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Photonica: Growing a 'Spin-out'

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Abstract. This case invites students to consider the challenges associated with establishing and growing an entrepreneurial, technology-driven, university 'spin-out' firm. Drawing heavily, though by no means exclusively, on the real-world experiences of Stress Photonics, the case examines the performance and activities of the fictitious firm, Photonica, from the perspective of its two principle founders, Bob and Jake. Students are encouraged to consider key features in Photonica's evolution, including the role of the University of Wisconsin in its establishment and development, how it created and exploited new technologies, the importance of its key clients and alliance partners, and the critical role of the US Small Business Innovation Research Program (SBIR) in promoting enterprise in Photonica and more widely across the USA. Students are invited to present a five year strategic plan for the company.

Keywords: university 'spin-out', product development strategy, management and control in small and medium-sized enterprises (SMEs), growing an SME, university research parks, the US Small Business Innovation Research Program (SBIR).

1. Introduction

On May 1st, 2004, Jake Kesselmann eased himself into the seat of the Airbus A320 for the three-hour flight back to Madison and immediately began to reflect

1. This case was written by Adam Cross, with the assistance of Alison Swales and Bob Handscombe. It is based on the findings of a White Rose Centre for Enterprise study visit to Wisconsin by Adam Cross, of the University of Leeds, and Eann Patterson and Bob Handscombe, both of the University of Sheffield (Eann Patterson is now Chair of Mechanical Engineering at Michigan State University). The case has been developed to illustrate the challenges of establishing a viable university 'spin-out' company. The study draws upon the history, experiences and product range of Stress Photonics (www.stressphotonics.com), a company founded in 1988 by academics and students of the Engineering Mechanics department of the University of Wisconsin (UW) at Madison, USA. The technologies described herein are real, as are the US government and educational establishments (except Templemead College) and the funding schemes mentioned. Otherwise, Photonica's employees, customers and related companies are fictitious, as are all the events described. Any resemblance to characters alive or dead or to events that actually happened is purely coincidental. The case serves as a basis for class discussion rather than to illustrate either effective or ineffective handling of an administrative situation.

on his day. He had mixed feelings. On the one hand, completing Photonica's fortieth US order for ThermaSPI analysers, purchased this time by the US Airforce at the Fairchild Airforce Base in Washington State, was intensely satisfying. Negotiations had been lengthy and involved – commonplace among Photonica's military customers – but the seven analysers were now commissioned and Jake had just finished the job of training the various aircraft maintenance crews to use them. Chief Engineer Major Ike Porterhouse was unrestrained in his praise for the ThermaSPI's accuracy and ease-of-use. The ThermaSPI-440, the latest in a range of thermoelastic stress analysis (TSA) equipment designed at Photonica, was about the size of a 1980s camcorder and supported by a computer not much bigger than an early laptop. The analyser was easily carried to the structure to be investigated (such as a wing component); a quick 'point and shoot' and the data obtained could be analysed there and then on its integral display screen or in the laboratory later for detailed study with a computer. The instrument could identify even the smallest of stress fractures and similar structural anomalies. The ThermaSPI-440 was a quarter of the size of Jake's early ThermaScan equipment and about a tenth of the cost. "Guys who need good stress data fast need a ThermaSPI" was Jake's mantra.

On the other hand, the Fairchild project now concluded, Jake knew he could no longer ignore several challenges presently facing his company, Photonica. Jake had become increasingly aware that he and Bob Backer, his long-time friend, business partner and a co-owner of Photonica, had micro-managed the company for far too long. It was time to stand back and reflect on Photonica's strategic direction. The monthly director's meeting the following week would be an ideal occasion to present a five-year strategic plan for the company. Jake waited for the aircraft to reach cruising altitude, ordered himself a Root Beer and began to sketch out the options as he saw them.

2. Background to the Founding of Photonica

Jake and Bob first met in 1990 as graduate students on one of the Masters programmes offered by the Electrical Engineering Department of the University of Wisconsin (UW) at Madison, USA. Both were talented engineers – Jake in instrumentation and sensors, Bob in circuitry and software development. They were both also keen inventors and they quickly became good friends, bouncing ideas off each other and prototyping Jake's instrumentation designs in the departmental laboratory well into the night. Their energy was quickly spotted by Professor Eric Taylor, Head of Electrical Engineering at UW, who invited them to do some tit-bit consultancy work for him at the edges of his research. Taylor was an academic-cum-entrepreneur with a keen eye for talent. It was his custom to identify high achieving sophomores (undergraduate students in the US system) and invite them to join one of his research groups after graduating. Taylor was able to tap into a pool of bright and committed graduate researchers to work on high-level projects for his clients, to the benefit of all concerned. As it would turn out, this included Bob and Jake, for whom Taylor's consultancy work provided a nice if rather erratic income to help finance their postgraduate studies. Nevertheless, during the spring and summer of 1991, with the ominous prospect of graduation and job-hunting looming steadily larger, Bob and Jake increasingly realised that the economic downturn in US manufacturing and the concomitant squeeze on graduate recruitment would mean finding a job in industry was going to be tough. Typically, budding entrepreneurs with an idea and a passion should do both market and product research to discover how their ideas might best be commercialised, to 'step out of the comfort zone', take risks and believe in themselves. Jake and Bob, however, cut straight to the last of these – they were young, bright and confident they could succeed outside of "the shackles of corporate life". Within one year of meeting and recognising their lacklustre prospects in industry, Bob and Jake decided to found Photonica. They invited Taylor to take an equity position too and in return he promised to direct as much consultancy work Photonica's way as he could (see Exhibit 1 in the Appendix). This kept some money flowing in and, provided Bob and Jake remained registered for their Masters, Photonica would enjoy rent-free accommodation in the University departmental laboratory too (see Exhibit 2). Surely one of their many ideas would have some commercial value?

3. Photonica's Early Management

It was clear from the beginning that Photonica's three founders had contrasting yet complementary capabilities. Jake was energetic, out-going and creative, combining an aptitude for selling with a strong ability to innovate; an ideas man. Bob, by comparison, was more retiring, grounded and methodical in outlook. He was quick to take on the responsibility of learning about establishing and managing a small business and enthusiastically he put his knowledge into practice, putting systems and procedures into place and running the accounts punctiliously, even when turnover was negligible. Taylor, on the other hand, brought to the business his strong network of contacts with the US government military and at the National Aeronautics and Space Administration (NASA) that he had nurtured over two decades of research and consultancy work. These contacts were to prove a valuable source of revenue for Photonica in its early years.

