Cutting Edge Research from Scotland

Knowledge Transfer

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Foreword

Knowledge Transfer in Engineering and Informatics

This issue of Science Scotland is dedicated to highlighting engineering and informatics successes where Scotland-based research, technology or new knowledge has transferred (i.e. knowledge transfer or KT) into successful innovative companies. This coverage of KT continues our previous features on emerging engineering companies: Renewable Devices and Pelamis Wave Power in our “Energy” issue in Spring 2006; ST Imaging and Microemissive Displays (which regrettably has since ceased trading) in our “Imaging” issue in Autumn 2007; Xilinx, Wireless Innovation Centre, Steepest Ascent and Wolfson Microelectronics in the “Electronics” issue in Spring 2007; and Artemis Intelligent Power (since acquired by Mitsubishi Heavy Industries) and Oxy-Gen in our “Greener Future” issue in Spring 2010.

One of the most financially significant recent commercial KT successes, growing out of an initial £200,000 Proof-of-Concept (SE PoC) funding provided by Scottish Enterprise, was the $275 million acquisition in 2007 by Petroleum Geo-Services of MT EM (Multi-Transient Electro-Magnetics), a rapidly growing 50-person marine geophysical prospecting university spin-out company.

Here we report on 13 companies, ranging in size from four to almost 80 employees, who are active in the sub-sea, space, vibration and renewable energy, as well as marketing and media spheres.

The origins of the companies featured vary widely. The University of Edinburgh was one of four runners-up in the EPSRC 2008 Initiating KT challenge competition, spending its prize money on establishing several modest initiating KT awards. The embryonic company D-Light (“Enlightenment for datacomms”) was started from this fund before securing more significant £200,000 PoC funding from SE. The other small, highly innovative software-based companies covered in this issue are Pufferfish, which produces spherical displays, Xi Engineering Consultants, which develops vibration software, ScienceSoft’s visualisation software for the oil & gas industry, and Cereproc’s text-to-speech products. Mobile Acuity has grown out of the SE-funded Prospekt, Informatics KT support programme. Xi Track, on the other hand, is a University-based technology licencing organisation which has been highly successful in deploying its vibration-allievating product into the worldwide rail industry.

NGenTec, a larger 13-person spin-out, is designing novel direct-drive electrical motors, particularly for renewable energy applications, and has already attracted £4 million of support. It is interesting to note here that both NGenTec and Artemis have competing approaches to improving the operation of off-shore wind turbines. We will thus have to wait and see whether a novel electric motor or new hydraulic gearbox design can be scaled up from the current 1MW design to meet the offshore 6MW turbine requirement and win this lucrative race.

SeeByte is a highly successful 40-person Heriot-Watt University spin-out which provides the world’s most advanced software technology for underwater robots, subsea engineering, offshore technology and remotely-operated vehicles, and is heavily supported by governments and industry worldwide. WFS Technologies, with 25 employees, is an excellent example of an industrial start-up company which has revolutionised underwater communications by moving from acoustic to electromagnetic propagation, enabling, for the first time, communication directly from a submerged submarine to an aircraft. Other examples of this direct route to company formation, included here, are Nautronix, Gas Sensing Solutions and Clyde Space.

We encourage you to read about these embryonic companies who are exploiting their intellectual property (IP) and leading the engineering and informatics technology revolution from their bases in Scotland. To ensure full coverage of Scottish KT, a future issue of Science Scotland will focus on KT activities in the Life Sciences sector.

Professor Peter Grant, OBE, FRSE, FREng, FIET, LFIEEE
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Entrepreneurialism and knowledge transfer: a personal view

Commercialisation is essential to our economic future, but David Milne argues that Scotland-based entrepreneurs and investors should be raising their game – deciding at the start-up stage whether they want to develop exciting new technology or build successful companies able to compete in the global arena and contribute to society at large...

New ideas in science and technology will always be welcome, but governments and funding bodies today increasingly focus on commercialisation – and the need for economic benefit. That is why research grant applications demand routes to market and researchers are encouraged to exploit their results commercially through licensing or direct company formation.

This transfer of knowledge to the market place and consequently to the public at large is inherently good and should be encouraged. Not all research, of course, is or should be near market, and it is a measure of the sophistication of a society how much of the economic cake is spent on ‘blue sky’ research. When it was first invented, the laser was a good example of a solution looking for a problem, but society now would be much the poorer without the many applications that have subsequently followed.

We are, however, at a different time in our understanding of the physical world and the balance between pure research and applied research should be tilted well towards the applied end of the spectrum. As can be seen from the small sample of activities described in the remainder of this publication, there is a healthy level of commercialisation of scientific ideas in Scotland, but it does not yet make a significant contribution to the country’s GDP.

One of the issues concerning the Scottish economy is the dramatic decline over many decades of the manufacturing sector. After heavy industry moved overseas, mainly to the Asia Pacific, employment was supported by the introduction of electronics manufacturing in the second half of the 20th Century. This certainly helped with employment, but the reality was that the companies in general were simply building products to specifications provided by the creative centres in the USA, Japan and elsewhere. There was no product ownership locally (with the notable exception of Hewlett Packard) and so when lower-cost countries developed the necessary manufacturing infrastructure, the factories departed again.

It had been hoped that the introduction of these electronics companies would have produced spin-offs and generated a healthy indigenous high-technology environment. However, the companies were never able to do this because they were focused on manufacturing, not on innovation. Management’s task was to turn out the products as cheaply as possible, not to generate new products. What we manufactured here was based on codified knowledge from elsewhere, which did not lend itself to entrepreneurial activity or innovation.
Although much of the investment in high-tech Scotland has been in multinational manufacturers, there has been an awareness in the universities and among a small number of entrepreneurs of the opportunities for developing high-tech companies based on indigenous research and technology. As expected, Heriot-Watt and Strathclyde Universities, with their engineering backgrounds, had strong technology transfer offices, Edinburgh University developed close links with the semiconductor industry, while Glasgow University, with a focus on optics, and Dundee University in pharmaceuticals, were active in trying to commercialise their research. Most of this activity took place through centralised Technology Transfer offices which had successes licensing to major corporations but were often criticised for their bureaucratisation of the process when it came to start-ups and interaction with smaller companies. Interminable IPR and investment value negotiations often killed the entrepreneurial spirit and with it the success of many potentially successful ventures. Protecting intellectual property is important, but it has little value until it gets to the market – and this usually takes far more investment than was made in the original research.

In spite of the difficulties, successful high-tech companies have been created. As a result, there is now a much better understanding of the dynamics of the process and more appreciation of the importance of this activity to the economy. Universities in Scotland have embraced the challenge, embedding commercialisation activities in appropriate departments such as Informatics, Engineering and Biotechnology. This has led to a blossoming of company start-ups on a par with or even ahead of the most active places anywhere in the world.

True success, however, is not measured by the number of companies created but by the growth and impact of these companies in the widest economic context: revenues, profit, employment, international presence, societal contribution, etc. It is regrettable that to date only a handful of companies, among which Wolfson Microelectronics plc is perhaps the most notable, have achieved this. The company spun out of the University of Edinburgh in 1985 and honed its technology through design contracts before transitioning into a semiconductor product company with a global presence that now employs over 400 people. It went for its Initial Public Offering (IPO) in 2003 on the main London Exchange and reached a market capitalisation in excess of $1 billion in 2006. Its “passion for great audio” has generated a brand that is appreciated worldwide and its products provide the audio in most of the leading consumer electronics products.

As the desire to create more indigenous companies of scale in Scotland has grown, efforts have been directed at providing a supportive ecosystem to nurture start-ups. At the earliest stages, students and researchers are sensitised to the possibility of company formation and the dynamics of commercialisation. The Business Schools are increasingly spreading their expertise across the universities, aiming to help budding entrepreneurs grasp the basics of business. And in a more formal programme, the Entrepreneurial Fellowship scheme funds researchers to commit a year to explore commercialising their research in a new company and get training in business skills. Specific organisations, such as Informatics Ventures in Edinburgh, are also providing support to software and electronic company start-ups, with a host of events, advice and incubator space next door to the research activities of the university. This close association of academic and commercial activity provides, in my view, the best environment for the initial stages of company formation.

The big issue, however, is the development of companies of scale from the initial stages with one or two people to an organisation focused on expanding their service or developing their product towards commercial reality. This usually needs some outside money, although I would always encourage entrepreneurs initially to bootstrap their activities from friends and family. Outside money in Scotland usually means ‘Angel’ investment, which is exceptionally vibrant here. There are many syndicates with well developed channels and significant experience. They are, in fact, collections of high-net-worth individuals who often have personal business experience and can help companies in more ways than simply providing finance. While Angel finance provides the basis for the development of the technology, deeper pockets are often required for the real growth of a company with its own products, sales and marketing activities on a global scale. This will usually involve the Venture Capital community and there is plenty of scope for conflict of interests with the Angels. Entrepreneurs need to be clear whether they are developing technology and hoping to sell out to another company – which is the realm of the Angels – or really interested in developing a profitable and sustainable company. If it is the latter, the challenge is formidable, but the journey is more exciting and eventually more rewarding.

