CANZ
COMPETITIVE ADVANTAGE NEW ZEALAND

Buckley Systems Ltd.

A History

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INTRODUCTION

In 1986 Bill Buckley founded Buckley Systems Ltd. (BSL). It was a modest engineering firm based in Auckland's Mt. Wellington that was dedicated to manufacturing coil electromagnets for ion implanters. Today, Buckley Systems is a global leader supplying electromagnets to 90 percent of the world's ion implant industry. Ion implantation is a key process in wafer fabrication plants that produce the silicon chips used in modern computer, communication equipment, automobiles and everyday appliances. The firm exports 350 tonnes of machinery each month to destinations such as the United States, Japan and the United Kingdom. According to Bill Buckley, *"nearly every silicon chip [in the world]… has most likely been produced with the assistance of some of Buckley Systems products"*.

In the fourteen years since its inception, Buckley Systems' annual turnover has increased from $3M to $50M, and staff numbers have risen from six to 150 people. The most significant years of growth were 1995 to 1997 when the firm nearly doubled its sales. For most of its existence, however, Buckley Systems has experienced steady and significant growth of between 30 and 40 percent each year.

The following sections describe Buckley Systems Ltd., as it is today, then trace the development of the firm from its inception, and finally conclude with Bill Buckley's thoughts on the future.

TODAY

Buckley Systems is a leading manufacturer of precision electromagnets, ion beam physics hardware, and high vacuum equipment used in the semiconductor ion implant industry, laboratory research and particle accelerators. An electromagnet consists of a coil of wire wound around an iron core, through which an electrical current is passed to create a powerful magnet. Ion beams are streams of charged particles that are focused by an ion implanter onto a target. A description of the ion beam's applications is given in the section on manufacturing.

The company's electromagnets and ion beam hardware are sold to machine tool manufacturers, who incorporate them into the manufacture of ion implanters. Ion implanters have a number of applications. One quarter of Buckley Systems' products are ultimately used in medical and nuclear research applications. For example, in 1998 Buckley Systems manufactured a beam line that incorporated over 40 electromagnets for use in cancer research and radiotherapy. The remaining three-quarters of Buckley Systems' products are used in the manufacture of silicon chips.

Manufacturing

Silicon is naturally a non-conductor, but for computer chips to function they require semi-conductive properties. BSL's ion implanters uniformly embed conductive ions into silicon wafers to a certain depth, thus changing the wafer from a non-conductor to a semi-conductor. Each impregnated wafer is broken into about 100 pieces – hence the name 'chips'.

The precision of Buckley Systems' machines is impressive. The ion beams are accurate to within one millionth of a centimetre. Furthermore, the ion implanters can draw 200 lines, with a gap between each, and still not cover the width of a human hair.

The modern and highly automated system of manufacture at BSL ensures the production of a diverse range of components in large or small runs with a low degree of variation. State-of-the-art computer numerical control (CNC) machining centres, magnetic field mapping and coordinate measuring capabilities ensure their production standards remain world class. The company has 11 Mazak CNC machining centres and 4 Mazak CNC turning centres (Appendix 1). Demand can be volatile in the ion implanter industry, yet it is difficult for companies like Buckley Systems to increase production quickly. The key CNC production machines that the company uses are expensive, and have a delivery lead time of nine to ten months. Buckley Systems' precision electromagnets incorporate a variety of coil types, low carbon steel plate and AC laminations, integrated aluminium and stainless steel vacuum housings, and fabricated chasses and bases. The company consumes about 350 tonnes of steel, 50 tonnes of aluminium and 30 tonnes of copper per month. Many of the completed systems include ion source assemblies as well as RF resonator and accelerator columns. All products are produced and tested on site, and then boxed up and sent to manufacturers and laboratories around the world. As owner Bill Buckley states, "*a key competitive factor [of Buckley Systems] is the ability to sell a complete, fully tested product, whereas competitors are only in a position to sell individual components"*.

The company places extreme importance on product quality, and has a dedicated team of quality assurance officers who constantly monitor production. Buckley Systems' achievement of ISO9001 certification in 1997 highlighted the firm's manufacturing controls, quality management and continual process improvements. Bill Buckley believes the New Zealand location of Buckley Systems helps to explain the firm's commitment to high quality production:

> *"Clients have been critical of me being too far away, but being in New Zealand disciplines you into putting quality first. You don't want to fly 130 tonnes of machine and have to fly that back to fix it"*.