4. The Company's First Successes

By 1992, Bob and Jake were busy, mostly carrying out 'soft' consultancy work and small research projects for Taylor's contacts in the US airforce and at NASA. Often this meant analysis of ambiguous data collected by NASA scientists; sometimes the opportunity to test damaged structures in the laboratory using Taylor's research instrumentation; occasionally, visits to NASA and other sites to use the client's own equipment, collecting data and working with their engineers. All this was an invaluable experience. The two young graduates quickly learned how to gain the confidence of technically demanding, highly qualified and vastly more experienced engineers in high-profile client organisations and, more importantly, how to 'speak their language'. At the same time, however, the two had become increasingly frustrated by the equipment they were forced to use for measuring structural stresses and strains. Taylor's equipment was certainly highly innovative, drawing upon his years of thermoelastic stress analysis (TSA) research, but these were laboratory-confined scientific instruments, cumbersome and impracticable for industrial applications or field use. Measuring equipment that could be used in the field (as exemplified by the market leader, Alphatron) employed a slow, point-by-point method of measuring which meant that the instruments were heavy, fiddly and laborious to use and did not always give reliable results. Jake was certain that he could apply principles he had learned during his TSA research with Taylor to make a much more accurate, cheaper and faster instrument than Alphatron's which he was sure would sell.

5. TSA Technology

Thermoelastic stress analysis (TSA) is a non-invasive technique that produces a stress map by detecting with a sensitive infra-red camera small temperature changes in materials under stress and presenting this information as an image from which stress calculations can be made. TSA technology is highly versatile and can be used to perform design comparisons or to survey stress patterns within existing structures, large and small, to identify structural flaws such as cracks and other potential problem sites in a non-destructive, non-invasive way. Taylor's group at UW was one of several institutions around the world researching TSA (other notables being Waseda University in Japan and Università degli studi di Bologna in Italy), but few had the resources, capabilities and links with industry to rival him. And only Jake had the vision to see that Taylor's approach to TSA could have industrial application. In the autumn of 1992, Bob and Jake drew upon their consultancy income and savings, and after some experimenting, they assembled a prototype full-field thermoelastic stress analyser which they named the ThermaScan (see Exhibit 2). Standard components were bought in where possible (the camera, the computer, the chassis) and the two focussed their attention on the design of the interface box between camera and computer (Jake's brief) and the software to process the signals (Bob's brief). Three product patents and a process patent were filed with the US Patent and Trademark Office (USPTO) in September 1992 along with several trademark registrations. In November that year, with some trepidation, Bob, Jake and Taylor presented a working prototype and supporting research findings to a small group of aeronautical engineers at NASA's Langley Research Centre, the pre-eminent civilian aeronautics laboratory in the USA and their main consultancy client. They need not have been anxious – the reaction was one of enthusiastic support. The full-field capability of the ThermaScan meant that the image of the whole target was available for scrutiny after just 20 minutes – the length of a coffee break – compared to three days using existing point-by-point equipment supplied by Alphatron, the current market leader (see Exhibit 3). This speed matched the processing capabilities of finite element analysis (FEA) software – a technique widely used in the aerospace and automotive industries to assist in the low stress design of components and structures (i.e. to find designs that would be less liable to failure under load). FEA was an excellent tool for the design engineer, but the stress maps produced by FEA needed some real, measured data to calibrate them. The Alphatron equipment provided some calibration points but was so slow and difficult to use that significant uncertainty was inherent in the FEA maps it generated. "The trouble with point data," said Jake, "is that the design engineer is essentially extrapolating from a single point. Those curves could go anywhere". The ThermaScan suffered from no such limitations.

Bolstered by the success at Langley, in February 1993 Bob and Jake submitted a number of formal, written proposals to the Pentagon in Washington, setting out the technical specification for the full instrument, its price and delivery period. From this an order was received to build a fully functional ThermaScan for NASA Langley, and Photonica's first ThermaScan100 analyser was installed there in November 1993.

6. Photonica Quits its Hatchery

Bob and Jake had developed and assembled its first ThermaScan using the laboratories and facilities at UW-Madison, which had been made available to them at cost. However, soon tensions and petty jealousies between Bob and Jake and the other solely academic researchers and laboratory staff had become obvious. There was also increasing friction with the University. Bob and Jake had put themselves, but not Taylor, down as inventors on the ThermaScan patents and had pursued them outside of the University's patent administration system. The University claimed ownership of inventions made by staff in the course of their duties but the rules were ambiguous with regard to students. Not unreasonably, UW suggested that if Bob and Jake wished to be based in the

University and use University facilities at cost, then the University should have some equity and some say in the running of the company. Jake was nothing if not headstrong. So, with confidence running high after their first ThermaScan sale, they moved in December 1993 out of the University and into a small unit in the MGE Innovation Center, part of the University Research Park (see Exhibit Four). Photonica now had its own purpose-built laboratory and full administrative support to run a small manufacturing business. But they also had rent and salaries to pay. Photonica's first employees were two post-doctoral researchers from the UW Mechanical Engineering department who joined as technicians a month later. The University administration gave up on seeking equity and settled for rental income from tenancy in the park, fully priced contracts for laboratory support and the valuable graduate employment and placement opportunities that seemed poised to expand in Photonica.

At the outset, Bob, Jake and Taylor decided to divide the shareholding of Photonica equally between them. However, as the company's business grew, the two young inventors became increasingly sensitive to what they felt was their inexperience in commercial matters, particularly in tapping venture capital needed to finance the company's burgeoning R&D effort. Certainly, neither they nor Professor Taylor were business-people. So, in December 1993, the decision was taken to dilute the directors' share-holding in Photonica by accepting onto the board two advisors, Alan Day and Sarah Cartright. Each received 15% of equity, but made no capital investment themselves. Alan and Sarah both had over twenty years experience in industry, Alan as a sales engineer for a large US petrochemicals company and Sarah as a finance director for a local public utilities company. Both remain in office today. It was hoped at the time that these new board members would bring general business expertise, advice and contacts with venture capitalists and other financiers, but they would soon disappoint.

