What will Hawke's Bay look and feel like in 40 years' time?

Technology Trends

Prepared for Hawke's Bay Regional Council

Susan Bates

Beagle Consultancy Ltd

March 2009

HBRC Publication No. 4860
Report No. SD16-32

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Introduction

Where's my jetpack?

Technology change is notoriously difficult to predict accurately; timeframes are usually the hardest to gauge. Some things change almost overnight, whereas other developments take decades to come to fruition. Thirty years ago, popular science shows on the television (e.g., *Tomorrow's World*) told us, amongst other things, that telephones attached to TV-style screens to allow face-to-face interaction would be commonplace. This particular technology has only just started to gain traction (Skype). Promises of flying cars — as in the 1997 movie *The Fifth Element*, set on a futuristic earth where really nothing has changed except the technology — have been slow to come to fruition.

The title of Daniel Wilson's 2007 tongue-in-cheek look at all the techno-wonders that 21st century man was promised by sci-fi dreamers of the past — *Where's My Jetpack?* — has become a catch-cry of sci-fi fans disappointed by the technological reality of the early 21st Century.

Most technology trend analysts are reluctant to make categorical statements about potential changes, let alone suggest likely timeframes. That said, some areas are clearly ripe for change and there were a number of recurring themes, with possible timeframes suggested in some cases. All of the commentators acknowledge that we can and indeed should prepare for the future, and that in many cases we can understand what's coming tomorrow. Johnson (2009) reminds us that "whatever happens, the one thing the world still has in abundance is ingenuity, and while we're unlikely to see those jetpacks any time soon, there's still plenty to look forward to".

General observations

Many of the technology trends highlighted in this report reflect the overarching trend of convergence. This point is echoed in the RAND Corporation[1] report titled *Global Technology Revolution 2020*, where the following statement is made:

> We see no indication that the accelerated pace of technology development is abating, and neither is the trend toward multidisciplinarity nor the increasingly integrated nature of technology applications.

The RAND research team identified 56 illustrative technology applications that might possibly be developed and implemented by 2020. Sixteen applications were selected for further analysis based on a net assessment combining technical feasibility on a commercial basis, potential marketability, and the number of societal sectors influenced. Most of these technology applications draw from multiple technologies, e.g., biotechnology, nanotechnology, materials and information technologies. The combined effect of further technology development and implementation will be significant,

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[1] RAND Corporation is a US-based, nonprofit research organisation providing objective analysis and effective solutions that address the challenges facing the public and private sectors around the world. RAND's research is commissioned by a wide range of groups. Federal, state, and local government agencies provide the largest share of the funding; however, RAND also conducts projects for foundations, foreign governments, and private-sector firms. Contributions from individuals, charitable foundations, and private firms, as well as earnings from RAND's endowment, offer a steadily growing pool of funds that allow RAND to address problems not yet on the policy agenda.

changing lives around the globe. The technology applications are summarised below, with a note as to where further information can be found in this report if applicable.

Technology Application	**Further information**
Cheap solar energy	
Rural wireless communications	
Genetically modified crops	
Filters and catalysts for water purification	
Cheap housing for adaptable shelter and energy	
Rapid assays to detect specific biological substances	
Green manufacturing	
Ubiquitous radio-frequency identification tagging of products and people	
Hybrid vehicles	
Drug delivery targeted to specific tumours or pathogens	
Improved diagnostic and surgical methods	
Quantum-mechanical cryptography for secure information transfer	
Communication devices for ubiquitous access	
Pervasive sensors	
Tissue engineering	
Computers embedded in clothing or other wearable items	

Other key findings of the RAND report were that:

- The global technology revolution will play out differently across nations, meaning that countries will benefit in considerably different ways.
- China and India are emerging as rising technological powers, with the scientifically proficient countries of Eastern Europe not far behind.
- Technological capability among the scientifically developing countries of South-east Asia and Latin America is variable.
- There is a large technological gap between the scientifically developing countries of Latin America, Turkey, and South Africa, and the rising technological powers India and China.
- There is an enormous technological gap between the scientifically lagging countries of Africa, the Middle East, and Oceania[2] and the advanced nations of North America, Western Europe, and Asia.
- Certain technology applications will spark heated public debate based on strong reactions and opinions over religious, environmental, or social concerns (including privacy). Many of the controversial technology applications involve biotechnology. Reactions could differ dramatically across countries and thus contribute further to the international variation in technology implementation.