He has a simple explanation for Buckley Systems' position as a world leader*: "I think we are building them faster and more efficiently than anyone else"*.

The Ion Implanter[1]

The ion beam implanter is used to alter the near surface properties of semiconductor materials by dosing them with conductive ions to a certain depth. Typical machines used in the manufacture of electronic devices use beam energies from 2KeV (thousand electron volts) up to 2MeV (mega electron volts). This energy accelerates the ion beam up to about 6000 metres/second. The cross-section of an implanter is shown below.

The ion source is a radio frequency (RF), multi cusp ion source that uses a gas delivery system to produce the desired beam species. The beam then passes through a pre-acceleration section, known as the source extraction. The bias voltage gives the beam sufficient energy to allow selection of the desired species required for implantation by a 90degree dipole analysing magnet.

An analysing magnet, which is what Buckley Systems manufacture, is positioned along the beam path between the source and the process chamber and filters ions from the beam while allowing certain other ions to enter the process chamber. The magnet includes multiple magnet pole pieces constructed from a ferromagnetic material and having inwardly facing pole surfaces. One or more current carrying coils set up dipole magnetic fields in the deflection region near the pole pieces. As the ions travel through the magnetic field, the magnetic force serves to move the particles in a circular path.

The ion implanter requires a high vacuum system shown below in the block diagram in order to generate a plasma[2] and transport an ion beam from the ion source through the analysing magnet to the process chamber.

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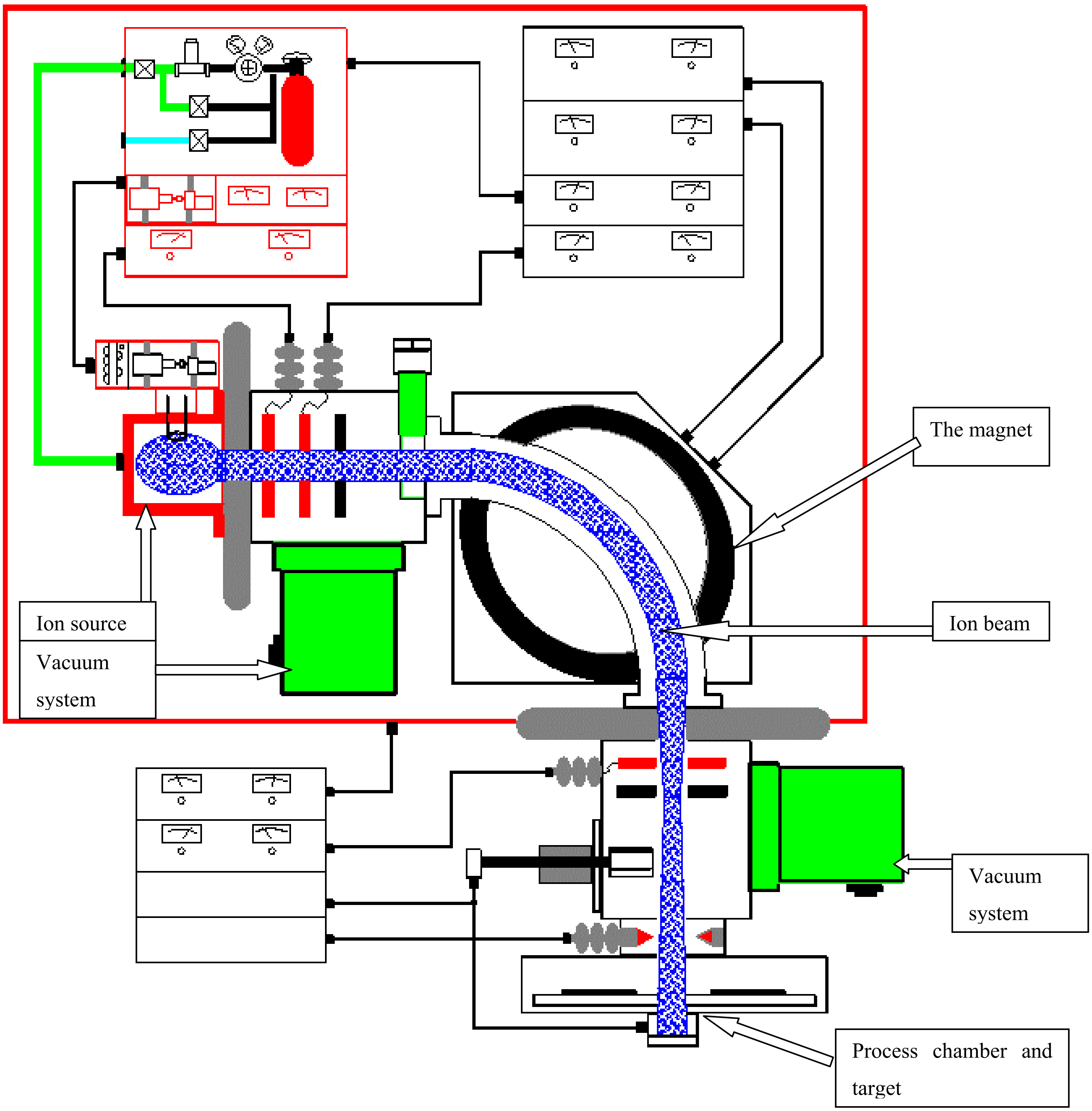
[1] Source: adapted from http://www.casetechnology.com/implanter/implanter.html