The thrill of the IPO and recognition of the company by the public at large is, in my view, an experience worth striving for and I would thoroughly recommend it. The choice for the entrepreneur will be influenced by many things and it is not simply one of logic – it is visceral. The ambitions of the founder and the management are what should drive the decision, treating the finance as the means to an end and not, as is often the case, the driving force. We need more leadership companies in Scotland with the capability and ambition to compete internationally and I am encouraged by the level of activity highlighted in this and other editions of *Science Scotland*. 

We need more leadership companies in Scotland with the capability and ambition to compete internationally.
Deep thinking (underwater)

The original business approach was deceptively simple but it worked extremely well, establishing SeeByte as a leading solutions provider to some of the world’s most powerful navies and oil & gas corporations. "The key to the company’s early success," says founder David Lane, "was listening to customers and focusing on their requirements."

The company develops intelligent software for unmanned systems so they can operate autonomously, scanning the environment and processing the vast amount of data this can generate, to make decisions, interface with other systems and display information in a meaningful format. And rather than developing bespoke solutions all the time, SeeByte’s foundation model was to re-use the building blocks developed for particular systems so it did not need to re-invent the wheel for every project. Once a specific solution was built, it could then be replicated and licensed or sold, thus reducing the company’s costs and helping margins in the critical early years.

SeeByte was founded in 2001 to bring to market new technologies designed at the Ocean Systems Laboratory of Heriot-Watt University. Lane and several colleagues had developed software for a number of underwater projects and thought it was time to break into the business world while still maintaining close links with their academic partners. “Is there more value in this?” was the question that first inspired Lane. “Can we do something better? After 15 years of basic and applied research, how could we put something back and make an impact on commerce?”

The big idea was “to improve underwater operations by combining streams of sensor-derived data from remotely-operated vehicles to create a single integrated picture that would deliver greater information and awareness of an inaccessible underwater situation/location.”

Today, SeeByte’s software is used in locations all over the world to search, classify and map the underwater environment, to automatically identify objects and to inspect ship hulls and oilfield infrastructure, enhancing the capabilities of various kinds of remote platforms.

In the early days, Lane and his team thought they would be a company who built underwater vehicles, but then they realised they would be better off developing software solutions for the vehicle makers and their customers. “This approach also better reflected our technical competencies,” Lane explains.

In Lane’s opinion, it was also essential to break free from the academic environment while still maintaining close links with Heriot-Watt. “The interface between the universities and industry does not always work,” says Lane. "Industry wants something that solves a problem. Academics do research. However, there was a lot to gain from maintaining a partnership with Heriot-Watt if the company was to prosper – for example, access to research and intellectual property – but it was also important to operate as a business rather than just a research lab. "There were tangible and intangible benefits," Lane says. "SeeByte was able to recruit key technical staff that created the research, while Heriot-Watt is not only a shareholder but also gained commercial exposure for its students through industrially-relevant project work, and support for further research. "Heriot-Watt doesn’t do lots of spin-outs," says Lane, “but it has a good track record with the spin-outs it’s currently involved with.”
Initially, the team at SeeByte explored the possibility of working with Yorkshire-based Slingsby Engineering to develop a solution for its ROVs (remotely-operated vehicles), but then it started looking much further afield.

The company’s first customer was the US Navy, attracted through Heriot-Watt’s research links with Florida Atlantic University. This taught everyone important business lessons from the start, and a ‘can do’ culture with the courage not to be afraid to fail and to have a go. The US Navy also sent SeeByte a cheque before its bank account had even been opened – a nice kind of problem to have.

In the early days, the company learned much about the importance of requirements as it worked within the spiral development approach of the US Navy “acquisition pipeline,” developing early capabilities in autonomous systems for detecting underwater mines. The UK’s Ministry of Defence funded some of the early-stage research, while Scottish Enterprise also supported ongoing staff training into commercial and managerial roles.

The rigour of understanding requirements also helped the company gain access to the offshore oil and gas market. Through a series of Joint Industry Programmes (JIPs) supported by major oilfield operators and contractors such as BP, Conoco Phillips, Chevron and Subsea7, SeeByte “de-risked game-changing solutions” using autonomous vehicles to inspect pipelines and other subsea infrastructure. These systems are now starting to be used commercially by customers, and have a bright future for expansion through trust generated in the technology and the team, and the commercial opportunities that have emerged. “However, it’s taken almost ten years and several JIPs to get to the stage where commercial capabilities are ready and can be accepted,” says Lane.

Lane stepped down as Chief Executive last year and now spends more time developing new research initiatives, encouraging students and supporting knowledge transfer activities. But he continues to take a close interest in SeeByte and is confident the company has a big future as it continues to expand in its chosen markets and develop its IP pipeline.

One of the key strengths of SeeByte technology is systems which can make their own decisions, but probably the best decision so far was to start up in the first place – and focus on being a solutions provider in one of the world’s most competitive and profitable industries.
Profile WFS Technologies

New wavelength

Core business: Underwater radio
Location: Livingston
Founded: 2003
Team members: 25
Turnover: £2 million

“We stumbled into underwater radio,” says Brendan Hyland, founder and chairman of WFS Technologies. “There were no textbooks and nobody thought it would work, but we struck it lucky. Business is what you do about that opportunity.”

As well as doing something technologically controversial, WFS today is very different from the company originally envisaged. The company was founded in 2003, to work in the “interface between wireless and optical” technologies and “the link from the kerb to the home,” but after it won a major contract from BAE Systems to develop a customised datacomms solution for aircraft, the company took a complete change of direction. The BAE project was both successful and profitable, but WFS did not own the Intellectual Property (IP). Hyland and his partners started to look in other directions – and that was when they “stumbled” into underwater radio and the development of data and video links for underwater signalling.

The technology may have been new, but the idea was more than 150 years old. In 1842, Samuel Morse discovered underwater radio “by accident” when a telegraph cable broke during a transmission across the Hudson River and the message still managed to “jump” across the break in the cable. Later on, many other inventors, including Nikola Tesla, tried to come up with solutions and, during the Cold War, the US and the Soviet Union spent “hundreds of millions of dollars” on research, and built low-frequency radio systems for submarines. At that time, there were no commercial applications for underwater radio: control systems were not installed underwater and commercial applications were hard to imagine. But the emergence of technologies such as broadband, Wi-Fi and Bluetooth led to widespread use of wireless systems. In the subsea world, the increased deployment of tethered remotely-operated vehicles (ROVs) and untethered autonomous underwater vehicles (AUVs) in the petrochemical and defence industries soon changed the rules of the game...
AUVs are like dolphins, who operate using acoustics (ears), and electromagnetics (eyes). WFS provides the ‘eyes’.

The breakthrough
According to Hyland, in 2004, when WFS first considered underwater radio communications, what made the critical difference was his “bloody-minded” refusal to accept the received wisdom that radio does not propagate underwater, and soon after, the research team at WFS developed a low-frequency (20kHz) signalling system which seemed to penetrate sea water.

WFS revisited an old technology, recognising the potential of shorter-range communications over distances of less than ten metres. Ironically, the company started its research unaware of earlier efforts – simply because there was so little documentation.

“We had to find what was possible – then find commercial applications that fitted within this envelope,” says Hyland, and in 2006, WFS unveiled the world’s first commercially available underwater radio modem.

Today, the company describes itself as “the world’s leading supplier of through-water and through-ground wireless technology for communication, navigation and power transfer.” It also boasts of 30 granted patents and 200 patent applications, and supplies its radio, acoustic transmitting and inductive power transfer technologies to the subsea oil and gas, environmental and homeland security and defence industries. WFS now has three product platforms for the energy, environmental, consumer and defence industries, while another major market is wireless back-up solutions for cables in case they malfunction. The key advantages of WFS technology are that it will operate in adverse conditions and is unaffected by acoustic noise or multipath problems.

“Our goal is to support the development of this new market,” says Hyland, who identifies two major reasons for the company’s continuing success:

1. Continuous investment in R&D to maintain technology and product leadership
2. An innovative approach to identifying those applications where the company’s products can make a difference

Rather than being a spin-out from a university, the intellectual traffic is going in the opposite direction. WFS provides its knowledge and equipment to researchers at universities including MIT, Georgia Tech, Oxford, Edinburgh, Strathclyde and Newcastle. The company has used academic consultants for several small projects, but still does its own R&D.

“When we began, universities were not interested in doing research in underwater radio,” says Hyland (who also believes universities should not hold on to IP but hand it over to people who start up new businesses). “This is changing as the scale of the opportunity has become apparent. We have managed to keep our IP untainted,” he continues. “This helps when doing commercial deals. And our aim is to grow shareholder value by developing IP, licensing technology and selling products and services.”

Working in such a new market also means WFS has to be very creative: “We have to create competition,” says Hyland. “We have been instrumental in setting up the Subsea Wireless Group (SWIG), a not-for-profit organisation tasked with defining open industry standards. This group, with a key theme of interoperability, will ensure all subsea wireless systems can communicate with each other regardless of manufacturer. Other members of the Subsea Wireless Group include BP, Teledyne Benthos, Chevron, Emerson, HIMA Americas, Technip, Yokogawa, Nautronix, MCS Kenny and Saab.

“As well as setting industry standards, we want to expose major players to what this technology can offer,” says Hyland. “A hundred per cent of nothing is not as much as a small share of a multi-billion dollar market.”

