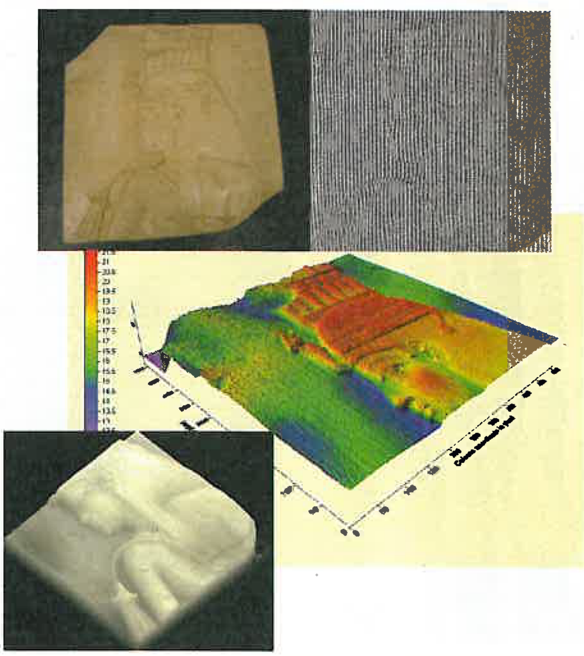
To counter this progressive and irremediable annihilation of the material remains of the past, Archaeology uses different recording techniques like photography, drawing... But all these techniques have a common rather poor flexibility and an unavoidable dependence on the subjectivity of reading and rendering of a human operator (Traunecker [6], 1987; Loeben [4], 1996).

Recording in Archaeology and Art History raises two essential problems, related one to the other: on the one hand, the objectivity, and on the other, the speediness and the flexibility of realisation.

The solutions offered by numeric image and optoelectronic technologies

To overcome these inherent constraints of the traditional recording techniques, it is necessary to use new technologies of recording, processing and storing the data that define the precise 3D shape of any archaeological object.

Nowadays, numeric image technology offers an almost infinite flexibility of use. Recent developments in Optoelectronics now allow a real global 3D recording that is at the same time faster and more reliable. These new technologies give enormous advantages regarding the flexibility and the ease of recording, processing, reading and storing; they also offer the possibility to imagine new ways of publishing ancient monuments, in an electronic form that is more realistic, more accurate and more interactive, as a real 3D structure and not anymore by means of fixed and inaccurate 2D images.



▲ Fig. 2: Detail of a 3D recording of the same relief with the projected moiré technique.

The available techniques [3-6]

There exist a few projects of global scanning of ancient artefacts (Clarke [3], 1998; Taubes [5], 1999). But, until now, none of the already available techniques is able to work in real in situ conditions (for example under the sunshine of Egypt), on a large scale, and with the precision needed for archaeological and art historical research.

For example the optical recording of the relief of an object can be achieved by the well-known linear scanning method. Many tests have revealed that it is very difficult to use this system with high precision in aggressive environmental conditions such as those found in many archaeological sites.

The main problem of the scanning method, that is the problem of moving precisely the scanning laser line, can be eliminated by projecting a constructed pattern or a grid instead of one single line. Its deformation is then used as the probe of the relief. This light pattern has to be periodically structured and static, based on a grid that is alternatively light and dark. One projects it on the surface to be analysed. By recording the scene with a CCD/CMOS camera, it is possible to superimpose the image of the grating modified by the relief with the reference image. This process creates geometrical shapes (Figure 1); it is the Moiré effect.

The interpretation of these Moiré pictures gives the whole relief information of the analysed object (Figure 2). The accuracy of this technique is comparable with the accuracy of the traditional laser scanning but its process is much faster, since a surface of one square meter can be analysed at one time. Besides, the elimination of the problems linked to the precise and regular moving of the laser line makes it much easier to use in difficult in situ conditions. The Moiré technique perfectly fulfils the requirements of archaeological recording: fast acquisition, accuracy, robustness and flexibility, necessary to allow working on site, in aggressive environmental conditions.