[2] Plasma: A fourth state of matter -- not a solid, liquid nor gas. In a plasma, the electrons are pulled free from the atoms and can move independently. The individual atoms are charged, even though the total number of positive and negative charges is equal, maintaining overall electrical neutrality.


The magnet
Ion beam
Ion source
Vacuum system
Vacuum system
Process chamber and target

Innovation

An equally high level of innovation complements Buckley Systems' first-rate production quality. Before Buckley Systems' inception, the process of producing silicon chips involved a number of spinning disks that had to be monitored every quarter of a revolution to ensure that a speed of 2000 rpm was maintained. Furthermore, the bearings required to maintain disk speed had a limited life, and cost $60,000 - $80,000 each. Buckley Systems replaced this antiquated process with a more efficient scanning system, and the company's machines have an almost indefinite life.

The company works with internationally recognised physicist consultants to design precision electromagnets, vacuum systems, and complete beam lines. Traditional job-shop flexibility and multi-disciplinary capability, combined with highly automated production processes has earned BSL its reputation as a world-class innovative manufacturer.

To understand the complexity involved in the design of this machine to meet the requirements of the wafer manufacturers, Bill explained their task and what BSL magnets could do. *"[We control the beam] to spread the ions very uniformly over the full crystal wafer which might be up to 300 mm in diameter at a very controlled speed which when it hits the wafer it imbeds [the ion] into a precise depth, within a nanometre. So you have to have [the particles in the beam] going to within a couple of [metres] per second [of the] precise speed [required]. And it's going at about 6000 metres per second so we have to be within a thousandth of that so [the ion] stops at exactly the right depth and the uniformity has to be really accurate. It's got to be within one part per million or something, and the beam has to go into the silicon at dead right angles to the wafer so it has to go in within angstrom of a degree. Our machines control all that. So it controls the speed, the purity of the beam [that] has to be 100% pure. So we've got to make sure we've got it pure, and we've got make sure it's going the right speed, and it's going in at the right angle, and the right uniformity. We've developed a scanning system to do that."*

Judges of the 1998 New Zealand Exporter of the Year Award highlighted, among other attributes, Buckley Systems' impressive production quality and leading edge technology. Buckley Systems has also won technology awards from Italy, and received commendations from corporations in Japan. The philosophy at Buckley Systems is:

> "*It's no good doing what anyone can do. You have to go after the stuff that is too complicated for the average engineer so you can be Johnny on the spot when the demand hits*".

Buckley Systems annually reinvests around 20 per cent of profits and engineers' time into R&D. Bill Buckley partially attributes the firm's success to his keeping up with technological developments and protecting his intellectual property. The quality of its products provides Buckley Systems with a competitive edge, which stems from their knowledge in the business; Bill Buckley helped create the first machine of what would become the ion implantation chip industry.