Hyland says that luck as much as hard work put WFS on the road to success, but the company is already thinking one step ahead, designing solutions for very small, hovering AUVs that dock underwater, harvesting data and dumping it, and wirelessly recharging equipment as well as themselves. “It will be a global market,” says Hyland, “and transform the economics of the underwater vehicle industry.”

About Brendan Hyland
Brendan Hyland, founder and chairman of WFS Technologies, studied electrical engineering at Queen’s University, Belfast, and worked in telecoms, industrial instrumentation and the chemical industry before he did his MBA and founded optoelectronics company Kymata in 1998. Hyland stood down as CEO in 2001 and Kymata was subsequently bought by Alcatel. In recent years, he’s focused on “business modelling and business strategy,” especially the meeting point between “emerging technologies and market needs.”
It was a pioneer in electromagnetic and magnetic detectors, and the more sophisticated tracking pigs developed since then have now become off-the-shelf products which still win ‘bread-and-butter’ sales for Nautronix.

In 1996, Nautronix established itself as a leader in DSP-based (DSP = digital signal processing) helium speech unscramblers – devices that enable operators to communicate with saturation divers by compensating for the high-pitched voice effect caused by breathing helium. The human voice is formed by a combination of resonances in the larynx and the mouth cavity, and the sounds from the mouth cavity are affected by helium. The resulting ‘Mickey Mouse’ sound effect may be amusing at first, but makes communication very difficult with divers undertaking difficult and dangerous work under water.

The unscramblers perform a complex task, reducing the frequency of some tones (i.e. lowering the pitch) while leaving other tones the same, so speech sounds normal. The resulting product has consistently scored 98% intelligibility on tough industry standard testing, (i.e. 98 words out of every 100 are clearly understood).

The company was also an early developer of commercial spread-spectrum communication and positioning systems. In the shallow waters of the North Sea, communication and positioning systems are relatively simple, in depths of less than 100 metres, but as soon as you begin to operate at greater depths, new problems emerge (depths of 3,000m are common in modern oil production operations across the world).
The ability to overcome communication difficulties in hostile environments is our biggest strength.

What makes Nautronix technology stand out, says Orr, is its track record in signal processing systems, including subsea digital acoustic communications – for example, where customers need to replace expensive, heavy and damaged subsea cables with a reliable wireless communication channel, or accurately track the position of large, moving objects being installed in deep water.

In the last ten years, the product range has extended to include blowout preventer controls – remote communications devices which are used as back-up to shut down subsea valves (and prevent leaks) when the primary control system fails in an emergency. In this situation, hundreds of lives and an environmental catastrophe can be at stake, and the industry trust in the NAsBOP product range is testament to the high reliability that it provides.

“The ability to overcome communication difficulties in hostile environments is our biggest strength,” says Orr. The problems faced include limited bandwidth, long path delays and extreme Doppler shift, high noise levels in-band from vessels and engineering operations, and full ocean-depth operations.

“We are also a small company compared to our major competitors, and this means we can be more flexible in responding to industry needs,” says Orr.

When the position of ROVs and subsea equipment needs to be accurately tracked, the NASNet® system creates a grid of position reference beacons. These are dropped to the seabed from a boat, which then circles the area to establish their position, typically to a precision of a few tens of centimetres. The NASNet® GPS-like positioning technology developed by Nautronix also makes it possible to space out the beacons at a distance of several kilometres, while alternative systems have to be positioned a few hundred metres apart, and this means significant savings and speeds up deployment.

The solutions which Nautronix has developed include true independent multi-user communications using spread spectrum. This means they avoid the need to have a synchronised network to decide who can communicate and when. As a result, when multiple vessels need to work in an area (e.g. in the Gulf of Mexico after the Deepwater Horizon incident), they can freely share the NASNet® system through the area without interference, to improve redundancy for surface vessels and as a sole reference for ROVs and other equipment subsea.

The high reliability and potential for covert operation underlying the communication and positioning systems was originally developed by Nautronix for military applications, where it enabled submarine communications to be undetectable above background noise levels. While today’s work focuses on the industrial and commercial market, the same products have been used successfully to provide tracking and communications in submarine ranges during trials.

Accuracy and availability are critical factors for positioning systems. Surface vessels needing an accurate fixed position have to supplement their differential GPS (DGPS) system (which can be affected by phenomena such as scintillation – spikes in solar activity which cause interference) with additional independent sources. Nautronix builds high levels of redundancy into its NASNet® DPR systems, and provides typical positioning accuracy of one metre.

“Unplanned downtime is unacceptable,” says Orr. “With offshore vessels costing up to $1 million a day, the pressure to fix any problems increases rapidly”

“We provide high-quality solutions for difficult environments,” says Orr. “And the more difficult the problem is, the more it requires Nautronix.” Orr believes that engineers in Scotland are undertaking “ground-breaking research” in subsea technologies, and with deep-water exploration and extraction becoming more common as the oil and gas companies widen their search for new fields, Nautronix and its academic partners are well placed to take full advantage – whether they are based in Aberdeen, Houston or Rio de Janeiro.

Knowledge Transfer

Nautronix recently set up a new technology department to manage knowledge transfer between engineering, academia and customers, and help to plan future product developments. According to Chief Technologist Nigel Orr, there is huge potential for cooperation with Scottish universities, where there is significant expertise in areas such as communications and signal processing. Over the last five years, Nautronix has increased the headcount in its engineering department from 12 to 26 people, to rise to the challenge.

According to Orr, the offshore industry is generally conservative when it comes to introducing new technology, but when there is an opportunity to save time and money, and improve productivity, customers do start to listen. In the past, Nautronix tended to be more “reactive” when it came to the development of new products, with incremental changes mainly led by customer requests, rather than offering the potential of totally new applications.

The new approach complements that responsiveness by being more proactive and forward-looking, says Orr, finding out early if customers are interested in new possibilities that they might not expect Nautronix can offer – for example, how about controlling 150 valves with a single device, instead of only sixteen valves, as at present? Would that be useful? What about sending data subsea over much larger distances?

Recent product developments include the extension of the NAsBOP product range to enhance the capability of the company’s blowout preventer controls, which was recently awarded the Subsea 2012 Innovation and Technology Award. Also in development are upgrades of the existing product range to benefit from developments in signal processing and communications to improve lifetime and capabilities, and the NASMUX product range to provide primary acoustic control of subsea equipment.
Profile Clyde Space

Watch this space

Core business: Small and micro satellite systems
Location: Glasgow
Founded: 2005
Employees: 24

The satellite may only be a few centimetres across, but it could be the next big thing in Scotland’s fast-expanding space technology industry. This year, Clyde Space plans to put the first made-in-Scotland satellite up into orbit, as part of a nationwide project called UKube-1, which also brings together the Advanced Space Concepts Laboratory at the University of Strathclyde as well as Glasgow-based Steepest Ascent and MESL Microwave of Edinburgh, plus several other UK-based organisations.

Clyde Space entered a Knowledge Transfer Partnership with the University of Strathclyde about three years ago, and the two partners took up the UKube-1 challenge in 2010, as part of an initiative supported by the UK Space Agency to launch the UK’s first miniature satellite – a device which measures only 10cm x 10cm x 34cm.

UKube-1 (UK Universal Bus Experiment) will enable scientists to test new space technologies and carry out new space research more cost-effectively and quickly, “making up in innovation what they lack in size.” It will also carry experiments selected from a competition open to companies and academics to come up with the most innovative ideas for payloads (see sidebar).

The UKube-1 project is a dream come true for CEO Craig Clark, to help Scotland “enter the space race.” And as well as being part of a project that promotes the new miniature satellites and inspires young people to get interested in science, Clyde Space has effectively become its own customer, developing a CubeSat all of its own. “We have the freedom to design and build exactly what we want rather than a custom-built solution,” says David Castle, who’s in charge of manufacturing at Clyde Space.

“The best way to market space products is through their successful demonstration in orbit,” adds Clark.

Take-off

The Clyde Space story can be traced back to the early 1990s, when Clark studied power engineering at the University of Glasgow – and dreamed about space flight. After graduating in 1994, he spent 11 years at SSTL (Surrey Satellite Technology Ltd)*, working as a power systems engineer, gaining experience in mission design, spacecraft testing, on-orbit operations and management. By the time he left SSTL, he had worked on a total of 25 missions – five times more than most people work on throughout their career.

Soon after he returned to Glasgow, Clark set up Clyde Space, to focus on power solutions for satellites, convinced there was a niche in the market. He also wanted the company name to reflect the fact the River Clyde had once made 25 per cent of all the world’s ships – and perhaps in the future could also make “spaceships.”

Soon after Clark returned from a space industry conference in Japan, Clyde Space won a SMART: Scotland award from Scottish Enterprise, and started to develop power systems for a new generation of CubeSats – tiny satellites which typically measure 10cm x 10cm x 18cm and weigh about 5kg.
There is an opportunity to do something different and develop the space business here – and create thousands of jobs in the process.

“I hadn’t heard about CubeSats before my trip to Japan,” says Clark, “but I recognised it as a great opportunity.”