Results of the OSIRIS Project

As a conclusion to this work, the European Centre for Archaeometry of the University of Liège, with the Hololab Laboratory have developed together a complete portable set-up (combining the whole optoelectronic acquisition and data processing) specifically dedicated to the quick and accurate numerical 3D recording of archaeological documents. It uses the projected Moiré technique. This project is named OSIRIS (Optical Systems for Interferometric Relief Investigation and Scanning), in a reference to Ancient Egypt's heritage, whose study was at the root of the above mentioned research*. For this application in the field of archaeology and art history, the following conditions have been defined:

- Depth resolution: 0.1 mm; lateral resolution: 0.3 mm
- Depth range 20 cm
- Acquisition surface 50x50 cm^2 - 1 m^2
- Adaptation to on site working conditions (temperature, sunlight, ...)
- Flexibility and easiness of transport and use
- Complete processing software (acquisition, multiple 3D visualisation possibilities, modelling, metrology, computer assisted interpretation, automatic features extraction, ...)

*Furthermore, Osiris is precisely the Ancient Egyptian God of periodical and cyclical phenomenon.

Since these conditions are very demanding in comparison with the capabilities of 3D recording devices already available, other fields of application are under consideration.

The results of the OSIRIS Project allow us to imagine for the near future new possibilities for scholarly publication of ancient monuments, i. e. in an interactive digital 3D virtual reality, directly usable for scientific research, as if one was actually in front of the real object.

From the OSIRIS Project to the DEIOS Company

Since 1998, the policy of the University of Liège has been to boost spin-off activities. An internal regulation has clarified the rules for researchers for intellectual property (IP) rights and for setting up companies. In 1999, Spinventure was established in a 50/50 based joint venture between Gesval and the local public investment company Meusinvest. Spinventure is a pre-seed and seed capital fund, only focused on high-tech companies. Together, they have set up more than 35 companies in 5 years.

In addition, an incubator dedicated to physical science and engineering has been installed in the Liege Science Park, just near the campus : Wallonia Space Logistics (W.S.L) can provide not only pre-seed financing, but also full support for starting a company, with space, logistic support and mainly commercial support.

On another hand, the entrepreneurial spirit is diffused in the research community through seminars, courses and events organised by the Entrepreneurship Centre of the Business School of the University (SEED).

In due time, the research team has entered in touch with the Technology Transfer Office of the University (Interface Enterprises-University and Gesval , an affiliated company of the University of Liège in charge of technology transfer) in order to build a IP strategy within the research project.. IP mapping has been set up by the Patlib Centre, which is an internal service of the TT Office. Of course, the research team had to maintain full confidentiality for their project, including scientific publications or connexions with possible investors. This is a necessary choice of the team, until the patent application is consolidated by the patent manager. Several provisional applications have been decided in order to get finally a package of technical and patentable information available for the patenting procedure.

For obtaining more practical results, the Walloon government proposes the so-called First Spin Off program, aimed at finalising the research up to a functional product. Such a program enabled one to obtain a prototype of the Osiris device.

Then Gesval and the TT office help the research team to set up a step-by-step business plan, and to enter into connection with other players.

At the end, Gesval brings the technology to the new company, Spinventure brings money, researchers bring money too, and the first round is completed by experienced people from industry, investing and acting as coaches.

Conclusion

The projection and the reading of the pattern of fringes is made by an original set-up based on a Diffractive Optical Element System [7-8].

Today the OSIRIS Project has given rise to the so-called start-up DEIOS (Development and Enhancement of Interferometric Optical Systems) which develops the scanning tools (Figure 3). Deios was established by early 2004, with a total capital of Euro 500.000, and is installed in the W.S.L. incubator.

Acknowledgements

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- The Région Wallonne (DGTRE - First Spin Off project)