In 1997 Buckley Systems contributed to a groundbreaking project, which was one of the world's first commercial applications of high-temperature superconductors. The collaborative venture combined the efforts of Industrial Research Ltd. (IRL), American Superconductor Company (ASC), Alphatech, and Buckley Systems in designing, building and marketing the new technology. Because copper wire is not a perfect conductor of electrical currents, its traditional use in electromagnets created problems of heat and size. Superconductors, however, offer no resistance to electrical currents. The joint venture constructed an electromagnet made of superconductor wire, resulting in an electromagnet of equal size to its copper wire predecessor, but one capable of creating a much stronger magnetic field.

Although the superconductor magnets are very strong, they are also very fixed in their magnetic characteristics. For this reason, superconductor magnets are of limited applicability in the chip industry, which generally requires versatile magnets. As Bill

Buckley puts it, *"they have got some use [in the chip industry] … and we're keeping an eye on them but we're not thinking it will take over our industry"*.

Workforce

Buckley Systems currently has a multi-disciplinary staff of 150 staff, who benefit from a range of programmes ensuring a high level of training, motivation and work safety. The company's flat structure encourages communication between the managers and shop floor staff.

The highly specialised nature of the work at Buckley Systems necessitates long-term permanent staff. Bill Buckley estimates staff turnover to be as low as 3%, and believes most of these people leave due to personal circumstances, rather than *"through better employment"*. By working alongside his employees, Bill is able to recognise where their skills would be best applied. He has striven to keep his employees excited about the business, and believes that the dedication of his workforce has been key to the success of Buckley Systems.

Finance and Ownership

BSL is privately-owned and Bill Buckley has a controlling interest in the company, which is not heavily indebted. As Bill states, *"the banks need me and I don't need the banks"*. He employs a team of accountants and keeps them fully informed to ensure sensible financial practices.

Markets

All of Buckley Systems' production is exported. The firm's major markets are the United States, Britain, Asia and Japan, where Buckley Systems' products are dominant among silicon chip manufacturers.

The firm's earnings recently topped the $50M mark. Buckley Systems' success overseas was recognized in 1998 when it won the New Zealand Trade Development Board's Exporter of the Year Award, and DHL's Medium Exporter of the Year Award. Bill Buckley partially attributes the firm's success to his learning how to do business the American and Japanese way. This involved acquiring a deep understanding of what was important to his customers in these countries and what their business expectations were. Approximately 60% of Buckley's sales are in the USA, 25% in Japan, and 15% to the UK and other countries.

Silicon chips are used in a wide range of products, including computers, communications equipment, cars and household appliances. There are only around ten ion implantation companies in the world producing silicon chip capital equipment and machinery. Buckley Systems supplies electromagnets and ion beam hardware to them all, and has captured 80 to 90 percent of the business. Buckley Systems' customers in turn supply giant manufacturers such as IBM, Intel, Sony, Ibis, Motorola, Nissin and NEC.

Customer relations

Ninety-two percent of Buckley Systems' business is repeat business, indicating a high level of customer satisfaction. The firm ensures that customer expectations are met by carefully monitoring feedback records. Buckley Systems works alongside its major clients, not only to meet their individual specifications, but also to develop prototypes. As Bill Buckley says, *"this commitment to customer service fosters relationships"*.

Working alongside the design and development teams of its major customers enables Buckley Systems to keep in touch with trends and future requirements. The judges of the 1998 Exporter of the Year Award remarked on Buckley Systems' ability to pick market trends, and its good client relationships. Company spokesman Mr Renaud notes that the philosophy at Buckley Systems is *“always to exceed our customers’ expectations. Hopefully most of the time they get more than they bargained for"*.

A sharp increase in demand for the company’s products in the last six months has, however, created difficulties in meeting delivery deadlines. Buckley Systems has responded by delivering its products increasingly by air, rather than by sea. The extra cost involved has not been passed on to the customer.

Competition

Buckley Systems has attained a specific knowledge of ion implantation – the most technical aspect of the chip industry. Bill Buckley notes that, *"there’s not a lot of people that really know how [these] machines really work"*. When new machines are being designed for customers, Buckley Systems staff members often work in conjunction with the design consultants. On some occasions the designers may choose another firm to build the design, but Buckley Systems’ close relationship with the designers means that it generally "gets the inside" on the new technology.