The company won its first customer in 2006, supplying two solar panels for South Africa’s SumbandilaSat mission. This was soon followed by orders from Malaysia, Japan and the US. Today, its client list includes the European Space Agency, NASA and the US Air Force, as well as customers in Turkey, South Africa, India, China, South America and Canada. The company has about a 30–40 per cent share of the global CubeSat power market, and has also supplied over 220 power systems for small satellites, making it the world’s biggest supplier of this kind of power solution.

Early last year, Clyde Space secured a funding package worth £1 million, led by private equity firm Nevis Capital, Coralinn LLP, Scottish Enterprise, the Science and Technology Facilities Council (STFC), the Technology Strategy Board and Regional Selective Assistance, “to support innovation and growth across all company activities” as well as “to expand its product range and capability offering and increase its global market share.” This injection of funds has paid for a new 1,000-square-foot clean room, as well as new automatic testing equipment.

Scotland’s space industry is currently worth only £20+ million a year but Clark thinks Scotland has the potential to grow very rapidly, taking advantage of the skills we already have and the graduates coming on stream in subjects such as astronomy, physics, electronics and engineering. Clark adds: “In Scotland, we can’t compete with the big guys like NASA, but there is an opportunity to do something different and develop the space business here – and create thousands of jobs in the process.”

* Formed in 1985, SSTL is a commercial spin-out from the University of Surrey, specialising in the design of very small satellites. In 2008, the company was acquired and incorporated as an independent British company within the EADS Astrium NV group.

UKube-1: The payload

- TOPCAT – a device to measure the ionosphere and plasmasphere (the regions of space just beyond the Earth’s atmosphere), to help GPS users cope with weather conditions that adversely affect the global positioning system (GPS) and its applications (e.g. satellite navigation and telecommunications).
- A payload to demonstrate the feasibility of a patent held by EADS Astrium on using the radiation environment for true random number generation.
- FunCube – a sub-system for educational outreach to students at schools and colleges.
- The Open University’s CMOS Imager Demonstrator instrument – developed as a collaboration between the OU’s Centre for Electronic Imaging and e2v technologies, a supplier of scientific imagers for the space market. This will perform a variety of imaging tasks, including taking pictures of the Earth and providing an experimental test-bed for radiation damage effects in space.
- myPocketQub – five experiments that UK students and the public will be able to interact with, including SuperSprite – a satellite-on-a-chip proof-of-concept experiment.

Clyde Space products

Clyde Space makes high-performance subsystems for small satellites and microspacecraft, including standard products available online and one-off products (bespoke designs incorporating heritage circuits or a completely new design). The company also offers heritage systems for non-standard spacecraft, including in-house products and licensed products from Surrey Satellite Technology Ltd (SSTL), as well as high-performance, bespoke designs for small satellite missions, including complete or part power conditioning and distribution systems (PCDU), lithium polymer batteries, solar arrays and DC–DC Converters.

Electrical Power Systems

Modular designs that can be easily configured for bespoke projects.

Spacecraft Batteries

Space-qualified lithium polymer batteries that have undergone extensive tests to assess their suitability for the space environment.

Solar Panels

Small solar arrays for small satellites.

Space DC–DC Converters

High-efficiency, galvanically isolated and multiple output DC–DC Converters for space use.

Twice the power

Clyde Space recently developed a “double deployable” solar panel system designed to increase the power available on board a CubeSat. The new system enables power to be generated from the front and the back of the deployed solar panel arrays – essential for missions that don’t track the sun.

FACT >>>

According to the UK Space Agency, the UK’s space sector contributes £7.5 billion a year to the UK economy, directly employs 24,900 people and supports a further 60,000 jobs across a variety of industries.
Better vibrations

Profile Xi Engineering Consultants

Core business: Noise and vibration solutions
Location: Edinburgh
Founded: 2011
Employees: 7
Clients: AES, Hammerfest Strom

From pneumatic drills to car engines, buildings and turbines, vibration is not just an irritation but a major design issue and a huge factor in costs. For example, if you could eliminate half of the vibration in a wind turbine near sensitive seismic equipment, it may be possible to double the number of turbines installed in a site. If you could reduce the vibration from railway lines, it may be possible to build new houses closer to the tracks. And these are exactly the kinds of problems which Xi Engineering Consultants has dealt with since the company was formed in 2011.

Xi was born out of Reactec – a spin-out from the University of Edinburgh – but what makes the new organisation so different is that instead of developing products and providing consultancy services to finance R&D, Xi focuses on being a consultancy, providing off-the-shelf or customised solutions in industries including renewables, construction and marine.

"Vibration is a problem which affects anything and everything – even champagne on a luxury yacht," says Xi managing director Dr Mark-Paul Buckingham, who is now a non-executive director of Reactec, the company he founded in 2001. According to Buckingham, the three drivers of the business are "performance, maintenance and legislation." Health and safety are of primary importance, but the bottom line is money – how to optimise investment, extend the life of buildings or equipment, and reduce costs.
As a team of highly-skilled engineers, we inherently like solving problems.

Buckingham graduated from the University of Edinburgh in 2001 with a degree in mechanical engineering, and developed the ideas for Reactec while he did his PhD there, focusing on vibration issues in complex composite materials used in skis and snowboards. For the next 3–4 years, he developed a generic solution to monitor and manage the vibration experienced by individuals operating different equipment – a device which became the HAVmeter. Buckingham also won SMART: Scotland and SPUR awards to develop and commercialise the control unit for the device. And at the end of 2005, he made his first big breakthrough when he won an order for 750 units from Tarmac for a product which didn’t exist yet. Banging the prototype vibration device on the table to demonstrate how robust the design was, Buckingham convinced Tarmac that he had the solution it needed, and then said his firm would design it however the company wanted. It took another three years to finalise details, solving problems such as inductive charging and making the device robust enough to deal with the rigours of a construction site; but finally the HAVmeter debuted in early 2008.

This was not the best time to be launching such a product – at the start of a recession in the company’s key industries – but Buckingham also continued to develop his consultancy work, providing vibration analysis services to companies such as Wind Energy, Rolls Royce and Intel. Three years later, increased demand for consultancy led to the spin-out of Xi, with £400,000 of investment from sources including Archangel Informal Investments and the Scottish Enterprise Co-Investment Fund, plus a Board including former defence minister Adam Ingram, ex-Lloyds TSB Scotland director Manus Fullerton, and Gordon Stewart, ex-managing director of PRTM, as Chairman.

When developing the prototype meter, Buckingham targeted a number of specialist markets and conducted trials with companies of all shapes and sizes to test the product to destruction; and this is one of the services Xi now provides to its clients – helping to design out vibration and noise problems in advance, rather than after the event.

The irony of modern materials, Buckingham explains, is that the lighter and more efficient they become, so too the vibration problems worsen – e.g. the Forth Rail Bridge has much more mass than modern bridges and therefore vibrates less.

Complex modelling

What gives Xi the edge is its use of advanced mathematical modelling software to predict and measure vibration, then diagnosing problems and developing solutions – for example, creating virtual labs to model turbines. “The modelling is complex and must be precise,” Buckingham says.

Buckingham describes what the company does as a “turnkey solution”, and is keen to demonstrate the practical benefits – e.g. the company’s work on the Newcastle Metro, building an acoustic trench to “bounce away” vibration so more houses could be built beside the tracks. Xi is also helping Hammerfest Strom to ensure that its ten tidal turbines have been “optimised for vibration” during a five-year trial for Scottish Power Renewables in the waters off Islay. Small-scale turbines also present very similar problems, including the gearbox, while manufacturers of semiconductors also need to reduce vibrations during production.

One of Xi’s greatest challenges is to reduce the vibrations in wind turbines, and for this it has developed the Seismically Quiet Tower (SQT), a hardware solution which can be retro-fitted to turbines or integrated during construction, for any tower height and power capacity. The impetus for SQT came from a project to deal with the seismic issues of the Eskdalemuir Seismic Array, which monitors seismic events, including nuclear explosions and earthquakes. Planners originally limited the number of turbines which could operate in the area around the array, so they wouldn’t interfere with any instruments. But now, thanks to Xi, the power company can multiply the number of turbines and potentially release an extra £1 billion of investment, at the same time as producing much more electricity.

So what is Buckingham’s target for the first year of business?

“We want to provide added value to a greater number of clients and assist them in solving problems and improving products,” he says. “As a team of highly-skilled engineers, we inherently like solving problems.”
Can Scotland lead the way in high-speed trains?

"Industry and academia need to work closely together to generate rapid progress in innovation and product development," Woodward explains. "Now is the age of the train!"

Woodward laments the UK’s reluctance to adopt new solutions for railways, but says that innovation is still taking place here, despite this. To drive more innovation, Heriot-Watt is setting up the UK’s biggest testing rig for railway technologies, and Woodward hopes that this will convince industry to set up a national testing centre, to stimulate development and also boost exports.

"We can’t compete with countries like China when it comes to manufacturing widgets,” says Woodward, “but the UK has got the ability to develop innovations. Our problem is how to commercialise these – for example, we developed the first tilting trains but Italy now exports its Pendelinos to us.”

The XiTRACK story

Woodward’s interest in railways developed in the late 1990s at Heriot-Watt, where he became a lecturer in 1994 after gaining his PhD in numerical geotechnics from the University of Manchester. In his early career, he focused on earthquake engineering, modelling ground waves and their effects on civil engineering structures – experience which he continues to use today in developing numerical modelling software for railways.