Building upon the success of the Langley unit, a further two ThermaScans were assembled in 1994 for the US Airforce bases at Charleston, South Carolina and at Fort Hood, Texas under Pentagon-awarded contracts. By this time, Jake and Bob had also made a successful Phase One application to the Small Business Innovation Research (SBIR) programme (see Exhibit 4). This is a Federal US Government scheme, established in 1982 to promote enterprise and entrepreneurship in American start-up companies. It had been Photonica's first application. The award of $98,000 provided Photonica with a vital injection of developmental finance. Part of this was used to fund improvements to the ThermaScan-100, later to be coined the ThermaScan-200. However, the largest tranche was allocated to the development and prototyping of a second-generation TSA instrument, which they called the ThermaSPI-220. This would be a cheaper, more portable and robust device than the ThermaScan range, using similar measuring principles but applying new camera head technology sourced from abroad. Again, Bob and Jake's skill at combining existing technologies to produce innovative ways to measure stresses and strains cost-effectively was more than amply demonstrated.

7. The Internationalisation of Photonica

In late 1995, following hard on the success of the sales of ThermaScans to the US airforce, Jake and Bob received their first international sale, from the Sensor Group at the University of Sheffield in the UK. The euphoria quickly vanished as Jake became bogged down with the minutia of international trade. Parochial is probably too harsh a term to apply to the First New Madison West Bank (see Exhibit 5), but the difficulty and cost Jake faced to untangle the confusion in the paperwork for the UK sale was unsettling. "Like they read Sheffield, England and assumed I meant Sheffield, Mass. Jeez, sorting that must have cost me the whole profit on the deal".

In 1995, following a courtesy visit to Sheffield, Jake extended his trip to take in the Thermal Sensing and Imaging Diagnostics conference in Stuttgart, Germany. There, he struck a friendship with Otto Bornemann. Otto was an ex-senior design engineer at the German electronics giant, Siemens, and now had his own company, Intellitron GmBH. Intellitron also made thermoelastic stress analysers, but using a novel and patented camera array more advanced than presently used in the ThermaScan. The two companies entered into a 10 year cross-licensing agreement later that year, exchanging complimentary patented technologies to co-develop the next generation of TSA technology, sold in the USA by Photonica as the ThermaSPI-220. With a lighter and more compact camera array, the ThermaSPI was a much more portable instrument than the ThermaScan, but equally accurate. It would be manufactured by Photonica in the USA and, in respect of the Intellitron input, Photonica agreed to pay Intellitron a 9% royalty on sales. In addition and again on the basis of 9% royalties, Intellitron secured the rights to sell all Photonica's products outside of North America and Photonica assumed responsibility for the sales and service of Intellitron's product range in North America, which it began to do in the autumn of 1996.

8. The Late 1990s: A Period of Consolidation and Setback

Except for 1995, Photonica's turnover grew steadily year on year through the 1990s and beyond, rising from \$284k in 1993 to \$1589k in 2003, an impressive five-fold increase for such a young engineering company (see Exhibit 8). The SBIR scheme was an invaluable source of income to Photonica. This was used mostly to finance Photonica's R&D effort, which as before was directed mainly towards discovering new applications for known technologies. However, inflows were lumpy and never guaranteed, and consultancy work remained the mainstay of Photonica's revenue stream throughout the 1990s (averaging around a third of all revenue). As sales in new equipment and accessories increased, consultancy work as a proportion of total sales gradually declined to below one quarter by 2002. However, the importance to the company of consultancy fee income was especially evident in 1995, a year of painful memories for Jake and not just for business reasons: within weeks of arriving back from his European trip a shocking skiing accident in Colorado saw him confined in traction at home with compound fractures to both legs. Jake was able to spend these seven months usefully, however, writing SBIR and other grant applications, not to mention publishing four academic papers and having the germ of an idea that would advance the ThermaSPI technology beyond that envisaged by him and Otto earlier that year. Nevertheless, his consultancy activity was dramatically curtailed and the impact of this on Photonica's revenue was clear. Although not a conscious decision, this experience probably encouraged the company to press ahead with its equipment manufacturing ambitions.

9. New Product Development

The modular design, speed, accuracy and functionality of the ThermaScan product range were all key selling points. However, only customers in the military, aeronautical and automotive sectors and the odd university department seemed to have the volume of stress analysis work needed to warrant the significant investment of capital – $110k for the basic module – and time needed to install a ThermaScan unit into their research and maintenance operations. So, both Bob and Jake were kept busy using ThermaScans to do short-term investigations and on-site project work on an ad-hoc and often urgent basis for a variety of US industrial and manufacturing companies.

However, the launch of the ThermaSPI-220 in late 1996 changed all this. Using Intellitron's new camera array design, coupled to a sophisticated metering system invented by Jake and a computer interface developed by Bob, Photonica was able to produce and manufacture a much more portable detector than the ThermaScan for around $50k less, without significant compromise to accuracy. Sales of the ThermaSPI-220 and later the ThermaSPI-440 took off dramatically, both in the USA and (but less so) Europe, with universities and other research institutions clamouring to join a growing number of industrial and military users as customers. Perhaps it was inevitable that the new product range would impact detrimentally on ThermaScan sales, which would henceforth only be bought for high-end laboratory research and in-service inspections, and even then mostly by overseas clients.

In order to raise output and meet demand, the company moved away from the University Research Park in 2000 to a large factory unit on an industrial park to the east of Madison with its own manufacturing, warehousing and distribution facilities. In addition to the directors and two part-time secretaries, Photonica now employed eight full-time technicians, each educated to at least masters level and mostly graduates of UW. They worked mainly on product development, assembly and testing. But these were fluid numbers. The shortage of skilled, quality people who would commit themselves to Photonica had become a major constraint to growth. A regrettable, but fortunately atypical, instance occurred with the recruitment from Boeing of Max Addler, a young, bright, fast-talking and likeable electrical engineer. Both Bob and Jake invested much time and money training Max for a senior design engineering role, only to see him leave, along with a 15 GB hard disk of sensitive data, just seven months after joining. Photonica's lawyers were still grappling with the fall-out.