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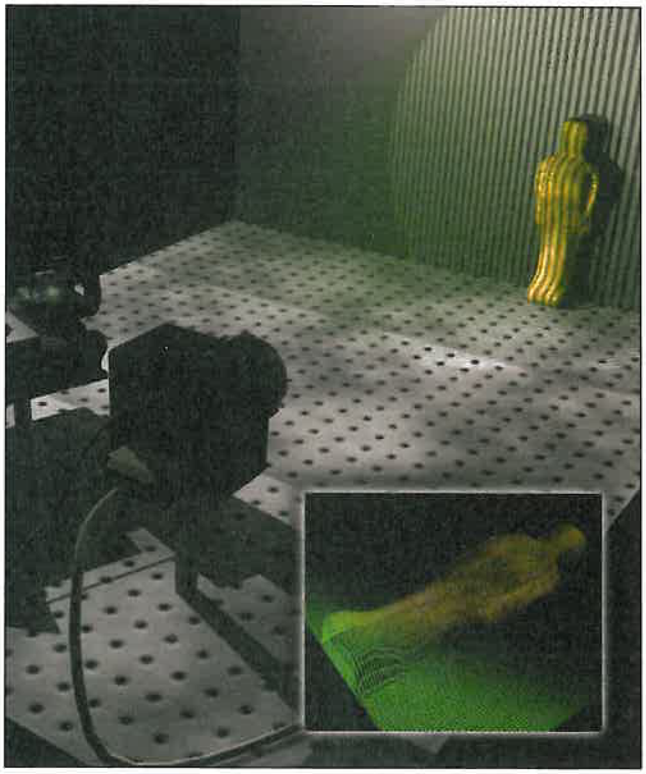


◄ Fig. 3: D scanning set-up developed by DEIOS s.a.

features

A new computer mouse called Horse

C.J. Snijders and P.C. Helder,
Erasmus MC, University Medical Center Rotterdam,
the Netherlands.

In the early 60's Doug Engelbart, a scientist at the Stanford Research Institute in California, invented the computer mouse. This may certainly be seen as one of those brilliant tools we hardly can do without. However excellent the functionality of the mouse—we all use it with great ease—its recent form can also be a significant source of discomfort.

Repetitive movements cause physical complaints. This is one of the causative factors of Repetitive Strain Injury (RSI) or Occupational Overuse Syndrome (OOS) [1]. Rigid work patterns and prolonged periods of heavy work load can result in physical stress. Personality aspects are also considered to play a role in the development of RSI [2].

About 20% of the working population has complaints related to the neck-shoulder-arm region and overuse complaints can be the result of using the mouse. This is why a biomechanical research program was started by Erasmus MC, University Medical Center Rotterdam, the Netherlands.

Biomechanical model

The present study has identified one cause for several physical problems in the neck-shoulder-arm region.

Based on a pilot study a hypothesis was introduced that forceful gripping or pinching goes with tension in the deep neck muscles. To investigate this, blood flow velocity was measured in the region indicated in Fig. 1 (with permission from Sobotta, Atlas of Human Anatomy).

The drawing shows the costoclavicular gate between clavicular bone and first rib (see circle).

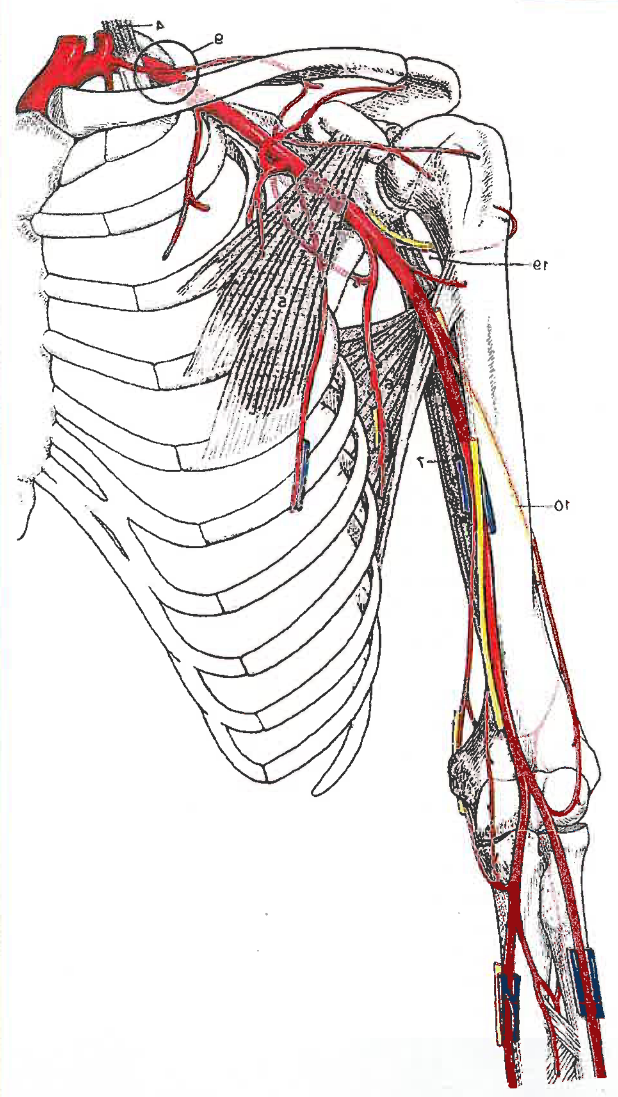
Neck muscle tension results in a narrowing of this gate and thus impingement of the subclavian artery and vein.