Initially, Woodward started looking at ground vibration waves and how they affect the ballast on railway tracks. Ballast is good at supporting the rails and helping drainage, but it also tends to ‘densify’ and can break down, due to vibration from trains running over the rails, and eventually this affects the geometry of the track – especially at switches and crossings – and requires regular maintenance. Some sections of track need checking once a year and others as often as every ten days. Anything which would prevent this would not only save money but also be safer.
In 1999, one of Woodward's colleagues was involved in the replacement of the cobbles in Edinburgh's historic Royal Mile, using polyurethane to help reduce the wear and tear on the new cobbles, filling in the space around the cobbles much the same as using grout for tiles. And this got Woodward thinking – maybe a similar polymer could be used for the ballast on railways. Woodward then started discussions with the polymer supplier, a company called Hyperlast, and started to develop a special solution for railways.

XiTRACK was first trialled at Bletchley on the west-coast line in early 2000 – points which used to need maintenance every three months. The new solution was installed while the trains were still running, using a pneumatic pump to apply the polymer between the sleepers. And the trial was so successful that the points did not need any further maintenance until they were decommissioned in 2011.

One of the special properties of the innovative geocomposite solution is that it cures (or sets) at different rates, depending on the formula – e.g. it is poured into the ballast (like cream over strawberries) and when it reaches a particular design depth (of between 100mm and 600mm), it stops running further. This means engineers can control application to meet individual requirements. Other formulas have also been developed to be effective in temperatures as low as minus 40°C.

According to Woodward, one of XiTRACK's major advantages is that it can be used to fix a problem overnight without interrupting the schedule. Concrete slabs are also low-maintenance options, but are more expensive to build and replace, and their longevity is still being debated. “XiTRACK offers the best of both worlds,” adds Woodward. After the initial trial, Heriot-Watt University then spun out a company called 2Ei to develop and market the product, and in 2001 Woodward founded XiTRACK as a 50:50 joint venture with Hyperlast Ltd (now the Dow Chemical Company). The company then won a contract from Railtrack to reinforce the track at 14 bridges nationwide, and Woodward started spending 25 per cent of his time working at XiTRACK – an arrangement which at that time was highly unusual for academics.

The business started gaining momentum when XiTRACK formed a partnership with Balfour Beatty Rail and started a series of trials up to 2005, using new electrical pumps to install XiTRACK at the contractor’s ‘worst sites’ – bridges, switches and crossings where stabilisation was needed the most. In 2005, XiTRACK was officially certificated by Network Rail (which took over from Railtrack in 2002) and the company was highly commended in that year’s ‘Innovation of the Year’ category at the 2005 National Rail Awards.

“There are two main arguments for XiTRACK,” says Woodward. “First, it reduces the maintenance costs. And second, it lowers the risks. The technology has the capacity to virtually eliminate the need for ballast maintenance, and Balfour Beatty Rail is now promoting the concept of ‘tamperless’ switches and crossings.”

XiTRACK has been used in Italy and is also due to be trialled at 25 sites in Germany and Hong Kong. Woodward comments: “Countries outside the UK are more ready to use innovative solutions. Some people in the UK seem to think that if the Victorians didn’t use the technology, we shouldn’t use it – but if the Victorians had XiTRACK then, they would have used it!”

**Modelling software**

In the process of developing XiTRACK, Woodward developed new modelling software to “model every aspect of the rail environment, including the effect of vibration on buildings and the people inside them.”

One phenomenon which this reveals is something called “critical velocity.” Every type of groundsoil has a ‘natural velocity’, with different densities absorbing the ground waves at different velocities.

The new software, called DART3D (Dynamic Analysis of Railway Track 3D), simulates these effects and allows the engineers to work out how to mitigate vibration – whether this means laying concrete rafts, improving the ballast using geosynthetics such as XiTRACK, or even rerouting the track. “Different types of soil may react at different speeds,” says Woodward, “but the faster you go, the more it’s a factor.”

Woodward and his academic colleagues, including Professor Michael Forde of the University of Edinburgh, have successfully applied for EPSRC funding for the simulation software and are also in discussion with researchers in China to use it for next-generation ultra-speed train modelling – travelling at over 250mph. “The Chinese are the new Victorians,” says Woodward. “They just get on and do things.”

Over the last few years, Woodward has done everything from shovelling ballast to chairing boardroom meetings, in his quest for railway innovation. This year, he will give the keynote speech at a major conference in China, where his ideas could be critical in planning for the new high-speed network. His talk is entitled: *The application of polyurethane geocomposites to help maintain track geometry for ballasted high-speed railway tracks.* He is also giving talks this year on high-speed tracks in Japan, Australia and Spain [the latter is a keynote on ultra-speed]. Will the same ideas resonate in Scotland?
With wind power gaining momentum worldwide, any company which promises to cut the cost of manufacturing, assembling and maintaining the turbines would be on to a winner – in a global market where investment is expected to be well over £100 billion over the next ten years.

NGenTec aims to become “the preferred supplier of direct-drive and slow-speed permanent magnet generators for the wind energy market,” both offshore and onshore, with its innovative drivetrain solutions. And what makes its technology so different is the modular, “air-cored” design, which reduces the weight by approximately 30 per cent and enables repairs and replacement of parts without excessive operational downtime – thus reducing costs and improving overall energy yield.

The company was spun out from the University of Edinburgh’s School of Engineering in 2009 by Dr Markus Mueller and his colleague Dr Alasdair McDonald, and within two years it has assembled a management team with the credentials to match its technology, including CEO Dr Makhlouf Benatmane (ex-Converteam), CTO Dr Nazar Al-Khayat (formerly with Williams Grand Prix Engineering), CFO Jim Boyd (former CFO at Aquamarine Power), and CMO Dr Charles Gamble (former CTO of Nordic WindPower). Backing them up are non-executive chairman Dr Derek Shepherd (ex-Agreko International) and non-executive director Dr Derek Douglas, CEO and chairman of investment firm Adam Smith Ltd (ASL).
Mueller has returned to the research lab, happy that the company is now in the mainstream of the energy business and looking forward to developing more powerful ideas.

The story starts in 2005 in Edinburgh, when Mueller started trying to develop a new kind of direct-drive permanent magnet generator (PMG) for wind turbines. The major problem, according to Mueller, is that wind turbines rotate very slowly – 10–20 revolutions per minute (rpm) – whereas conventional electrical generators want to rotate at thousands of rpm. A gearbox is required to step up the speed, but the gearbox can fail. If a gearbox is not used, the generator rotates at the low speed of the turbine. Such direct-drive generators are large in diameter and very heavy – for example, a 5MW direct-drive generator could weigh 150–200 tonnes and be 5–6m in diameter.

“The gearbox is not the most unreliable part of the turbine, but it’s responsible for most of the downtime,” says Mueller. And if manufacturers could get rid of the gearbox or develop a hybrid design, combining gearbox and direct drive, the turbines would be more reliable, economical and more efficient.

With generators, Mueller says, compromise is always the difficult issue – between the structure, the electrical performance and mechanical design. And NGEntec’s modular, lightweight design goes some way to achieving the balance required, producing energy efficiently as well as being easy to maintain.

Mueller and his team have developed a number of prototypes over the last few years, starting in the lab and later moving out into the field, testing the design on fully operational turbines. The first prototypes were funded by a $400,000 Proof Of Concept award from Scottish Enterprise, helped by additional funding from a SMART: Scotland award. After verifying the performance and mechanical, structural, electro-magnetic and thermal characteristics of the design, NGEntec was born and the management team came on board – adding their experience and industry contacts as well as their ability to bring in investors.

The four founders – Mueller, McDonald, Douglas and Shepherd – invested first, followed by SET Venture Partners of Holland and the Scottish Co-Investment Fund (£1 million each), plus a £800,000 grant from the Department of Energy and Climate Change (DECC) and £200,000 from the Edinburgh Technology Fund.

Another major move has been the forming of a non-exclusive industry partnership with David Brown Gear Systems, part of the Clyde Blowers Group, which helps NGEntec manufacture and test its equipment.

The current challenge is to get a 1MW version into the field and win the company’s first customers, then build a full-scale (6MW) prototype – which will require about £6 million in investment over the next two years.

After one year as the acting CTO, Mueller has returned to the research lab, happy that the company is now in the mainstream of the energy business and looking forward to developing more powerful ideas.
It’s a family affair

Core business: Visualisation and analysis software for the oil & gas industry
Incorporated: 1995 (first product launched in 2000)
Employees: 18
Turnover: £3 million
Major customers: Statoil, BP, Shell, Conoco, Chevron, Marathon – 120 customers in 80 countries

In 1995, Dr Lindsay Wood wanted to move back to Glasgow, but because he couldn’t get a job in science, he decided to start his own company, in partnership with his wife Angela and his brother William. And 16 years later, Sciencesoft has established itself as a leader in visualisation and analysis software for the oil and gas industry – and is still in family control, with Lindsay now in charge of research and development, Angela director of business and William looking after sales and marketing.