In 2001, Photonica's lawyers had also been busy sorting out the terms of agreement of a joint Phase II Small Business Technology Transfer Programme (STTR) (see Exhibit 5) grant application involving Photonica, Templemead College and NASA. Like the SBIR, this federally-run programme was designed to promote innovation and enterprise in small private firms, but this time by funding the commercialisation of technologies invented in non-profit research institutions such as universities. Research by an electronics group at Templemead College MA and funded by NASA Langley under a Phase I STTR grant had produced some interesting results, and a novel photo-elastic stress analysis device had been patented jointly by NASA and Templemead. But Templemead College had no experience of 'spinning out' firms or commercialising technology, so when the Templemead project leader bumped into Jake at the annual Society for Experimental Mechanics conference, and knowing of Photonica's recent successes, she pressed Jake hard to become involved. Jake had experience of collaborating with academics at Madison and Sheffield and was impressed by the quality of the work and the ease by which he could interact commercially with them. So Jake agreed that Photonica should buy-in Templemead's photo-elastic stress analysis technology and commercialise it for them under license. However, he quickly discovered that Templemead was not in the same class as the other institutions. The researchers he dealt with there were pleasant enough individually, but they proved highly reluctant to share with him anything more than the information and technology already disclosed in their patents. Despite sales of the Phostascope taking off in 2003, the atmosphere of mistrust at Templemead gave Jake serious doubts for the long term viability of Photonica's alliance with them. The experienced was to tarnish Jake's view of alliances in general.

In 2000, Photonica took the decision to pursue a strategy of shifting its manufacturing emphasis away from the ThermaScan range (high-end, low volume equipment for 'technically-savvy' customers) to the ThermaSPI range (low-end, low unit price, high volume equipment for more general-purpose applications), mainly in response to customer demand. This trend was further evidenced by the development of new products under several SBIR grants with the Federal Highway Agency and John Deere, the leading American manufacturer of agricultural and construction machinery. Two years in development and using different measuring methods to the ThermaSPI, both the ThermPac and Phostoscope products had been introduced to the market in 2003 and their sales potential was yet to be revealed. At the same time, a number of other vehicle manufacturers led by General Motors and Ford had enquired with Photonica about the possibility of installing ThermaSPI systems into their production lines as real-time quality control monitoring devices. Interest in Photonica's product range was at an all time high.

10. Related Diversification

An increasingly important source of revenue to Photonica by the late-1990s was the growing amount spent by existing customers on accessories, spares and upgrades to the installed base of TSA equipment, especially on software. Bob had written specific application software, branded VisioGen, for the collection and management of data gathered by all Photonica's TSA instruments. This new package offered superior graphics, various presentation modes, advanced data manipulation, support for popular computer platforms and integration with industry-standard engineering software. Demand for it was strong. Moreover, the modular design of equipment to date, for example, the interchangeability of the ThermaScan 200 and ThermaSPI 440 camera head with older models, offered enticing upgrade opportunities to users with ageing equipment, producing measurement gains of several orders of magnitude. The impact on new equipment sales of this unintended customer migration strategy was unclear, however.

11. Overseas Sales Prove Disappointing

Initially, the business relationship with Intellitron had been cordial. Both companies had benefited considerably from the technology transfer; indeed, Intellitron's technology had been pivotal to the later successes achieved in the ThermaSPI system by Photonica. In the beginning, Otto and Intellitron worked tirelessly to sell ThermaScans and, later, ThermaSPIs, through its worldwide network of agents and distributors, and with some success. Equipment had been sold to large industrial and government organisations in Germany, Japan, France, Italy, the UK and Singapore. However, by 2002 non-US sales and royalty income had failed to grow as quickly as Bob and Jake would have liked. And, because they had such little contact with foreign end-users, it was hard for them to discern why. Clearly, the strength of the dollar against other major currencies had not helped. Nor had Otto's worsening heart problem. A potentially lucrative contract with a Berlin university had been lost during Otto's hospitalisation in 1998. But was this the full story? Bob was not so sure. "If we push Intellitron's wares more vigorously stateside, maybe they'll do the same for us worldwide?" Bob suggested to Jake in the fall of 2002. But both knew that Photonica was already hard pressed keeping abreast of the volume of US orders for Photonica products, where profit margins were considerably greater than the 9% royalty on Intellitron products, and the notion was quickly forgotten. On January 5th 2004, a letter arrived on Bob's desk from Heinz Schmidt, Intellitron's Managing Director, stating that they would refuse to market the Phostascope and ThermPac products without a $150k up-front fee from Photonica for "service and support materials". Heinz also reported that he suspected one of their agents in France of passing-off a Photonica sensor as their own, in flagrant breach of Photonica's patent. Bob had yet to reply.

12. The Role of the SBIR Grant Scheme

By the late-1990s Photonica's consultancy work was generating a healthy cash-flow, debts were low and the company was quite strong financially. Nevertheless, consultancy income was insufficient to finance the company's substantial R&D effort, which was costing around $500k per annum by 2002. Photonica was almost entirely reliant on successful Phase I and II SBIR grant applications to fund the design and commercialisation of new products. The list of Photonica's funders under the SBIR and STTR schemes was impressive, including Forbes 500 firms such as General Electric, General Motors, Ford, Boeing, Caterpillar, 3M, Lockheed Martin and Deere and Co, as well as government agencies such as NASA and the Federal Highway Agency. Over $2.6mn of R&D funding had been secured in this way. Nevertheless, Bob and Jake still needed a large facility with the First New Madison West Bank of over $350k to finance the purchase of sub-components needed to fulfil the shipment of high-end, high value orders. Although each of the directors had made a reasonable living from the company, this meant that they were each effectively in negative equity with the Bank and could not sell-up, even if they wanted to. Literally, they were in business for the long-term. "Another good reason to re-orientate production to low value, high volume manufacturing?" mused Jake.

13. Marketing

Even by 2002, Photonica had done little formal market research other than that required under Phase II of the SBIR applications. Bob and Jake felt they were able to gauge industry trends and dynamics reasonably well through their consultancy work. "We know what our customers want and we sure as hell know what they don't know they want" Jake would often assert. And, in any case, word-of-mouth and recommendation had served them well. Photonica also placed great emphasis on relationship marketing. The two made regular calls to existing clients, using a contact database to identify lapsing customers. They mailed existing clients a quarterly newsletter containing summaries of the latest academic research in the area of stress analysis along with product and up-grade announcements. And the website that Bob's partner and graphic artist, Clarissa, had designed in 2000 was attracting interest in the company from around the world, helped considerably by the use of internet technology that ensured that Photonica's name appeared at the top of any search containing keywords such as 'thermoelastic' and 'photoelastic'.