[2] New Zealand was not specifically analysed. Australia was rated as scientifically advanced.

Recurring themes

Time line

Research environment — past, present, future & implications for NZ

Technology and its importance to the future was the subject of 2005's BBC Reith Lectures. Each year the broadcaster invites a prominent figure to deliver a series of radio lectures on matters of contemporary interest. That year, Lord Alec Broers, president of the Royal Academy of Engineering, discussed how technology is shaping and influencing lives around the globe.

The first of the five lectures was called "Technology will determine the future of the human race". Broers explains that "humankind's way of life has depended on technology since the beginning of civilization. It can indeed be argued that civilization began when humans first used technologies, moving beyond the merely instinctual and into an era when people began to impose themselves on their environment, going beyond mere existence, to a way of life which enabled them to take increasing advantage of their intellect".

He contends that "technology is sidelined and undervalued…the cost of this major social failure will progressively disadvantage all of us. Technology is determining the future of the human race. We need it to satisfy our appetite for energy, perhaps through nuclear power; to help us address hunger through plant breeding throughout the world; to monitor and find the means for avoiding global warming so that we can rescue our planet for future generations. Technology can improve our health, and lengthen our lives. I want this lecture series to act as a wake up call to all of us...We should recognise this and give it the profile and status that it deserves".

The third lecture, "Innovation and Management", tackles the research environment. In 1965 the most exciting research was being pursued in the laboratories of the large American technology companies and at that time the ideal model for technology development was the large, well funded, industrial research laboratory staffed with talented PhD graduates from the world's leading universities. This support of fundamental science was in effect a philanthropic activity that could be afforded because the companies that practised it on a significant scale were in fact monopolies.

Now the world has become more competitive and domination of the large industrial research laboratory has ended, in all fields except perhaps pharmaceuticals. Very little fundamental research remains in corporate research laboratories. The world of technology and science has also expanded so much that it is no longer possible to sustain a research effort that can cover all the disciplines used in any one product.

Broers' solution is to put in place mechanisms that draw on the global research output, which is no longer confined to Europe, Japan and North America but is emerging rapidly in the East. The aim must be to draw upon the entire world of science and technology. He concludes that fundamental research is best carried out in universities, and that new product development can only effectively be carried out "by dedicated teams who can devote 100% of their time to the activity. To be successful the innovators will almost certainly need an intimate knowledge of the science that underlies the technology, but their aim will not be to further the science. They will use their knowledge to break down the barriers that stand in the way of practical application. The resources needed to innovate are typically greater than those needed in research. As Thomas Edison famously said, the process is '"1% inspiration and 99% perspiration"".

Broers notes that most of the creative input will have to come from all over the world. It is therefore important for small companies to be in touch with all sources of expertise — universities, large companies, government-funded establishments, etc. — feeding off their ideas and using the larger organisations' resources to lever their own activities. Sound intellectual property procedures are essential.

This globalisation of research is already well under way. Broers describes the events of the last decade of the 20th century as "a new industrial revolution. Companies ceased to make entire products themselves and became assemblers of the world's best, and to do this they had to know the world — both its technologies and its peoples. And these trends are only going to accelerate as the emerging powers of India and China enter the world of innovation as powerfully as they entered high technology manufacturing. It is immensely exhilarating to be a player but there are no places reserved for amateurs". His analysis is extremely credible, and one is left wondering how well placed New Zealand companies and research organisations are to thrive in this new world order.

Technology research in New Zealand is at a relatively low level, and what research is carried out tends to be focused on prime value-added areas for the country's agrarian economy: forestry, fishing, and high-tech derivatives such as biotechnology. New Zealand is a technology taker but does have some specialities, principally in bioscience. Critical for New Zealand over the forecast period will be access to, and application of, new technologies generated offshore. That will in part depend on technology transfer by foreign firms operating in New Zealand. Government policy will also be relevant (Bates and Kane 2009).