In the early days, the company sustained itself by providing consultancy services to leading oil and gas companies, leveraging contacts in the industry built up by both of the brothers, and behind the scenes developing its visualisation and analysis software, launched in 2000 as S3GRAF.

Today, the company’s Reservoir Simulation Suite of products, “help engineers analyse the results from reservoir simulators by quickly producing 2D and 3D images of an oil or gas field.” This enables companies to decide whether or not to exploit the particular field.

Eleven years ago, bespoke products had been around for many years, but they ran on proprietary systems and supported a single vendor. The driving force behind the new product was widespread industry demand for a solution which would work on different platforms, including Windows PCs. Other companies tried to develop new software from scratch, but Sciencesoft also recognised the need for a backwards-compatible version which provided a familiar user interface – allowing engineers to use existing data as well as reducing the time required for training.
According to Wood, engineers told Sciencesoft at the time that they liked how the old software worked. They simply wanted a more open version with new improved features, and Sciencesoft could also recognise the market opportunity for a more cost-effective solution. “We believed that our role was to solve people’s problems,” says Wood, “not to build a mini empire or fight technological wars.”

Just before the product was unveiled in 2000, the company (still a small team of five people, with only two developers, including Lindsay Wood) knew it required an injection of funds — not to help the final stages of development but to beef up its sales and marketing efforts. “We had our proof of concept, but we needed market presence,” Wood explains. Until then, the company had funded development with the revenues from its consultancy work, and the product was close to completion. Wood and the rest of the family wanted to retain control of their creation, but several potential investors said they were wrong — and proposed investing much larger amounts. In the end, however, Sciencesoft brought in a company called Mdina Investment, who provided funds of £200,000 — much less than the £5 million some venture capitalists said was required. This amount was matched by Sciencesoft’s bank, backed by the appropriate insurance. “We wanted to look at the finance on our terms,” says Wood. “Why spend £1 million on something we don’t really need?”

The company strongly believed it should stick with its vision — an open, platform-independent solution, backed by world-class service and responsiveness to customer needs. The team was also happy to start off with one or two sales to a few companies, and gradually build up its business, and Statoil of Norway was one of its earliest reference sites, buying several licences. For these initial customers, says Wood, S3GRAF simply solved the problem by updating the old technology without interrupting the workflow. Customers wanted a new, improved product that was easy to use and displayed better visuals, but nobody wanted to change overnight and abandon the old ways of working. Users also did not want to throw away existing investments or learn a completely new product.

The other key to the success of S3GRAF was that the engineers now had a visualisation tool which they could show to non-technical people on Windows PCs — what Wood describes as “presentation quality.”

From a company standpoint, the technology was not the only critical factor. “What enabled us to succeed,” says Wood, “was the fact that we were small and quick to solve problems.” In addition, Wood believes it is important for developers to meet the customers whenever they can — e.g. at trade shows. “They speak the same language and also know exactly what customers want.”

Looking back, Wood also says the company spotted a gap in the market because it was happy to handle small sales — for example, contracts worth £50,000 rather than the big sums other companies wanted.

“Lots of companies like working with small companies,” Wood says, “because they know that we can react very quickly and deliver solutions.”

Since 2000, Sciencesoft has had a second round of investment, with Aberdeen’s Nova Technology Fund putting in £350,000. The family has since regained the equity from Nova, allowing it to exit with a healthy return. Since 2002, Sciencesoft has had an annual growth rate of 25 per cent, and turnover this year will reach £3 million, with profits of £1 million, and the management team have set a target of £10m in turnover by 2014.

Growth has been steady but sure. Every year, the company has hired one or two extra people, reaching its current head count of 18, including six “high-end technical specialists” hired during the last two years. The next two years will see a slight surge in the workforce, however, with staff numbers doubling as the company also doubles its office space.

For Sciencesoft, the harder it gets to exploit oil and gas fields, the more its products will be in demand. And with new products coming onstream every year, the company is confident of steady growth in the future — as long as it retains its “small is beautiful” approach to the business.
Core business: Visible light communications (VLC)
Location: Edinburgh
Founded: 2010/11
Team members: 4
Proof-of-Concept funding: £400,000

The idea is not new – transmitting data via light – but Harald Haas and Gordon Povey, along with their colleagues Mostafa Afghani and Wasiu Popoola, have bought the concept into the digital age and transformed a bright idea into an exciting new technology – and a new company.

Based in the University of Edinburgh, the D-Light project run by Haas and Povey is being spun out as a company called PureVLC, ready to commercialise and market its system, focusing initially on niche applications such as oil & gas exploration and mines, where the sparks caused by antennae can be a hazard. Another big potential market is providing an alternative to cabling for in-flight entertainment in aircraft. Ultimately, every home and office could also be equipped with the technology, to provide extra bandwidth as well as security.

The “lightbulb” moment for Haas was when he realised that VLC was going to become a key technology thanks to the increasingly widespread use of low-cost LED lightbulbs. Haas, who did his PhD at the University of Edinburgh (1997–99), then worked for Siemens in Munich and became an Associate Professor at Jacobs University in Bremen before returning to Edinburgh in 2007 and becoming Professor of Mobile Communications in 2010, started doing serious research in VLC in 2003. Two years later, he demonstrated the system in action at an exhibition in Bremen, then published a paper describing the science involved. At that time, his system transmitted data over a very short distance at a rate of only a few Mbits per second.

Today, the system is capable of 130Mbits per second over a distance of several metres, using standard LED lightbulbs, in real time, under normal lighting conditions. In fact, the current speed is more than ten times faster than required for a quality video signal, and the error rate is less than one bit per 10,000 bits. The advance, says Haas, is largely down to using “multiple data carriers” simultaneously – sending and receiving multiple streams of data at the same time as correcting any errors.
The company is well on its way to turning this idea into a commercial product – and a successful new business.

Visible Light Communications (VLC) works by modulating standard LED lightbulbs (i.e., varying intensity) without interfering with the primary function of lighting, controlling the light source to send out a signal then using a detector to receive it. Eventually the system will be an integral part of the lightbulb, added to the electronics already built into standard LED lightbulbs.

VLC: The benefits

> Low power consumption
> Does not cause electromagnetic interference (EMI)
> Does not use valuable regulated RF spectrum
> Uses standard, low-cost, easy-to-install, long-life white LEDs
> No health implications
> Security – signals don’t travel through walls
Sensible sensors

Core business: CO₂ sensors
Location: Cumbernauld
Founded: 2006
Employees: 16
Turnover: Approaching £1 million

It’s usually “last one out, turn out the lights,” but a new type of sensor developed in Scotland by a company called Gas Sensing Solutions (GSS) promises to revolutionise the way we manage buildings by detecting how many people are in different rooms, using smart wireless networks of low-power sensors to optimise office conditions – and save lots of energy and money in the process. And according to GSS Chairman and CEO Des Gibson, this is only one of many applications for the new technology.

Gibson has 30 years’ experience in industry, including spells at Barr & Stroud, Pilkington and Carclo plc, before moving on to set up three successful optical-based businesses. With a PhD in thin film optics from Queen’s University, Belfast, he also has a good understanding of the science involved in the development of GSS products.

The company was founded in 2006 by sales and marketing director Alan Henderson, and Gibson first got interested later that year when he did due diligence on behalf of Tweed Renaissance Investors Capital (TRI Cap) and Scottish Enterprise Co-Investment Fund. And he liked the company and its new technology so much, he not only invested his own money but managed to get himself appointed the Chairman.

“What stimulated me,” he says, “was the market potential. This was a new type of CO₂ sensor for a wide range of applications – including building control systems – which could not only help to improve air quality and ensure safety, but also save energy and therefore money.”

The new technology was also very different. The sensors developed by GSS use a unique semiconductor-based mid-infrared light source and detector combination. In simple terms, this means using light to measure gas [CO₂] levels based on the fact that different gases absorb light at specific wavelengths. And what gives the GSS products the edge is that they use solid state light sources and detectors instead of incandescent light bulbs and pyroelectric detectors, a new combination which greatly reduces the power consumption and also speeds up the process – from minutes to seconds.

Another key factor that clinched it for Gibson and other investors was that this was a “legislation-driven” market, with authorities in the US, Europe and Asia about to put the finishing touches to new regulations for building controls. And thanks to this new emphasis on energy efficiency, the GSS sensors will be used by leading building control system suppliers, enabling offices to fine-tune their heating, lighting and air-conditioning systems by measuring CO₂ levels to calculate how many people are using particular spaces, and adjusting accordingly.
You can have the best technology in the world, but for successful commercial implementation, the essential focus has to be delivering innovative, on-time and cost-effective solutions the market requires. Effective marketing is essential to ensure delivered technology is ahead of the curve.

– Des Gibson, chairman & CEO of Gas Sensing Solutions

According to Gibson, GSS has two key advantages over all other gas sensor solutions. First, the device is battery-operated and requires no hard wiring. The sensors use up to 1/50th of the power of standard light sources and detectors, and they stabilise immediately so you can measure the level of gas straight away, unlike previous sensors which took up to ten minutes to warm up. And this adds up to 1/2,000th of the energy used and means a single battery will last for several years. Ultimately, the sensors will be self-powered, using power-scavenging technologies such as solar cells.