14. Tensions Among the Board Members

The roles of Photonica's individual board members had crystallised quite early on, though not through any formal process. In addition to his research and development roles, Jake assumed the responsibility of sales person and on-site engineer. He negotiated contract terms with clients, installed and commissioned the equipment, and provided on-site training, tasks that were becoming increasingly burdensome. As the number of sales increased, inevitably Jake found himself spending more and more time away from Madison. Although he would not admit it, this was putting some strain on him and his young family. It also removed him from the laboratory and from the broader academic scene, which, Jake felt, was stifling his creativity. Similarly, most of Bob's time was spent on after-sales support and, significantly, new software development, which was proving to be a real money-earner. Although both had become highly stretched they found it almost impossible to delegate. On the other hand, the remaining board members had become more or less sleeping partners. Taylor and his contacts had been essential in the early years, but, as technologies advanced, so his usefulness diminished. His impending retirement in 2004 would need to be managed. And as for Alan Day and Sarah Cartright, it had become quickly apparent that they lacked the 'speed-of-thought' needed to run a fast-moving and entrepreneurial company, while their asset as conduits to venture capital remained unused. By 2003, all three had receded into the background. Together, Jake and Bob took the day-to-day decisions, which the rest of the board normally accepted "without argument or suasion". Nevertheless, both felt guilty that they had taken their eye off the 'strategic ball' and they knew that some hard decisions were being avoided.

15. Setting Photonica's Strategic Direction

As Jake drained his third Root Beer, he surveyed the notes in front of him. He had several questions under several headings.

- Product Development Strategy How wise is it to focus Photonica's R&D effort on the low-end, high volume area of business when its key competence in the past has been in the high-end, low volume area of experimental stress analysis? Should they continue to move away from the consultancy work that had proved so lucrative in the past? And how best should they finance new product development?

- Board of Directors What, if anything, should Bob and Jake do about Taylor's retirement and Alan and Sarah's 'free-riding'? Their shareholdings could be bought back, but at what price to Photonica's R&D effort? And how much longer can Bob and Jake micromanage the company? Are their skills being used to maximum advantage? Should a commercial director be recruited, and if so, what shareholding, if any, should be offered?

- Internationalisation How should Photonica address its foreign markets? Is the relationship with Intellitron irreconcilable? Should other alliances be entered into, and if so, how should Photonica extricate itself from the Intellitron arrangement?

- Marketing Should Photonica change its marketing strategy? If so, how?

- Corporate Strategy In short, how should Bob and Jake grow Photonica? Should they continue with their strategy of greater market penetration and product diversification through innovation? Should they consider branching out into new areas of business? Or should they retrench, with a view to selling the company when sales improve?

Jake knew that he and Bob had some tough decisions ahead.

Possible Case Study Questions

1. How would you describe Bob and Jake's management style? Has their management style helped or hindered Photonica's growth to date? And in the future?

2. How would you describe Photonica's product development strategy? To what extent is Photonica's R&D effort technology-driven rather than market-responsive?

3. Characterise the various stages in Photonica's development from academic research group to stand-alone company.

4. To what extent has Photonica's close relationship with the University of Wisconsin at Madison benefited it?

5. In what ways does the business environment for fostering spin-out firms differ between the USA and UK?

6. Carry out a SWOT analysis of Photonica. Do the company's strengths and opportunities outweigh its weaknesses and threats?

7. Devise a strategic plan for Photonica for the next five years.

APPENDIX

Exhibit 1: A Chronology of Photonica

1990	Bob and Jake meet at the University of Wisconsin-Madison as graduate students working on a research project for Prof. Eric Taylor. They begin to do consultancy work for him.
1991	Photonica, owned jointly by Bob, Jake and Prof. Taylor, begins trading, primarily doing consultancy work for the latter.
1992	A prototype ThermaScan is assembled and demonstrated. Four patent applications concerning ThermaScan technology are filed with the US Patent and Trademark Office (USPTO).
1993	Photonica submits proposals to academic and military funding agencies to finance commercialisation of the ThermaScan technology. An application to the Pentagon is successful. In November, the first functional ThermaScan100 is installed at NASA Langley. In December, Photonica moves into the MGE Innovation Center, University Research Park, Madison WI. Alan Day and Sarah Cartright join Photonica's Board.
1994	The ThermaScan technology patents are granted. Photonica's application to the Small Business Innovation Research (SBIR) scheme is successful and a grant of $98,000 injects vital capital to finance further development and production of the ThermaScan100 for NASA.
1995	Two ThermaScan100s are sold to the US Airforce and the first international sale is made to a Mechanical Engineering department of a top British university.
1996	Joint product development efforts between Photonica and Intellitron of Germany begin. Intellitron sells and supports Photonica's products outside of North America and Photonica reciprocates in North America. A prototype ThermaSPI 220 is produced.
1997	NASA agrees to fund the development of a single-input variable-amplitude approach for use in conjunction with the ThermaSPI 220. Improvements in the ThermaSPI 220 design leads to the development of the ThermaSPI 440, launched to market in October. Launch of two new software products to complement and improve ThermaSPI – motion compensation software and box averaging software
1998	Completion of the Phase II SBIR contract of $454,000, funded by NASA, to develop the ThermaSPI 440. Several patent applications are made to the USPTO. Photonica, together with NASA Langley, are awarded the coveted "Landmark Innovation Award" for the ThermaSPI 440 array camera. The successor to the ThermaScan 100, the ThermaScan 200, is offered onto the marketplace.
1999	Launch of the VisioGen graphic user interface (GUI) software to rapidly process and present data from the ThermaSPI 440 and ThermaScan models
2000	Photonica begins a Phase II SBIR contract worth $600,000, funded by the US Federal Highway Administration, flaw detection in large steel structures like bridges. Photonica moves into a larger, purpose-built factory unit. A website is launched as an open source of information for customers. Photonica is awarded a US Airforce funded SBIR

contract to test TSA under high temperatures.

2001 Introduction of new line of accessories for the ThermaScan 200 to assist measurement in elevated temperature applications.

2002 Awarded a Phase II SBTT grant (funded by NASA Langley) to commercialize (under the brand Phostascope) PSA technology invented at Templemead College.

2003 Awarded a SBIR Phase I grant (funded by the US Federal Highway Agency) to develop the ThermPac system. Development of the Phostascope unit under a Phase II SBIR (with Deere and Co.) grant. First sales of the Phostascope and ThermPac products in October.