The specific knowledge Buckley Systems has accumulated provides a barrier to competitor entry. As Bill states:

> *“For [a new entrant] to be serious opposition to me [would] cost them a lot of money. What I can do for $1 million would take $10 million for somebody else. Furthermore, I’ve always tried to keep my prices competitive"*.

YESTERDAY

Bill Buckley

As a teenager Bill did not enjoy high school, and he often fell asleep at his desk. Wanting to build the biggest things he could think of, Bill dropped out of school after two years to become a shipbuilding apprentice. He became interested in nuclear physics by "hanging around" his elder brother, who was studying mechanical engineering at university. Bill's interest in nuclear physics led him to spend eight years at Hurst Precision, where he met physicist Hilton Glavish who persuaded him to work in the field of magnets. As Bill explains, the lure of building "big things" also influenced his decision; *"I was just looking for a heavy machine to make big things and I figured that making big magnets was quite engineering-intensive".*

In 1968 Bill joined forces with a group of nuclear physicists interested in building high-energy electromagnets for the university research market. They were unable to attract the necessary funding, however, and eventually went out of business. Bill then found employment as a manager of a general engineering firm, during which time he contributed to the making of accelerator magnets for universities and other research laboratories.

During the 1970s, silicon chip manufacturers produced the necessary semi-conductive properties by a process called chemical deposition, whereby impurities were painted and then baked onto the chip. In 1976, however, Dr Peter Rose of a large US accelerator company envisaged ion implantation to be the chip industry's future. He contracted the magnet and ion optics work to a New Zealand-based company, which in turn subcontracted the heavy engineering component to the general engineering firm that Bill managed.

Although Bill was keen to enter the computer chip market, the heavily US-dominated and protected area of computer manufacture discouraged Bill's boss Jim Hurst. He challenged Bill to pursue the computer chip market with his own company, and Bill accepted the challenge in 1978 by creating Buckley Engineering. Bill recently made the apt comment that *"it's putting your money and life on the line that teaches you the most"*.

Whilst the company survived on simple engineering jobs, Bill was overseas trying to break into the U.S market. His efforts met with little success, however, and as Bill explains *"it wasn't easy to get work out of the U.S. in this sort of field. The Americans thought they could do it better"*. By 1982 Buckley Engineering was in trouble, and Bill was forced to sell shares to another engineer, becoming a minority shareholder in his own company.

Further difficulties arose in 1983, when the New Zealand company that subcontracted work to Buckley Engineering went bust. The big engineering companies it was working for, such as GE and Edison Electric, replaced their lost supplier by contracting work to firms in San Francisco and Boston. Fortunately for Buckley Engineering, these firms were what Bill described as *"dirt-floor companies"*, which provided an opportunity for Bill to win contracts in America eventually. At this time, he found that the US companies were not set up well for manufacturing high technology products. Many literally had dirt floors. There seemed to be no technical expertise and not technology background at these firms. However, it took Bill a number of years to convince the big American engineering companies that Buckley Engineering could do the job better. In that time, the company was able to adapt and survive, winning big contracts unrelated to the chip industry with firms such as Pacific Steel.

By 1983, Bill had only ever made the steel framing for coil electromagnets, and did not have the capability to produce the magnets themselves; he would have to learn how. Following the receivership of Buckley Engineering's main contractor, the company's equipment was sold by auction; Bill purchased it *"for next to nothing"*. Attaining the equipment was, however, only the first step. Bill enlisted the help of two talented employees, and over the next three years they figured out how to build electromagnets.

While Bill continued his attempts to break into the American chip industry, his business partner back in Auckland kept Buckley Engineering running with tool and die work for companies like Fisher and Paykel. Between 1983 and 1986, the tool and die work became profitable for Buckley Engineering, and staff numbers grew to around 50.

In 1986 Bill's partner in the company became discouraged with Bill's attempts to enter the computer chip industry, and they parted ways. This was uncannily like Jim Hurst's frustration eight years earlier. Bill sold his remaining share of Buckley Engineering and created another company to pursue the U.S. market. Thus, in 1986 Buckley Systems was born.