The Reith Lectures are available at http://www.bbc.co.uk/radio4/reith2005/ [accessed 21 March 2010}.

ICT

Internet

The internet is a fairly recent phenomenon, yet it seems that it has almost become an irreplaceable part of many of our lives. The first type of internet was known by many as "Web 1.0". This was a read-only system. With "Web 2.0" came the ability to contribute to and craft your own web pages. Social networking became a new phenomenon, with millions joining networks such as Facebook and MySpace. The internet seems to be becoming more and more accessible with gadgets such as iPhones and advanced wireless technology…

The Semantic Web (Web 3.0)

- The internet will start to learn about us. Your internet server will observe what you view online so that future searches may be more successful in finding information relevant to you.
- Instead of doing several searches, you will be able to type in one complex sentence into your search engine. The Semantic Web will then organise your results for you. This will be achieved by the running of several searches at once for efficiency.
  Some internet experts promise that in future you will not have to search for information via the internet — the internet will search for you (*see* Data Management, p.?).
- The Semantic Web will be like having a personal assistant providing instant, relevant information.
- Web 3.0 will be able to "**understand**" information on the internet.

Accessibility

- Due to significant advances in areas such as ICT and nanotechnology, the internet will continue become more portable. Internet will be accessible from your phone, watch, even your car.
- Even household appliances are set to be connected to the internet.

Collecting Your Information

- Due to the growing accessibility of the internet and its future "learning" abilities, information about many of the everyday tasks you undertake will be recorded. For example, if your watch also had GPS and happened to be connected to the internet, it would be able to record where you were and at what time.

These issues are explored in greater depth in the sections that follow.

Virtual life

Virtual anthropology is already becoming noticeable. Many people, especially the young, spend a great deal of their time on-line with other people in virtual environments, games, chat rooms and profile sites. New ways of socialising are evolving already, and will eventually evolve into new ways of doing business and new ways of wielding influence and political power. Getting to grips with the anthropology of on-line groups will be very important for companies and government. This will not level off but will grow in importance into the very far future, culminating in the unification of man and machine in the 2070s (according to Pearson 2008b).

Sir Tim Berners-Lee, founding father of the internet, explains in his book "Weaving the Web" that the internet was always meant to be more of a social creation than a technical one. The ultimate goal, he wrote, was to come up with something that, first and foremost, would make it easier for people to collaborate with one another. Social networks have already done much to achieve that goal but, arguably, this is just the beginning of an exciting new era of global interconnectedness that will spread ideas and innovations around the world faster than ever before (Economist 2010a).

Facebook celebrated its sixth birthday last month (February 2010) and, at the time of writing was vying for first place with Google as the second most popular site on the internet. The globe's largest online social network boasts over 350m users — which, if it were a nation, would make Facebook the world's third most populous after China and India. Other globetrotting sites include MySpace, which concentrates on music and entertainment; LinkedIn, which targets career-minded professionals; and Twitter, a networking service that lets members send out short, 140-character messages called "tweets" (Economist 2010a).

Social networks are part of a growing trend known as the "consumerisation" of IT. Thanks to companies such as Apple, Google, and Facebook, people now have access to communications devices and web applications that are often far superior to those offered by their employers. And thanks to cloud computing, which allows all sorts of computing services to be delivered via the internet, they can use these devices and applications pretty much wherever they like, including in offices and factories. This trend is accelerating as more digitally savvy youngsters enter the workforce with their iPhones at the ready (Economist 2010a).

Indeed, most important of all is the mobile phone. Using a web-enabled phone to post status updates and send messages is still a niche activity in many countries, but it will rapidly become a mainstream one as mobile broadband services overtake fixed-line ones in a few years' time. Mobile phones in emerging markets, or devices such as cheap notebooks linked to the internet via mobile networks, will open up a brand new audience whose use of social sites has so far been hampered by a frustrating lack of fast, PC-based internet connections. Gartner, the IT research company, predicts that within 3 years more than half of internet users will be accessing the web via mobiles and other handheld devices. In developing nations like India, where PC penetration is low, the majority of internet activity already takes place on mobiles — some countries are effectively already living in a post-PC era (Economist 2010a; Robinson 2010).