Exhibit 2: Photonica's Product Offerings

<table>
<tr><td colspan="2">Product Range A: Thermoelastic Stress Analysis (TSA) Equipment</td></tr>
<tr><td colspan="2">A system based on thermo-elasticity. Sensitive infrared cameras mated with high-speed digital electronics measure slight temperature perturbations in stressed materials. A full-field stress map is produced in seconds from which stress calculations can be made.
Models: ThermaScan 100, ThermaScan 200, ThermaSPI 220, ThermaSPI 440</td></tr>
<tr><td><u>Suited to the following specific engineering applications</u>:
• Automotive – wheel, finite element analysis, connecting rod checks
• Aerospace – non-destructive evaluation of aircraft structures
• Composites – damage evolution
• Structures – structural metal plate connectors
• Contact stresses
• Industrial applications</td><td><u>Key selling points</u>:
• Fast – high speed digital electronics correlate load and stress induced temperature changes for immediate video presentation of stress patterns
• Portable – small and lightweight (particularly the ThermaSPI range)
• Versatile – operates over a wide temperature range
• Customisable software can be tailored to suit application requirements
• Constant or variable loading accepted.
• Self-contained and robust unit.</td></tr>
<tr><td colspan="2">Product Range B: Photoelastic Strain Analysis (PSA) Equipment</td></tr>
<tr><td colspan="2">A strain measurement system based on photo-elasticity. The measuring instrument is very different to the TSA range but works on the same principles. The Phostascope illuminates an object with circularly polarized light, which becomes elliptic in the presence of shear strain. The degree of ellipticity in the light is proportional to the level of maximum shear strain, the extent of which is calculated by VisioGen software.
Model: Phostascope 100</td></tr>
<tr><td><u>Suited to the following general applications</u>:
• Locating "hot spots" (high strain areas)
• Verifying finite element analysis models
• Monitoring fatigue tests in progress
• Visualising residual strains in glass and plastic, e.g. automobile windshield – compressive and tensile regions
• Load stepping techniques</td><td><u>Key selling points</u>:
• Automated full-field strain measurement
• Compatible with all material coatings
• Fully computerised digital interface
• Automatic measurement of coating thicknesses</td></tr>
<tr><td colspan="2">Product Range C: Thermal Non-Destructive Evaluation Equipment</td></tr>
<tr><td colspan="2">ThermPac is a highly adaptable thermal inspection system. This system is ready-to-go and can be quickly configured to meet an inspection challenge
Model: ThermPac</td></tr>
<tr><td colspan="2"><u>Suited to the following general engineering applications</u>:
• Verifying numerical and analytical models and calculations.
• Measuring stress concentrations and stress intensity factors
• Surveying a structure for potential problem sites
• Tracking damage</td></tr>
</table>

***Exhibit 3*: Competitor Analysis**

Bob and Jake have never conducted a formal competitor analysis, mainly because they have been confident that they know their industry and rival firms very well. They had attended many conferences and trade fairs, and have kept abreast of the academic research literature. Their view of the competitive situation in the late 1990s can be summarised as follows.

Product Range	Competitors (National and International)
TSA Equipment Models: ThermaScan 100 and 200 ThermaSPI 220 and 440	• Without rival in the USA. The only competing equipment is 'point by point' technology from Alphatron, a sleepy US subsidiary of the British Omegon company. • In the UK, Omegon is well established and active and produces a single point thermal detector equipped with scanning mirrors. This is aging technology but is still being used in many laboratories. • BRURP in France produces a similar device but sales are known to be few • In Korea similar products are being researched. • In Canada, research papers reveal that a system has been designed and built but has not been commercialised.
PSA Equipment Model: Phostascope	• Diagnostics Metering Inc is the world market leader with an international sales force but with a stale product range. It is based in South Carolina and has a major British subsidiary covering Europe. • In the rest of the USA and Europe there is a plethora of small, one man companies offering specialist services and instruments. • Photonica offers the most innovative instrumentation at the moment.

***Exhibit 4*: University Research Park, Madison, WI.**

For the source see: http://www.universityresearchpark.org/

University Research Park (URP) – An Overview

The University Research Park (URP) was set up in 1984 by then University of Wisconsin (UW)-Madison Chancellor Irving Shain and the UW Board of Regents. University land no longer conducive to agricultural research was sold to University Research Park Inc., a separate non-profit entity that developed the land and leased it to companies interested in maintaining close contact with the university community. The research park provides an atmosphere custom-designed to nurture a productive combination of economic and technological development.

Surrounding the MGE Innovation Center is the rest of the 255 acres set aside for the University Research Park. Here, companies that have outgrown the incubator or companies from outside the Park have chosen to construct their own facilities on parcels of land leased from University Research Park Inc. By 2000, there were 88 tenants housed in 31 buildings, including the MGE Innovation Center. Unlike most research parks, URP receives no city or state funds to support its infrastructure. On the contrary, URP pays property taxes to the City of Madison.In addition to providing land and infrastructure, the University Research Park offers unique opportunities and incentives for start-up companies through specialized growth environments in the Park's technology incubator, the Madison Gas & Electric (MGE) Innovation Center.

The University Research Park Inc., is not only self-sustaining, but returns all profits to UW-Madison research programmes, fuelling the kind of technology transfer and economic growth that the Park encourages. The hallmark of URP's operation and growth is a strong commitment to carefully planned and responsible development in the context of a long-term outlook. The University Research Park has been steadily attracting new tenants since its inception and shows no signs of changing its course.

URP Mission

To provide an environment that encourages technology development and commercialization. To advance this mission, University Research Park Inc:

- supports technology transfer and commercialization of intellectual property arising from University of Wisconsin-Madison research.

- provides research and educational opportunities.

- supports educational outreach.
- provides facilities and services needed by start-up companies.

URP Lease Information

University Research Park's sites and facilities are primarily available to companies commercializing university research and companies with potential to collaborate with university researchers, facilities and students. The Park offers science and technology companies the following opportunities:

- flexible office and laboratory suites from 2,500 square feet to 10,000 square feet for rapidly growing companies in the University Science Center.
- established companies can construct and own or lease from a building owner their own facilities on a site under a long-term ground lease.
- the Park also offers opportunities for companies to lease quality office space in one of three, privately owned, multi-tenant office buildings.