This conclusion is supported by a biomechanical model of the aetiology of tennis elbow [3]. It describes the role of extensor muscles in the hand and lower limb and substantiates the finding that restriction of blood flow is caused by forceful pinching. Therefore we conclude that certain force application by the hand is related to tension in the deep neck muscles which explains a variety of shoulder- and arm complaints.

Design of a computer mouse called "Horse"

The use of a conventional computer mouse requires continuous lifting of the fingers. This results in excessive use of extensor muscles to avoid unwanted switching which can be seen as a possible cause of tension in the deep neck muscles. It was therefore decided to design a mouse that does not provoke extensor muscle activity.

This new concept is called Horse in view of its functional design: the palm of the hand as well as the middle three fingers "sit" on the main body while thumb and little finger rest at a lower level at the side as if supported by stirrups (Fig. 2). Thumb and little finger work together to realize optimal control in the horizontal (X-Y) plane. The design of the Horse allows for the three middle fingers to adopt a flexed position to relax the tendons. A major part of these fingers rests in a more or less vertical position.



▲ **Fig. 1:** Narrowing of costoclavicular gate (see circle) resulting in impingement of artery and vein (with permission from Sobotta, Atlas of Human Anatomy)

In view of this supported position of the hand and fingers, extensor muscles can relax.

Extensor action is no longer required with the palm of the hand and fingers resting on the Horse. A light flexing action of the top of the fingers is sufficient to switch. This action results in a force on the touch switches situated at the lower end near the tips of the fingers.

These switches react on touch force only which reduces or virtually eliminates the movement of the tendons when switching. Moreover, complete support of the fingers will reduce the necessity of co-contraction of the intrinsic muscles of the hand [4]. Other features as a result of the design of the Horse are:

- a better stability control in the X-Y plane
- the possibility to reduce friction of the Horse on the table top

▲ Fig. 2: Thumb at the side, major part of the three fingers more or less vertical, finger tips touch at the side of the switches.

Result of development

A working concept of the Horse was produced using Rapid Proto Typing (RPT). This technology generates prototype bodies directly from 3D Computer Aided Design (CAD) files.

The electronics of a conventional mouse were installed in the RPT body. The prototype was then tested in a day-to-day working environment. Horse and mouse could thus be compared.

Figure 3 shows a hand on the Horse manufactured by means of RPT and on a conventional mouse. Relevant joints, phalanges and transversal contours are indicated in red clearly showing the difference between the two.

▲ Fig. 3: RPT Horse, relaxed hand; conventional mouse, stressed hand.

Production

A working concept of the Horse was produced using Rapid Proto Typing (RPT). This technology generates prototype bodies directly from 3D Computer Aided Design (CAD) files.

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Conclusion

The combination of fundamental research based on the anatomy of the human body and the availability of state of the art technology, enables the production of small series of custom made products prior to large-scale production. In this case the development and production of a computer mouse which aims to provide an appropriate extension of the human body.

The selected approach aims at reducing the risks involved with market introduction of new products.

About the authors

Chris J. Snijders, PhD, Erasmus MC, University Medical Center Rotterdam
Research on biomechanics of low back and pelvic pain and on neck-, shoulder- and arm-problems. Product design for a number of medical disciplines.
Teaching: undergraduate and graduate courses for medical and engineering students in theoretical mechanics, biomechanics and product design.

Paul C. Helder, MBA, BA, BSc
Management of innovation, as member of the board of commercial organizations involved in various developments that combine mechanical engineering and biotechnology.