Arguably, the most important contribution that social networking sites have made is to offer a free and immensely powerful set of communication and collaboration tools to everyone on Earth who has access to a broadband internet connection. This democratization of technology is driving the socialisation of the web and fundamentally changing the way that people interact with one another, as well as with businesses and governments. It is now possible for anyone to form a globe-spanning discussion group with just a few clicks of a mouse. Not so long ago that would have been the preserve of an elite group of companies and institutions that had the necessary financial and technical clout to perform such feats (Economist 2010a).

Sentient computing

As computer users become increasingly mobile and the diversity of devices with which they interact increases, the need to configure and personalise these systems also increases. A new generation of location and tracking technologies with accuracy levels as good as a few inches, indoors or outdoors, enables a variety of entirely new special applications which track people and assets in real time, in many different application areas. This new type of interaction between computers and people is often called pervasive or sentient computing. The term "sentient" is used because the applications appear to share the user's perception of the environment. The environment itself becomes the user interface — a natural goal for human-computer interaction (Addlesee *et al.* 2001; Batty 2005).

Imagine a world where intelligent environments, or "smart spaces", know where everyone and everything is, to a high degree of accuracy, in real time. You could be in a shopping mall and walk up to one of the many screens located around the mall. The display instantly changes to show a small map that indicates where your children are in the mall and you also see a live video of them. You didn't even need to press anything to make all this happen — you just walked up to the screen and the system knew you were there and took the appropriate action. This is just one example of sentient computing in action (Batty 2005).

Hospitals have enormous potential for this type of technology. A sentient computing system could record interaction between staff and patients without any effort from the staff. This has many potential applications. For example, from the location of staff and patient in an operating theatre the system could determine that an operation was taking longer than planned and automatically reschedule subsequent work; or equipment in need of repair could be placed in a particular location, triggering the system to record that this equipment needs repair and schedule someone to pick it up (Batty 2005).

Location tracking technologies include GPS, phone-locating technologies, microwave, ultrasound and laser, UWB, WiFi and RFID (*see* p.?).

Along with the benefits attached to being able to track people to a high degree of accuracy in real time come certain concerns, particularly in regard to privacy, and it is important that appropriate policies are put in place to address these issues. That said, our privacy is being eroded by technology in general, not just location tracking. More and more data are recorded about us and our actions — what we buy, where we buy it, when and where we take money from an ATM, etc. Should we simply get used to the idea of having no privacy? (Batty 2005). Facebook founder Mark Zuckerberg asserts that people no longer have an expectation of privacy — it is no longer a social norm (Johnson 2010). For further discussion see Stepford Society, p.?

RFIDs

Radio-frequency identification (RFID) is the use of an object (typically referred to as an RFID tag) applied to or incorporated into a product, animal, or person for the purpose of identification and tracking using radio waves. Some tags can be read from several metres away and beyond the line of sight of the reader. Most RFID tags contain at least two parts. One is an integrated circuit for storing and processing information, modulating and demodulating a radio-frequency (RF) signal, and other specialized functions. The second is an antenna for receiving and transmitting the signal. There are generally three types of RFID tags: active RFID tags, which contain a battery and can transmit signals autonomously, passive RFID tags, which have no battery and require an external source to provoke signal transmission and battery assisted passive (BAP) which require an external source to wake up but have significant higher forward link capability providing great read range (Wikipedia). RFIDs are tiny (the size of a grain of sand).

Hailed as the biggest manufacturing, distribution and retail revolution since the internet, these devices have been in existence for more than a decade but have failed to reach their potential due to fears regarding privacy of information — consumer behaviour will be instantly trackable. Whilst pervasive wireless is seen by most commentators as not a matter of 'if' but 'when', the timing and impact is still a matter for debate. Attractive pricing may drive exponentially greater usage, but environmental concerns regarding disposal remain, as does the potential for criminal fraud because the devices can operate past their use-by date.