Buckley Systems Ltd.

Bill had retained links with the directors of Buckley Engineering's previous contractor, who, after going into receivership in 1983, started a consulting firm to the American computer chip industry. Bill was able to solve many of their technical problems, and in turn Bill was increasingly recommended to the companies they consulted. As the company's reputation grew by word of mouth, Buckley Systems' products became highly sought after.

The 1987 stock market crash also served to increase American interest in the little Auckland-based engineering firm. As Bill explains, "*after the market crashed, our potential customers [in America] became price conscious and I was able to give them good pricing"*. Buckley Systems soon broke into the U.S market, and in Bill's words: *"they appreciated the job I did and we just got bigger and bigger"*. As early as 1988, Buckley Systems was a major supplier to the American factories servicing Silicon Valley. Competing companies had "tinkered" with the ion implantation component of the computer chip industry, but Buckley Systems was too strong for them. The Danish engineering firm Danphysik, for example, was unable to break past Buckley Systems, and now specialises in ion implantation for the tool industry. Similarly, the big Canadian engineering firm EBCO Industries moved into making cyclotrons for the medical industry. Bill was involved in the manufacture of the very first ion implanter back in the mid-1970s, and was able to beat his competitors by utilising the advantage that often accompanies being "in first".

Within the first few years, when the company only had 6 staff members, Bill made a significant investment in computer-controlled (CNC) machinery. The investment put a considerable financial strain on the company, and as Bill states, *"we really put ourselves on the line"*. A banker at BNZ named Belmont Singh took an interest in Buckley Systems, and procured a loan to finance the company's expansion. However, in 1989 when the BNZ went into receivership, Belmont lost his job, and Buckley Systems lost its financial support. Fortunately, Bill received a loan from ANZ based on Belmont Singh's recommendations.

During the following years, Buckley Systems expanded its range of products and increased its knowledge base. The firm's maturity was demonstrated in 1996 when it collaborated with IBIS Technology to produce the world's first machine capable of insulating circuitry within silicon chips. This technique is known as SIMOX-SOI. SIMOX stands for Separation by IMplantation of Oxygen, which is an SOI technique whereby oxygen is implanted below the top surface of a silicon wafer. SOI stands for Silicon-On-Insulator which is a semiconductor manufacturing technology in which an insulating layer is created in a silicon wafer. The insulation reduces heat generated within personal computers by 90 percent. SOI wafers allow integrated circuits (IC's) to have increased operating performance and decreased power consumption. These characteristics make SOI wafers well-suited for making IC's that are used in many commercial applications, including servers and workstations, portable and desktop computers, wireless communication devices, optical components and automotive electronics. The main target market for these machines are companies that produce CMOS (Complementary Metal Oxide Semiconductor) IC's. The size of the market for these IC's was estimated by Dataquest to be a $US100 billion market in 1999. Such an innovation could be particularly relevant for the manufacture of supercomputers, which otherwise require bulky cooling systems to function optimally. Bill believes the next generation of supercomputers will be made using these chips.

The BSL 500

As a young man, Bill Buckley raced motorcycle sidecars, became a national speedway champion in the 1960s, and retired from competition in 1986. By that time, Bill was starting his new company, and in 1988 it *was "running successfully and making a few bob"*. However, he found the increasing number of deals between American and Japanese wafer manufacturing firms concerning. As Bill explains, *"the Japanese didn't want to deal with me, so I got a bit worried that the whole market would go to Japan and I'd be out of work again"*.

At that time, the Japanese dominated the motorcycle Grand Prix racing. To grab the attention of Japanese engineering giant Sumitomo and prove Buckley Systems' engineering capability, Bill began to build a 500cc motorbike. Bill explains that he found traditional approaches to gain access to the Japanese businesses unsuccessful: "*You can spend a fortune going up there to pester them, but I'm keen on motor racing and I thought if I build a 500cc motorbike and went up there and raced it they would notice"*. However, before the bike was completed, Bill's earlier marketing attempts and American business paid off, and the Japanese computer chip manufacturers approached him. The motorbike project was shelved.