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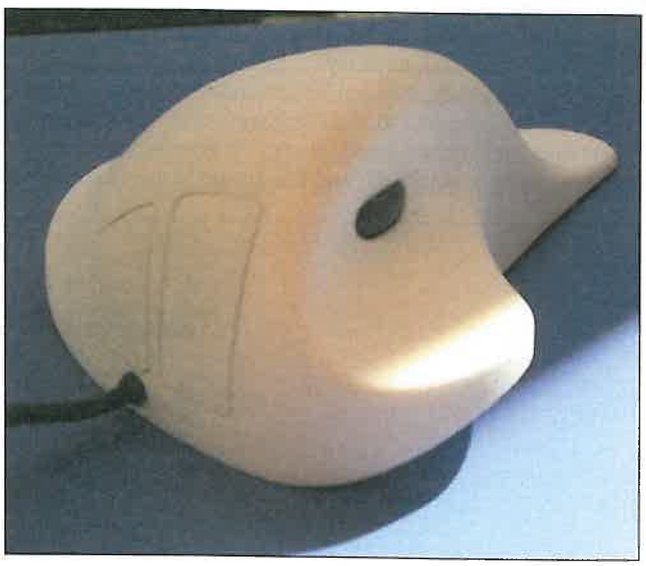


▲ Fig. 4: Front view of the Horse manufactured by means of RPT with touch switches and scrool wheel.

Future challenges for nuclear energy in Europe

Kevin Hesketh, BNFL
Andrew Worrall, BNFL
David Weaver, University of Birmingham

Although it cannot yet be considered proven, all the indications are that man-made global climate change is already with us. Although it may take a little longer to prove beyond doubt, in the mean time the only sensible approach is to apply the precautionary principle and to take pre-emptive action. Recognising the importance of these arguments, the European Union has committed itself to meeting the Kyoto Protocol and the recent commitment to meeting a target of 22% of electricity generation from renewables by 2010 is encouraging. The central problem is finding a means by which developing countries can improve their living standards while limiting global carbon dioxide emissions. The developed countries have a moral responsibility to take the lead.

Although the theoretical potential of renewables is very large, placing total reliance on renewables is a risky strategy. Surely a more sensible strategy is to aim for a balanced mix of generation options, using all the options available, including nuclear? The practical difficulties of biomass, wind, wave and solar energy make it a very difficult prospect to meet the target for renewables. Although rapid progress is being made, investment in renewables has so far only been possible with the aid of large subsidies and it is arguable whether they will ever be fully competitive unless electricity prices rise well above current levels. It is ironic that while political support for renewables is relatively easy to come by, this is not presently the case for nuclear power that has for years been helping to reduce carbon dioxide emissions.

Nuclear generation in Europe is already contributing towards reducing carbon dioxide emissions and the European Union would be hard pressed to meet its Kyoto targets without it. Yet apart from Finland and France, there is little government support for new reactors to be built and the prospects are that Europe's nuclear electricity capacity will decrease as old plants reach the end of their lives. If we are not to lose the valuable contribution nuclear generation is already making to carbon dioxide reduction, action is needed now to ensure that new nuclear plants are built to replace old ones as they close down. In the short term, replacement plants will be evolutionary light water reactors (LWRs) such as the European Pressurised Water Reactor (EPR), the first examples of which will be built in Finland and France. Such plants are economically competitive and have a demonstrably good safety pedigree. But in the longer term there is now an international consensus that the so-called Generation IV reactor designs will be needed (see Figure 1).

The motivation behind the Generation IV Initiative, is the recognition that maintaining global nuclear capacity at its current level of roughly 400 GWe will be insufficient to stabilise carbon dioxide emissions in the longer term against a background of increasing energy demand, even if a substantial contribution from renewables is realised. What would be needed would be reactors which could deliver the higher capacity in a manner which would be regarded as long term sustainable. The judgement is that evolutionary LWRs would not be able to fully meet this requirement and this has led to the drive for Generation IV reactors.