Current examples

- **Marathon timing**. Many forms of RFID race timing have been in use for timing races of different types since 2004. It is used for registering race start and end timings for individuals in a marathon-type race where it is impossible to get accurate stopwatch readings for every entrant.
- **Passports**. Countries that put RFID in passports include Norway, Japan, most EU countries including Ireland and the UK, Australia, the United States, Serbia, Republic of Korea, and Albania.
- **Tracking**. Tags are used in library book or bookstore tracking, jewellery tracking, pallet tracking, building access control, airline baggage tracking, and apparel and pharmaceutical items tracking. High-frequency tags are widely used in identification badges, replacing earlier magnetic stripe cards. These badges need only be held within a certain distance of the reader to authenticate the holder (Bates and Kane 2009).

It would appear that rapid growth in RFID uptake is imminent — within the next 5 years.

Augmented reality

A growing number of cell phones, cameras and other digital devices now feature augmented reality. This technology displays 3D virtual elements on a real-world camera view. GPS units in combination with inertial references can map a user's precise location, then relay graphics from the web (or a web-based application such as Google Earth) and superimpose them on screen.

This concept has already been used in military training (to display imaginary aircraft and vehicles for example), but is now spreading to mainstream uses — such as travel, outdoor pursuits, communication, gaming and entertainment. Other applications include architecture and interior design (to show virtual objects in a room, for example, or to view buildings before they are constructed). In the coming years, this technology will be available in sunglasses.

The market for mobile AR services is expected to reach $732 million by 2014, with revenues derived from a combination of paid-for app downloads, subscription based services and advertising.

Source: FutureTimeline.net (www.futuretimeline.net).

Data management

The amount of information available through the internet has exploded over the past decade. The world contains an unimaginably vast amount of digital information which is getting ever vaster ever more rapidly. Until now the focus has been on access to information, but it is likely that the focus for the next decade will be how to make sense of all this information. Even though search engines such as Google are immensely useful, they still struggle to separate the meaningful from the meaningless. Nevertheless, it is now possible to do many things that previously could not be done: spot business trends, prevent diseases, combat crime and so on. Managed well, the data can be used to unlock new sources of economic value, provide fresh insights into science and hold governments to account. According to Mr Craig Mundie, chief research and strategy officer of Microsoft Corporation, "the data-centred economy is just nascent. You can see the outlines of it, but the technical, infrastructural and even business model implications are not well understood right now" (Maynard 2009; Economist 2010b).

Already websites such as Wolfram Alpha (www.wolframalpha.com) compute answers to queries rather than simply returning search hits, and Microsoft's Bing (www.bing.com) helps take some of the guesswork out of searches (Maynard 2009). Farecast, a part of the aforementioned search engine, can advise customers whether to buy an airline ticket now or wait for the price to come down by examining 225 billion flight and price records. The same idea is being extended to hotel rooms, cars and similar items (Economist 2010b).

The business of information management — helping organisations to make sense of their proliferating data — is growing by leaps and bounds. In recent years, Oracle, IBM, Microsoft and SAP have collectively spent more than US$15b on buying software firms specialising in data management and analytics. This industry is estimated to be worth more than US$100b and growing at almost 10% a year, roughly twice as fast as the software business as a whole (Economist 2010b).

The number of Chief Information Officers (CIOs) is growing, and a new kind of professional has emerged — the data scientist, who combines the skills of a software programmer, statistician and storyteller/artist to extract the nuggets of gold hidden under mountains of data. Data are widely available; what is scarce is the ability to extract wisdom from them (Economist 2010b). Indeed, most CIOs admit that their data are of poor quality. In a study by IBM half the managers quizzed did not trust the information on which they had to base decisions (Economist 2010c).