MGE Innovation Center

The MGE Innovation Center has 50 small office and laboratory suites with shared services for early stage companies. The centre is a collaboration between the URP and Madison Gas & Electric to facilitate the transfer of technology from UW-Madison to the private sector. Since 1989, the centre has provided laboratory and office space as well as support equipment (photocopying, telephony, computer networking and an ISDN link to the main campus) and personnel (such as secretarial and accounting support) to nearly fifty early stage companies. In March 1999, the centre moved into a 65,000 square foot, state-of-the-art facility on the URP and in June 2001, a 51,000 square foot addition opened. The entire facility houses office suites, 32 laboratories, 9 conference rooms, as well as a shared shop facility, laboratory and common areas.

***Exhibit 5*: Small Business Innovation Research Program (SBIR)**

Source: http://www.sba.gov/sbir/indexsbir-sttr.html. See also:http://www.zyn.com/sbir/#agsites

SBIR is a highly competitive program that encourages small business to explore their technological potential and provides the incentive to profit from its commercialization. By including qualified small businesses in the nation's R&D arena, high-tech innovation is stimulated and the United States gains entrepreneurial spirit as it meets its specific research and development needs.

Competitive Opportunity for Small Business

SBIR targets the entrepreneurial sector because that is where most innovation and innovators thrive. However, the risk and expense of conducting serious R&D efforts are often beyond the means of many small businesses. By reserving a specific percentage of federal R&D funds for small business, SBIR protects the small business and enables it to compete on the same level as larger businesses. SBIR funds the critical start-up and development stages and it encourages the commercialization of the technology, product, or service, which, in turn, stimulates the U.S. economy.

Since its enactment in 1982, as part of the Small Business Innovation Development Act, SBIR has helped thousands of small businesses to compete for federal research and development awards. Their contributions have enhanced the nation's defence, protected the environment, advanced health care, and improved the ability to manage information and manipulate data.

SBIR Qualifications

Small businesses must meet certain eligibility criteria to participate in the SBIR program.

- American-owned and independently operated
- For-profit
- Principal researcher employed by business
- Company size limited to 500 employees

The SBIR System

Each year, ten federal departments and agencies are required by SBIR to reserve a portion of their R&D funds for award to small business.

- Department of Agriculture
- Department of Commerce
- Department of Defence
- Department of Education
- Department of Energy
- Department of Health and Human Services
- Department of Transportation
- Environmental Protection Agency
- National Aeronautics and Space Administration
- National Science Foundation

These agencies designate R&D topics and accept proposals.

The SBIR Three-Phase Program

Following submission of proposals, agencies make SBIR awards based on small business qualification, degree of innovation, technical merit, and future market potential. Small businesses that receive awards or grants then begin a three-phase program.

Phase I is the start-up phase. Awards of up to $100,000 for approximately 6 months support exploration of the technical merit or feasibility of an idea or technology.

Phase II involves awards of up to $750,000, up to 2 years, to expand Phase I results. During this time, the R&D work is performed and the developer evaluates the commercialization potential. Only Phase I award winners are considered for Phase II.

Phase III is the period during which Phase II innovation moves from the laboratory into the marketplace. No SBIR funds support this phase. The small business must find funding in the private sector or other non-SBIR federal agency funding.

Small Business Technology Transfer Program (STTR)

The STTR program was initiated by Congress in 1992 to facilitate the transfer of technology from non-profit research institutions, such as federal laboratories and universities, through entrepreneurial small businesses to the marketplace. Five federal agencies participate in the STTR program. Funding for these programs is provided by each agency's allocation of a percentage of its extramural R&D budget.

The program is a highly competitive, three-phase award program (closely resembling that of the SBIR scheme) based on the small business/nonprofit research institution qualifications, the degree of innovation proposed, and the future market potential of the technology to be developed.

SBA Role

The US Small Business Administration plays an important role as the coordinating agency for the SBIR program. It directs the 10 agencies' implementation of SBIR, reviews their progress, and reports annually to Congress on its operation. SBA is also the information link to SBIR. SBA collects solicitation information from all participating agencies and publishes it quarterly in a Pre-Solicitation Announcement (PSA). The PSA is a single source for the topics and anticipated release and closing dates for each agency's solicitations.

For more information on the SBIR Program, contact the US Small Business Administration Office of Technology 409 Third Street, SW Washington, DC 20416 (202) 205-6450.

All of SBA's programs and services are extended to the public on a non-discriminatory basis.

***Exhibit 6*: The First New Madison West Bank**

There is a question as to the extent to which small banks with a focus on providing a local service to small companies can also provide the international support as these companies grow. Jake's experience with the First New Madison West Bank may only be an extreme example of a systemic problem.

Given below is an edited version of an interview with Mark Felling, chief executive of the First New Madison West Bank, made in 1996 by Maura Prizinkski, editor in chief of Madison Westside, a free circulation broadsheet that blossomed briefly in the mid-nineties:

> Many small local banks do exist and increasingly have space on business parks – often as pre-lets in speculative buildings designed to attract the new tech companies. Visitors to Madison will quickly see the Johnson Bank advertising itself on the American Family Park and, like us, the First Business Bank is on the University Research Park.
>
> Our bank started 5 years ago when the founder left a big bank that kept getting bigger and with two other investors bought a country bank and moved to the city. The big banks are highly regulated by procedures and profit target but smaller ones like us are different. We can say that's a great idea why don't you implement it. And I guess we have some good people too. I think the smaller banks attract bankers who are restless.
>
> We are privately-owned and therefore can feel more relaxed about longer term investments. We are free of quarterly earnings pressure. We have no formal link with the university but we do have a good track record of university related companies.
>
> There is a bit of a conflict between lending and investing. The upside potential is the venture capitalist's focus whereas the downside is the banker's focus. We do offer some financial packages with Business Angels to the small start-ups. A mixture of venture capital, an expanding line of credit, some loan guarantees, that kind of thing. We offer three to five year loans currently. We don't take ownership but do require personal guarantees. We are beginning to look at equity kickers.
>
> It costs 5M$ to 10M$ to start up a bank. First Business started just before us and since then three other banks have followed in this area. There is big bank dissatisfaction among small firms.
>
> We are a bank for small and medium sized companies (SMEs). Typically, our borrowers have a turnover of less than \$5M and borrowing needs up to \$3M though on average around \$1-1.5M.
>
> It is not our style to provide start-up financing. We prefer to follow the angel investors. Ok, we can do checking accounts and provide loans on collateral but we wont give 1M$ till we see a bankable proposition.