However, in 1997 one engineer at Buckley Systems rekindled interest in the project, and by November 1998 the BSL500 was unveiled at the Big Boys' Toys show in Auckland.

The BSL500 was the world's first motorcycle to be designed and manufactured entirely by computers. As racing team co-ordinator Dave Stewart notes:

> *"The engine is machined out of a solid block of aluminium, as is the chassis; which allows for a precisely controlled construction technique. It has been produced without a whole lot of guys having to make patterns and moulds and sculpt things and build things. It's a very precise, exact way of doing it."*

Bill believed the result was a stronger and lighter bike than those of traditional castings, giving it a significant weight advantage. Around $3.5M had been spent developing the BSL500 by the end of 1998. The engine is a 500cc V3 two stroke. Dave Stewart points to the BSL500 project as a demonstration of Bill's confidence: *"One of the things that really hits home to me is the huge boldness and the balls that Bill has to do this"*. Bill believed the bike has not fully reached its potential, and planned to enter it in the Australian round of the world championship. However before that could happen, the sport's ruling body changed the rules for the 500cc class and banned two stroke engines. The BSL500 project is now shelved again. Bill has returned to his speedway roots by taking over the Western Springs speedway track in Auckland, and using his motorcycle team to run the operation.

TOMORROW

Bill is still enamoured with heavy engineering, the challenge of making things, and finds it difficult to *"get out of that driving [frame of mind] that [makes] you want to achieve"*. However, having said that he believes that *"you've got to push ahead and live for the future, and make sure you leave a better place for the next generation"*.

The market for ion implantation seems likely to continue to grow as more applications of the technique are developed. One idea Buckley Systems has is developing and investing in processes to facilitate further growth in the company by extending their involvement in the ion implantation equipment value chain. They are considering offering to supply fully "turn-key" implant systems. So instead of just supplying the magnet to the equipment maker they will make the complete system. The equipment makers are keen on this idea and are working hand in hand with Buckley on the development work that is currently taking place.

On another front, Buckley Systems is currently working on a machine that makes solar panels more cheaply. This is also seen as a market with huge potential because of the problems with coal and nuclear power generation. The challenge is to get power generation costs for solar down to seven or eight cents a kilowatt-hour. If that were possible, Bill says they would be competitive with coal-generated electricity, and at this point *"we think we can bust into that market."*

Meantime they will tackle anything from precision ion-implanter magnet assemblies, to offshore yacht keels and hull fittings, pharmaceutical equipment, and performance racing engine components, as Buckley Systems had the capacity and expertise to deliver a wide range of high technology products to leading edge customers around the world. Buckley Systems believes that by combining leading edge Kiwi innovation and engineering expertise with the cream of offshore technological developments, they will remain a world leader in the field of precision engineering.

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APPENDIX 1: Machine Capability at Buckley Systems Ltd.

PLANT CAPACITY

CNC Machining Centers
Mazak V-100
Mazak V-40
Mazak H-1250
Mazak H-800
Mazak H-880 (x2)
Mazak FJV 35/60 (x2)
Mazak AJV-35/80
Mazak AJV32/405
Mazak AJV-60/160
Mazak VTC-20C
Mazak VTC-16C

CNC Turning Centers
Mazak YB-50 Integrex
Mazak QT-15
Mazak Super QT-18
Mazak Mega-Turn-12

Coil Production
Copper strip winders (x3)
Hollow conductor winder (x2)
Copper wire coil winder
Vacuum impregnation Vessels (x6)
Epoxy curing ovens (x2)

Welding, Plating, and Finishing
Electroless nickel plating
Copper plating
TIG / Manual Arc welder (x2)
MIG / Manual Arc welder (x2)
Buffing and Polishing
Blanchard surface grinder
High Precision Surface Grinder
Brake Press (15 ton)

Inspection and Test
Transformer Inter-turn Insulation test
Magnet test power supplies Walker/ Power-10 (x3)
Computerized M-Scan precision field plot (x2)
Helium leak test (x3)
Trimos 3 digital height gauge
DEA Co-ordinate Measuring Machine-DMIS Upgrade

Design and Drafting
AutoCAD/Solid Works
Gibbs-CAD
Mazak Camware
E-mail and CompuServe facilities