As the world is becoming increasingly digital, aggregating and analysing data is likely to bring huge benefits in other fields as well. For example, aggregate healthcare data can be mined to spot unwanted drug interactions, identify the most effective treatments and predict the onset of disease before symptoms emerge (Economist 2010b). Most of these insights come from "dead data": stored information that is examined to reveal hidden correlations. Companies are now beginning to analyse real-time information flows. One use for such information is to forecast when machines will break down. This hardly ever happens out of the blue: there are usually warning signs such as noise, vibration, or heat. Capturing such data enables firms to act before a breakdown. Similarly, the use of "predictive analytics" may transform health care. For example, research is being carried out to spot potentially fatal infections in premature babies. Subtle changes in seven streams of real-time data are monitored, such as respiration, heart rate and blood pressure. Instead of being recorded on paper and examined, say, once an hour, the data are fed into a computer so that the onset of an infection can be detected before obvious symptoms emerge (Economist 2010c).

Two technology trends are helping to fuel these new uses of data: cloud computing (*see* below) and open-source software.

Cloud Computing

The term "cloud computing" refers to the use of the internet as a platform to collect, store and process data, thereby allowing businesses to lease computing power as and when they need it, rather than having to buy expensive equipment (Economist 2010e). Users can gain access to their applications from anywhere, through any connected device. Cloud computing is more evolution than revolution. In fact, it is the next step in the evolutionary progress of computing from the mainframe of the 1960s, to the client server of the 1980s, to the web-based application of the 2000s. It is also a natural step in the evolution of services — from the physical to the virtual — that has characterised much of society's progress (Economist 2010e; IBM 2009).

Cloud computing has generated significant interest across the IT industry, along with multiple perspectives and interpretations of the technology. There are myriad variations on the definition of the cloud — William Fellows and John Barr at the 451 Group define cloud computing as the intersection of grid, virtualisation, SaaS, and utility computing models. James Staten of Forrester Research describes it as a pool of abstracted, highly scalable, and managed compute infrastructure capable of hosting end-customer applications and billed by consumption (Surgient, 2009).

Definitions of the concept vary; so too do opinions as to its validity. One of the harshest critics is Richard Stallman, founder of the Free Software Foundation and creator of the computer operating system GNU. He has opined that "It's worse than stupidity: it's a marketing hype campaign". Larry Ellison, the founder of Oracle, criticised the rash of cloud computing announcements as "fashion driven" and "complete gibberish" (Johnson, 2008).

Most of the concerns about cloud computing are related to security and loss of control over data. Stallman, a staunch privacy advocate, said "if you use a proprietary program or somebody else's web server, you're defenceless" (Johnson, 2008; Economist 2010e).

Even though safety concerns are currently multiplying, evolution dictates that cloud computing will one day become the norm. The monetary system is a good example of the evolution of services from the physical to the virtual mentioned earlier. Civilisation started with barter, then invented coins to make money more portable. The first step in the virtualisation of wealth came with the introduction of paper money. These promissory notes, with no intrinsic value, forced people to deal with the concept of attestation — certifying that something is genuine. And with that, the advent of financial instruments such as stocks, bonds and mutual funds created ways of sharing wealth so that when one person wasn't using it, another could. Today, virtual money dominates the money supply. In much the same way, virtual processing will one day dominate the computing supply. Unfortunately for cloud computing, that day is still a long way off — around 2020 (Economist 2010e).

Given this seeming inevitability, it is appropriate to examine the five defining characteristics of cloud computing (Surgient, 2009):

1: Dynamic computing infrastructure
Cloud computing requires a dynamic computing infrastructure, the foundation of which is a standardised, scalable, and secure physical infrastructure. A dynamic computing infrastructure is critical to effectively support the elastic nature of service provisioning and de-provisioning as requested by users while maintaining high levels of reliability and security. The consolidation provided by virtualisation, coupled with provisioning automation, creates a high level of utilisation and reuse, ultimately yielding a very effective use of capital equipment.

2: IT service-centric approach
Cloud computing is IT (or business) service-centric, in stark contrast to more traditional system- or server-centric models. In most cases, users of the cloud generally want to run some business service or application for a specific purpose without getting bogged down in the system and network administration of the environment. System users should have easy access to powerful pre-defined computing environments designed specifically around their service. An IT service-centric approach promotes business agility.