> We are a business bank. We have no retail base. Our front line staff are better than retail tellers – it's a one stop shop for business needs. It's mostly a local service. We differentiate ourselves from the bigger banks by the teller service and by running our own small business – locally owned, locally managed. The small companies can associate with this and feel happy to do business with us. We put on seminars for our clients and look at issues they might be struggling with. We are an SME too and can be responsive to client requests.
>
> The research park really does help as a location. For example, we get to attend the CEO lunches every quarter. A tight knit group of people, scientists, entrepreneurs, angel investors, a dozen small tables with approximately six people on each. It's a real focused networking.
>
> PhDs spinning out is typical but what you need to do is encourage the Professor. He has some money and often owns a bit of the company anyhow. The ideal is where the Prof. is nearing retirement and there is a pension deal to look at.
>
> Consulting is a typical way for these young companies to fund themselves as they move to a product line. Some could use a commercial gap year to get some experience before they start out. Spinout life can be kinda harsh.

***Exhibit 7*: Press Release**

In January 1998 Photonica Inc. was selected by more than 100 leading scientists as a recipient of the coveted *Landmark Innovation Award*, sponsored by the Getty Foundation, for its development of the ThermaSPI Stress Analysis System. As winner of this international competition sponsored by the magazine R&D Today, the ThermaSPI was honoured as one of the most important technological advances of 1997.

R&D Today began the Landmark Innovation award in 1966 to recognise scientists and innovators who develop breakthrough technologies and products. Each year 100 winners from around the world are selected. Past winners of the award are now commonplace, such as anti-lock brakes (1968), the VCR (1970), the fax machine (1974), and the digital compact cassette (1992).

Exhibit 8: Photonica's Profit and Loss (Income) Statement 1990 to 2002 ($000s)

Fiscal Year	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
INCOME													
Revenue (Sales)													
Consultancy fees	20	68	110	293	62	319	455	556	527	320	336	330	263
ThermaScan (US sales)	0	0	110	222	115	118	240	360	220	0	80	0	0
ThermaScan (royalty payments from foreign sales)	0	0	0	0	11	24	0	80	80	44	0	0	0
ThermaSPI (US sales)	0	0	0	0	0	68	390	130	150	300	525	480	595
ThermaSPI (royalty payments from foreign sales)	0	0	0	0	0	0	29	18	34	47	14	14	23
Phostascope and ThermPac	0	0	0	0	0	0	0	0	0	0	0	0	96
Intellitron royalty receipts (US sales)	0	0	0	0	0	28	32	48	40	38	46	52	50
SBIR and other grant income	0	0	60	124	86	248	494	40	44	610	320	540	122
Accessories, spares and upgrades	0	0	4	23	8	50	88	111	226	223	432	527	440
Total Revenue (Sales)	**20**	**68**	**284**	**662**	**282**	**855**	**1,728**	**1,343**	**1,321**	**1,582**	**1,753**	**1,943**	**1,589**
Cost of Sales													
Purchases													
Electrical and electronic components	0	17	45	80	120	180	380	364	290	252	390	305	365
Misc. hardware	4	4	18	16	34	20	42	40	36	26	38	35	30
Software and licenses	2	1	2	4	4	4	6	4	6	6	6	8	8
Royalty and fee payments	0	0	0	0	0	9	3	9	11	8	1	2	2
Patenting costs	0	4	2	3	2	7	4	4	5	12	5	9	12
Total Cost of Sales	**6**	**26**	**67**	**103**	**160**	**220**	**435**	**421**	**348**	**304**	**440**	**359**	**417**
Gross Profit	**14**	**42**	**217**	**559**	**122**	**635**	**1,293**	**922**	**973**	**1,278**	**1,313**	**1,584**	**1,172**
EXPENSES													
Variable (selling) expenses													
Outside services (UW and others)	0	8	10	11	14	10	14	17	18	22	10	14	18
Research and development	0	8	26	52	60	210	240	360	166	183	440	520	422
Office supplies	0	0	0	12	14	10	14	10	9	15	11	12	14
Advertising and marketing	1	1	2	3	1	4	2	3	2	10	14	8	8
Training and technical support provision	0	0	2	8	8	12	14	11	10	16	12	10	14
Packaging	0	0	2	6	10	22	28	26	28	24	18	16	20
Freight	0	0	1	3	8	24	23	22	26	28	15	13	16
Car and travel	4	5	5	10	18	14	12	22	20	18	16	18	24
Total variable expenses	**5**	**22**	**48**	**105**	**133**	**306**	**347**	**471**	**279**	**316**	**536**	**611**	**536**
Fixed (administrative) expenses													
Repairs and maintenance	1	1	3	6	4	8	10	8	4	2	16	4	2
Machinery, tools and equipment	0	3	22	26	14	22	18	26	14	18	22	10	44
Executive salaries	4	30	30	56	56	60	60	78	78	78	78	140	140
Labour and wages expenses	0	0	0	48	70	90	100	144	160	200	210	212	220

Exhibit 8: Photonica's Profit and Loss (Income) Statement 1990 to 2002 ($000s)

Accounting and legal	2	2	6	6	7	8	8	10	10	11	11	12	12
Memberships and subscriptions	1	1	2	2	2	2	4	4	4	5	4	6	6
Office rent	1	1	1	18	18	18	20	22	22	48	48	50	50
Office telephones	0	0	0	1	2	2	3	3	2	3	3	4	4
Utilities	0	0	0	4	5	5	6	6	7	10	11	12	12
Insurance and company benefits	2	2	2	6	6	6	10	10	12	14	14	14	14
Taxes (real estate, etc.)	0	0	0	0	4	4	4	4	4	8	8	8	8
Depreciation	0	1	2	9	11	16	19	14	12	10	14	16	20
Total fixed expenses	**11**	**41**	**68**	**182**	**199**	**241**	**262**	**329**	**329**	**407**	**439**	**488**	**532**
Net interest payments received (paid)	**-2**	**-12**	**-14**	**-18**	**-24**	**-18**	**-26**	**-14**	**-10**	**-16**	**-17**	**-18**	**-15**
Total Expenses	**14**	**51**	**102**	**269**	**308**	**529**	**583**	**786**	**598**	**707**	**958**	**1,081**	**1,053**
Net Profit (before taxes)	**0**	**-9**	**115**	**290**	**-186**	**106**	**710**	**136**	**375**	**571**	**355**	**503**	**119**