Because the new technology is different, it also requires a new approach to production, and GSS has turned to the University of Glasgow to help it research and develop new mid-infrared sources and detectors. Moreover, the electronics and nanoscale engineering research division at Glasgow University, headed by Professor Iain Thayne, is working with GSS to implement new manufacturing methods which will result in high-throughput production capability.

As further evidence of the strong bonds between the two organisations, GSS and Glasgow University recently secured an industrial CASE Studentship, to focus on research to improve GSS’s mid-infra-red device technology. The award is jointly funded by the Engineering and Physical Sciences Research Council (EPSRC) and GSS.

The company is also working with the University of Strathclyde on research into optics, while the University of the West of Scotland’s microsensors group is helping it model the sensors. “All three universities have worked well,” says Gibson, “and kept their focus. When universities work with industry, they need a change of mindset, and our relationship with all three has been highly successful.”

Because it clearly has significant market potential and has four patents, GSS has attracted the interest of several investors and has already been through five rounds of funding. For the last five years, most of the company’s efforts have been focused on research and development, setting up a global distribution network, building partnerships with industry and establishing production capability, but since it started active sales a year ago, turnover is already approaching £1 million.

Based in Cumbernauld, the company sources components from various countries, including China, and then integrates and calibrates all the components in-house, with a team of 16 people running the show, including Henderson and Gibson, plus financial director John Burgon and engineering & operations director Calum MacGregor.

GSS recently secured first place in the regional final of a Shell Springboard Competition, based on the potential offered by the company’s products for energy reduction.

Building control systems promise to be a huge source of demand for the company’s products, but other markets also have significant potential, including horticulture, with networks of smart sensors helping to optimise plant growth, and safety applications in various industries, as well as mining, diving, automotive (in-cabin) and transport systems. Future products will be used to measure methane – further extending the company’s market.

New GSS sensors

Gas Sensing Solutions (GSS) recently launched a new range of CO₂ sensors trademarked as COZIR, designed for use in battery-powered applications such as hand-held devices and wireless systems, where low duty cycle is important to maximise battery life.

The benefits of the new sensors include:

- Low power consumption
- Battery operated 3.3 volts
- Auto calibration
- Compatible with wireless communications
- Minimal power-up time
- Standard digital output

The new sensors reach full accuracy less than two seconds after powering up, and extremely low power consumption can be achieved by powering down between measurements.

The sensors can be easily fitted into handheld portable devices and wall-mounted control systems, and come in two ranges:

- COZIR ambient (diameter 43mm, height 15mm) – for applications such as heating, ventilation and air conditioning (HVAC), indoor air quality (IAQ), education and horticulture.
- COZIR wide-range (diameter 18mm, height 20mm) – suitable for process control applications such as diving, industrial, safety and automotive.

According to GSS, the new sensors measure CO₂ levels twice every second and consume only 3.5mW in continuous operation – 50 times less than standard non-dispersive infra-red (NDIR) sensors. The new range utilises GSS’s patented mid-infrared optics and light source detector technology.

GSS also recently launched an ultra-high-speed version of the sensor called SprintIR, which samples 20 measurements per second. SprintIR is aimed at applications requiring absolute real time CO₂ response, such as temporal measurement of CO₂ exhalation, in-flow process control and analytical instrumentation.
Core business: Mobile visual search for advertising and retail

Location: Edinburgh

Founded: 2006

Employees: 1–10

Customers: Marketing & media companies and retailers, including Tesco

What if you could point your mobile phone at any product, take a photo and instantly access a web site that tells you all about it, including what it is and where to buy it, price comparisons and customer reviews, then press a button and buy it? What if you could point at any object or image – e.g. exhibits in a gallery or cars in a showroom, a building, an advertisement or magazine cover – and also access all sorts of digital content including web sites, audio and video?

Most of us are already familiar with barcodes as well as their more grown-up versions, QR codes, which provide a kind of digital label that connects you, via a scanner or camera phone, to the relevant web site. But a company called Mobile Acuity has developed a technology for mobile devices which enables you to do the same – and much, much more – with ordinary images and objects, effectively turning the world into an extension of the World Wide Web, with web sites accessible via your camera by clicking on images and three-dimensional objects, the same as clicking on a hot link in a document or browser.

This new technology is called “mobile visual search,” and it’s already been adopted by major marketing companies and retailers including Tesco, who are looking to integrate it into their e-commerce system.

Mobile Acuity founder and CEO Anthony Ashbrook has specialised in computer vision technologies for over 15 years. Before coming to Scotland, he did his PhD in machine intelligence at Sheffield University and he has also worked with companies including Vision Innovations, Virtual Mirrors and C3D, better known now as Dimensional Imaging. In his earlier commercial work, he focused on imaging, computer vision and computer graphics, for industrial and niche applications, but mobile visual search is the mass-market product he’s always been hoping to find.

The big idea

Ashbrook’s lightbulb moment came in 2003, when mobile phones started appearing with a digital camera built in as standard. The big idea was “the mobile that can see” – a new way to search just by pointing the phone, interrogating image databases just like a text search. “The mobile phone with camera provided a platform for thousands of new applications,” says Ashbrook, “for very little capital outlay by individual consumers.”

While still working as a consultant, Ashbrook teamed up with Dr Mark Wright at the University of Edinburgh to develop the idea of “image recognition applications for camera phones” and mobile visual search – and Mobile Acuity started taking shape as a commercial reality.
The idea has incredible potential.

After winning £120,000 proof-of-concept funding from Scottish Enterprise to advance its research from 2004 to December 2005, the company was founded in early 2006 as a spin-out from the University of Edinburgh, backed by a private investor. Within a year, Ashbrook and co-founder Wright had a commercial product ready for market and quickly won business from major brands such as Disney and Nike, but it took a few more years to establish a recurring revenue stream for the business. “Six years later this technology is still just emerging – we were way ahead of the market, which in itself is a challenge,” says Ashbrook.

The question for Mobile Acuity in the early days was: “We have a great technology but how can we most effectively turn this into a business?”

One idea was to develop an app which would recognise virtually everything, but how would you convert that into profits? To make the product work for every object in the world would also take an army of assistants working for thousands of years – collecting millions of images, identifying and classifying every single image, then building the database. Apart from the enormous investment required before you would start to earn money, this would mean competing head-on with established industry giants such as Google, which already collects millions of images from its own users.

Ironically, the launch of Google “Goggles,” an image recognition application which works in a similar way to the system developed by Mobile Acuity, has been a very positive thing for the young Scottish start-up, because it made the technology much better known and more widely accepted – potential customers already know that mobile search is practical and a major technology player is leading the way.

What makes Mobile Acuity different, however, is that it does not intend to compete in the same market sector. Instead of building up a universal database with millions of images, it goes to customers who have their own specialist images ready compiled, and provides a solution which enables that client’s consumers to point at a product or an image of a product in an advertisement or other visual media, and search an image database, using their own mobile phones and a special downloadable app – to browse information and also make purchases.

“The customer who has the most potential for us is the one who wants to give its consumers the best user experience,” says Ashbrook.

First major breakthroughs

Winning a major contact from Tesco is a huge advance for Ashbrook and his colleagues. Last year, the retail giant issued a tender for a new barcode reader solution for mobiles, and Mobile Acuity came out the winner in a shoot-out with a number of international competitors.

The initial specification was simply for barcodes, but Ashbrook reveals that he “sneaked in a camera button” which demonstrated extra capabilities, including mobile visual search. Tesco’s Grocery app has been downloaded and used for millions of scans.

Another recent breakthrough was a partnership with TurnIntoCash.com, enabling users of the company’s website to work out how much their old music and film collections are worth, integrating Mobile Acuity barcode scanning technology across all mobile phone platforms, including iPhone, Android and Blackberry, and “working together to add future visual search functions to the apps.”

As a measure of its impact, the iPhone app was downloaded over 1,000 times in its first full week on the iTunes store.

Another partnership with “digital media delivery company” 7digital will enable users to “discover” music by pointing their phones at an image on a CD cover or another visual medium to access information then decide whether to preview or download and purchase the music.

Mobile Acuity does not earn its revenues from selling software licenses but provides an “unbranded solution” and then deploys a web-based service to clients, hosting the database and processing queries from users.

In the longer term, the company will generate its revenues by earning royalties from usage and the number of transactions. “We want to be in the transaction path,” Ashbrook explains, “and monetise the process.”

The idea has incredible potential. For example, Tesco operates more than 5,000 stores in 14 countries and had revenues of over £60 billion in the last financial year. It reportedly sells 1.5 billion bananas a year and delivers over one billion items to customers’ homes every year. If Mobile Acuity earned a commission every time a Tesco customer used its mobile app to purchase a product...
When the new National Museum of Scotland opened in July, one of its most innovative exhibits was a 2-metre digital sphere displaying geology-focused content stories, developed by a company whose office is only a few hundred metres away from the revamped museum. This year, a similar 1.8-metre-diameter sphere has also been installed in the London Stock Exchange, while smaller 90cm spheres, also permanent exhibits made of acrylic, have gone on show at the National Maritime Museum in Greenwich and the Royal Scottish Geographical Society in Perth. With other clients ranging from the Wagner Fest and musical legends such as Coldplay, who used its spherical displays — PufferSpheres — for special effects on a record-breaking world tour, to high-tech companies such as IBM, O2, Symantec and Google, Pufferfish is fast establishing a global reputation for its specialist projection solutions.