Generation IV reactors are intended to satisfy demanding criteria under safety/reliability, long term sustainability, economic competitiveness and proliferation resistance. Generation IV designs would emphasise inherent safety and fault tolerance and it is believed that this would enhance public confidence by making the safety arguments more transparent and accessible. Improved sustainability would extend nuclear fuel supplies into the long term future by recycling used fuel and also enable nuclear to contribute outside the electricity generation sector to include transport by utilising the hydrogen economy. Generation IV reactors would, ideally, be economically competitive without having to invoke any externalities such as carbon credits; their design and construction would minimise investment risks to encourage private investment in deregulated markets. Finally, Generation IV fuel cycles would aim to minimise the inventories and accessibility of weapons-useable materials.

Six reactor systems have been chosen because of their potential to meet the Generation IV goals. These are the gas-cooled fast reactor (GFR), lead-cooled fast reactor (LFR), molten salt reactor (MSR), sodium-cooled fast reactor (SFR), super-critical water reactor (SCWR) and the very high temperature gas reactor (VHTR). While most of these systems can claim, at least to some extent, to build on existing knowledge and experience, they all push the boundaries of existing technology quite far. The Gener-

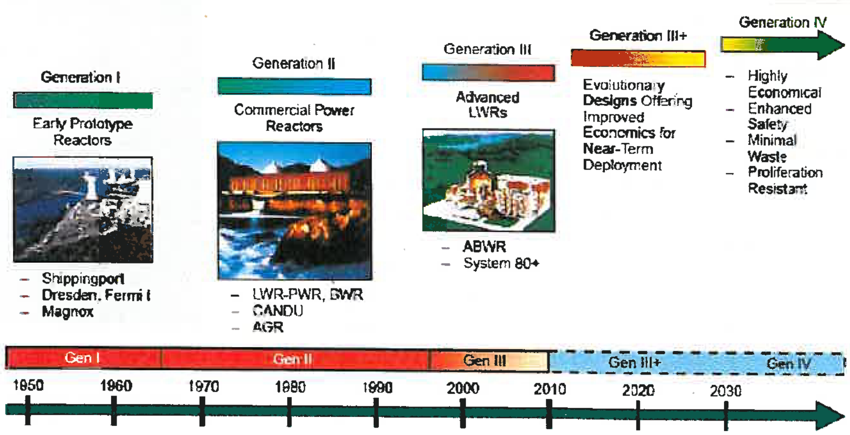


Fig. 1: The Generation IV initiative is targeting reactor deployment by around 2030

ation IV Roadmap[1] has identified all the technological gaps that would need to be addressed for each system. Many of these are common to more than one system and the Roadmap identifies several areas where cross-cutting R&D will be required. One of these is fuels and materials; this is useful to highlight here because it illustrates the R&D timescales needed:

The periods of time for selecting, testing and commercial implementation of new materials for nuclear fuel and primary circuit structural components are all very long; even with a fully committed R&D programme as envisaged in the Generation IV Roadmap this phase is expected to last almost 20 years (see Figure 2). The principal reason is the need to conduct extensive irradiation tests to prove the durability of materials under the intense radiation and temperature fields. This constrains the earliest timescale on which Generation IV reactors could be introduced. The necessary R&D will also be very expensive and no single country has the necessary facilities and expertise to carry it out alone, hence the need for international collaboration.

Europe is playing a full role in the R&D needed to underpin Generation IV system. Three European countries (France, Switzerland & UK) are members of the Generation IV International Forum (GIF) in their own right and the EU has now joined, being represented by Euratom. The European contribution is being coordinated through the Euratom 6th Framework programme, which has been developed with Generation IV very much in mind. Several of the proposed projects will form a distinctive European contribution, particularly for VHTR and GFR, which are seen as the top priorities in Europe. The total value of the 6th Framework projects is yet to be determined, but is expected to be in the region of Euro 20m to Euro 40m over a 5 year period.