Pufferfish Ltd emerged from the University of Edinburgh in 2004, when its co-founders Oliver Collier and Will Cavendish (now Technical Director) had an idea for an innovative digital display which would enable them to project images onto a sphere, in sharp focus on every part of the surface. Seven years later, the company has gone through several rounds of investment, including substantial funding from the Braveheart Investment Group, plus further backing from Scottish Enterprise’s Scottish Co-Investment Fund and several private investors, and built up a who’s who of clients in countries all over the world, selling and renting solutions for events and permanent exhibits in America and Asia, plus the Middle East and all around Europe.
We have an open approach to supplying solutions, but we always want to make sure that everything works.

In 2002, Collier (music & physics) and Cavendish (who studied architecture) had developed a prototype system which responded to MIDI (musical instrument digital interface) sensors, and spent many hours gluing spheres together with solvent before the undergraduate project became a serious business proposal. The Edinburgh Pre-Incubator Scheme (EPIS) gave the business early-stage financial support when it was established in 2004, and early on Collier and Cavendish also won a SMART: Scotland award, matched by Braveheart, which enabled it to fine-tune its technology and develop its marketing strategy.

The technology has progressed out of all recognition since those early days, but the company has also evolved since it entered the business arena, providing a complete package of services, as well as hardware and software solutions. According to sales and marketing manager Ben Allan, the key to success has been the company’s “hands-on” approach and its international network of partners, as well as its technology and understanding of content. Its partners come in different shapes and sizes, but many of them have a lot of rental experience – essential when so many clients use Pufferfish displays for one-off events.

Every client means a different challenge, says Allan. One day, he is talking to the Ruhrtriennale (Wagner Fest) in Germany, using PufferSpheres for a production of the opera Tristan & Isolde, and the next it is the BBC, shooting a trailer in Cape Town. The company made its first sale in 2006 and, as the years went by, continued to develop its solution and reduce prices. In financial year 2010–11, its gross sales topped £1 million, including 40 PufferSpheres of different dimensions.

The technology

The breakthrough made by Pufferfish was to develop special lenses and projection techniques to display images (output from standard projectors made by companies such as Projection Design, Christie and Barco, etc.) onto a spherical surface from sources including a laptop computer or media server, converting (or “spherising”) digital content designed for a flat surface onto a sphere, so every single pixel remains bright and equally focused. The process may seem simple, but Pufferfish is clearly a few steps ahead of its rivals, who have struggled to provide a higher-quality or lower-priced alternative. The principles of the core technology are “essentially the same,” Allan explains, but they have learned a lot along the way not just about projectors and lenses but also the materials and coatings used for spheres, many of which are inflated on site in a matter of minutes, like balloons. The technologies are also open, says Allan, so PufferSpheres can integrate with most other media systems, including specialist devices.

What makes the technology so different, says Allan, is the original design of special “omni-focus” lenses, plastic coatings and novel projection techniques, with images controlled by special software. But another key difference is attention to detail and the flexibility to build solutions matched to client needs – for example, spheres robust enough to meet strict safety standards at the same time as being easy to transport, maintain and install.

For Allan, one of his proudest achievements is when someone comments on one of its systems by saying “that’s a Pufferfish,” as if the brand name is already recognised as generic – like Thermos or Hoover. But even though its systems may give Pufferfish the edge in this particular technology, Allan also believes that the service it offers is what makes the critical difference. “We focus on being the company people want to work with,” he explains. “We have an open approach to supplying solutions, but we always want to make sure that everything works.”

Pufferfish has come a long way in the last seven years, but it still keeps in very close contact with the university where it all started, and a new generation of students in the Informatics Department is now using Pufferfish systems to develop innovative interactive displays – as if the spherical idea has come full circle.
When Matthew Aylett answers the phone, some people may wonder if it is him or not. After all, his company (www.cereproc.com) is one of the world’s leading developers of speech synthesis systems, and he may just be trying out one of its latest creations.

There are many bad examples of speech synthesis systems, including speak-your-weight machines and Daleks. Text-to-speech or TTS technology can also have its funny side – e.g. the American editor who wasn’t aware Stephen Hawking was English because of his “American” accent. Voice synthesis is also nothing new – Alexander Graham Bell also tried to develop a Speaking Machine. But according to Aylett, robot-like voices will soon be a thing of the past as machines learn to speak more like humans, thanks to recent technological advances.

“We give machines a personality, character and emotion,” says Aylett. “We can also clone human voices, duplicating them so a machine can use the voice, or humans can replace their own voices.”

Aylett, who is Cereproc’s chief technical officer and co-founded the company with Paul Welham and Christopher Pidcock six years ago, is a self-confessed evangelist for “characterful” voices for machines. “I want to get the industry to move past conventional command and control systems,” Aylett explains.

It is ironic that when CereProc first developed its interest in voice synthesis, many industry pundits did not see the appeal of more human-like voices. The orthodox opinion was that machines should sound neutral, but Aylett questioned the value of the “ unearthly” voices of so many systems.

Aylett’s interest in creating emotional voices started eight years ago, when his sister was investigating “bullying” as part of a the “FearNot” project at Heriot-Watt University and asked him if he could produce five “expressive” characterful child voices to help her research. Aylett, then a senior engineer in a TTS company called Rhetorical Systems which spun out of Edinburgh University in 2000, realised that the current technology needed to be improved to achieve this goal.

Rhetorical was later bought by Nuance (formerly Scansoft), and after a spell working at the International Computer Science Institute (ICSI) at Berkeley, California, Aylett teamed up with Pidcock and Welham to form Cereproc, “lamenting the lack of innovation by speech technology companies around the world.”
Academics, says Aylett, tend to look for publishable, theoretically interesting ideas, while commercial enterprises need end results. Cereproc, he says, has taken a “mixed approach” to advance its technology, in the quest to develop more characterful voices. The classic industry approach was to think in terms of male or female voices, and there was little incentive to create something better. But Cereproc’s founders had different ideas.

Initially, the company’s resources were ploughed into developing the “voice-building process,” so they could produce a wide variety of voices easily and quickly to meet different client requirements. Choosing the right accent for particular uses can be an interesting challenge, says Aylett, because many accents are “loaded” with their own associations. Realistic-sounding speech can be important, but if an automated machine is stating your bank balance, for example, neutral speech may be more appropriate. On the other hand, to read out an entire paragraph, the voice has to have a more “natural” tone to convey complex meaning – or it will sound very boring.

To explain this process, Aylett refers to the “emotional continuum” of voice synthesis systems, including the basics of “happy or sad, positive or negative, active or passive” (see sidebar). To make a voice sound human, it should be capable of speaking in a natural manner that seems to appreciate context and meaning, etc., but Aylett also cautions that the aim is not to misdirect or “trick” the listener but simply make the machine sound more “normal.”

The growth of the voice synthesis market has also been driven by changes in other technologies such as smartphones and tablet computers, which come with built-in microphones and are starting to popularise speech recognition solutions. A few years ago, it was thought the killer application would be automated travel agents, “speaking” to customers over the phone, but visual presentation (e.g. websites) for some applications will always be much more effective.

Like the Daleks, voice synthesis once had a bad reputation, says Aylett, and the technology was “a design-free zone,” but this is now rapidly changing. Voice synthesis is not always the most appropriate interface, however. We don’t need our toasters to tell us the toast’s burned, for example, but voice synthesis systems are now going through a renaissance, because they’re being used in more appropriate ways. “The problem is designing it so it is right,” Aylett says.

Speech synthesis systems are also beginning to spread into more and more aspects of life, not just electronic games and voice-response systems but mobile and virtual devices, including “smart homes,” where technology “speaks” to people with disabilities such as impaired vision.

Another application gaining in importance is “aggregated data” systems combined with TTS – for example, a “personalised radio” system which can search the web for news alerts and then read them out, in the voice of your choice, as a customised “package,” while you are driving. Other alerts could be set up for air fares or special promotions – much the same as “live” traffic announcements. Radio, says Aylett, is making a comeback, and “push-down” (as opposed to “pull-down”) data systems could be part of this resurgence. “We are wading through a sea of information,” says Aylett, and using TTS could turn it into a “rich audio experience.”

Aggregated data was one of three Cereproc projects funded by Scottish Enterprise under the SMART: Scotland programme, starting in 2006, when the company received a grant for £50,000 to develop a semi-automated voice synthesis system. Voice cloning is another exciting area for Cereproc – and not just for fun. If people are about to lose their voices because of a medical problem, the voices can be sampled and then reproduced so they sound “just like themselves.” A humorous example of this kind of technology can be heard at http://www.idyacy.com/cgi-bin/bushomatic.cgi, where you can type in words and listen to President Bush say whatever you want him to say.

Cereproc has sometimes swum against the tide as it developed speech synthesis systems, but has now established itself as an industry leader. In Aylett’s view, the future of the company depends on “staying at the cutting edge of the technology,” because for such a relatively small business to survive, it has to be one step ahead of its rivals. Cereproc’s success so far has come from the freedom small companies have to pursue their own vision, and Aylett believes this has enabled it to be more innovative – and will continue to help it in future.
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