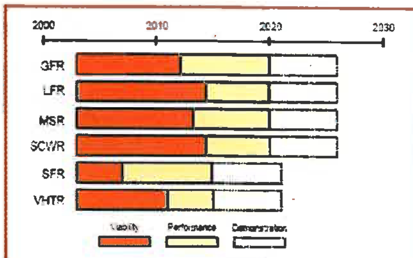
Considering the long R&D timescales and the large expense, it is apparent that the Generation IV reactors will not be able to break into the commercial market without first establishing the correct political conditions. Although Generation IV reactors are expected to be economically competitive without subsidies, private investment cannot be expected to support them through the R&D phase. Government support will therefore be needed that is best regarded as an enabling investment that will create future energy options from which the deregulated markets can later choose. This would be no different to the present situation of renewable energy in Europe; the investment in which is only possible because of heavy subsidisation. In the longer term, the objective is that the investment in renewables will be recouped when investment and operating costs decrease sufficiently for renewables to operate without subsidies. Whereas government support for renewables is presently considered politically acceptable, the same cannot be said for nuclear generation in all European countries. Indeed, many European governments are reluctant to associate themselves with nuclear technology and this imbalance needs to be overcome. This is one of the principal challenges facing Generation IV reactors.

Key issues in Europe, if we are to maintain open the possibility of new reactor build, are skills retention and knowledge preservation:

Nuclear power technology needs to be perceived as an active and interesting area if it is to be successful in attracting new graduates in science and engineering, especially with the shortage of students wanting to study these subjects. The stagnation in reactor construction in Europe over the last decade has not been helpful in this respect and there is a real risk of losing the skills base as the present generation retire. The funding of university courses specific to nuclear science and engineering remains uncertain and this does not help to guarantee the involvement of the university sector in the long term.

Knowledge retention is another critical area of concern. Knowledge accumulated over nearly 50 years is in danger of being lost. Much of this knowledge may potentially be relevant to Generation IV systems and it would be tragic if it were lost at this crucial stage. Fortunately there are some examples where active steps are being taken to preserve historic knowledge. For example, in the UK a database is being built up to preserve information pertaining to the UK's sodium cooled fast reactor programme. The monetary investment in this historic work, in current values, is valued at billions of Euros. Preserving it will safeguard a resource that may potentially save much time and effort in Generation IV. Another example of active knowledge preservation is the OECD/NEA's efforts in preserving knowledge in the areas of fuel performance and reactor physics experiments. In addition to preserving the extraordinarily large amount of information, these activities have successfully encouraged the release into the public domain of information that was previously proprietary; there is general recognition that the benefits of open accessibility of the data outweighs narrower commercial interests.

The reasons why most European governments have distanced themselves from nuclear power technology are principally political and societal and are well outside the scope of this article to analyse. However, it is interesting to note that the inherent inertia of the electricity generation industry has allowed governments to adopt positions which are evidently not defensible in the long term, for the sake of political expediency. An example is the commitment of several European governments to phase out nuclear generation without any coherent strategy for replacement power. Such a position has only been possible because nuclear phase-out has largely meant retaining nuclear plants until their operational lifetimes are expired such that very little capacity has so far actually been lost. The approaching imminence of the closure of old plants and the realisation that Europe's Kyoto obligations are looking increasingly difficult to meet are the reasons why there are now signs that some European governments are now starting to reconsider. The long timescales required for the deployment of new reactors means that the options for responding to changing demands are very limited. Some politicians would prefer to defer decisions of Europe's nuclear future until renewables have been given an opportunity to deliver. Unfortunately, by the time this becomes clear, it may well be too late to obtain the fullest advantage of nuclear generation. Even if renewables prove able to meet their target in Europe, they would barely match the contribution that nuclear is already making at present and further carbon savings will be needed. Faced with the extreme dangers of global climate change, the only sensible strategy is to keep the nuclear option open.



◄ **Fig. 2:** The progression of R&D activities is in 3 phases; viability, performance and demonstration

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Address:
MAX-lab, Lund University
P.O. Box 118
SE-221 00 Lund
SWEDEN.
Fax +46-(0)46-222 47 10
http://www.maxlab.lu.se

Contact persons:
Prof. Ralf Nyholm,
tel. +46-(0)46-222 44 52
e-mail ralf.nyholm@maxlab.lu.se
Prof. Nils Mårtensson,
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For further information, please write or call Prof. J-P. Antoine, Chairman of the Department of Physics, chemin du Cyclotron 2, B-1348 Louvain-la-Neuve, Belgium. Tel. +32-10-473283, Fax +32-10-472414, E-mail : antoine@fyma.ucl.ac.be .