3: Self-service model
Interacting with the cloud requires some level of user self-service. Best of breed self-service allows users to upload, build, deploy, schedule, manage, and report on their business services on demand. Self-service cloud offerings must provide easy-to-use, intuitive user interfaces that equip users to productively manage the service delivery lifecycle.
The benefit of self service from the users' perspective is a level of empowerment and independence that yields significant business agility. One benefit often overlooked from the service provider's or IT team's perspective is that the more service can be delegated to users, the less administrative involvement is necessary. This saves time and money and allows administrative staff to focus on more strategic, highly valued responsibilities.

4: Minimally or self-managed platform
Best-of-breed clouds enable self management via software automation, leveraging the following capabilities:

- A provisioning engine for deploying services and tearing them down recovering resources for high levels of reuse.
- Mechanisms for scheduling and reserving resource capacity.
- Capabilities for configuring, managing, and reporting to ensure resources can be allocated and reallocated to multiple groups of users.
- Tools for controlling access to resources and policies for how resources can be used or operations can be performed.

All of these capabilities enable business agility while simultaneously enacting critical and necessary administrative control. This balance of control and delegation maintains security and uptime, minimises the level of IT administrative effort, and keeps operating expenses low, freeing up resources to focus on higher-value projects.

5: Consumption-based billing
Finally, cloud computing is usage-driven. Consumers pay only for the resources they use. Cloud computing platforms must provide mechanisms to capture usage information that enables chargeback reporting and/or integration with billing systems.

Memory stick capacity

Memory sticks are now becoming widely available in 8GB and 16GB sizes, which is enough to hold all the files a typical worker needs for their work. They could take all their documents with them everywhere they go and think of any PC as theirs. The application environment is gradually migrating onto some memory sticks, e.g., the U3 environment. The next step is memory sticks designed to carry a user's entire application, profile and file environment, followed by the inclusion of their photos and MP3 tracks, followed in turn by all their videos. Wireless USB could start to make serious impacts very soon, after which we will start to see the rise of memory stick networking and the evolution of pod casting into organic distribution (Pearson 2008b).

AugCog

In 2002 the USA's Defence Advanced Research Projects Agency — the ones who developed the internet four decades ago — embarked on a futuristic initiative called Augmented Cognition, or AugCog. At the heart of the system is a crown of sensors to monitor activity in the brain such as blood flow and oxygen levels. The idea was that modern warfare requires soldiers to think like never before using large amounts of information. The system can help soldiers make sense of the flood of information. For example, if the sensors detect that the wearer's spatial memory is becoming saturated, new information will be sent in a different form, say via an audio alert instead of text. In a trial in 2005 the device achieved a 100% improvement in recall and a 500% increase in working memory (Economist 2010d).

It is unlikely that the general public will gain access to such a sophisticated and personalised means of managing information overload in the foreseeable future. Certainly, machines can help deal with the data deluge, with algorithms doing more of the thinking for people. However, the technology is far less reliable than people realise. For every success with big data there are many failures, such as the inability of banks to understand their risks in the lead-up to the financial crisis. Sometimes the technology stops working altogether (Economist 2010d).

However sophisticated they may become, it is unlikely that computers will completely replace humans (*see* Singularity, p. ?). The human ability to consider as-yet-unforeseen consequences during critical decision making and other abstract reasoning behaviours built up over years of experience will not be readily replaced by a computer algorithm (Economist 2010d).

Questions have been raised about whether the scramble for more information is wise. Information such as the blueprint for a nuclear bomb can cause great harm in the wrong hands, but this is not necessarily a new problem. There has always been more information than people can mentally process. The cornucopia of data now available is a resource. On their own, resources and technologies are neither good nor bad; it depends how they are used. In the age of big data, computers will be monitoring more things, making more decisions and even automatically improving their own processes — and man will be left with the same challenges he has always faced (Economist 2010d).

Stepford society

The technological capability to monitor every part of our lives is increasing rapidly and some governments have enthusiastically embraced that capability to the full. Each year since 1997, the US-based Electronic Privacy Information Center and the UK-based Privacy International have undertaken what has now become the most comprehensive survey of global privacy ever published. The Privacy & Human Rights Report surveys developments in 70 countries, assessing the state of surveillance and privacy protection (Pearson 2008a; Privacy International 2007).

In 2006 Privacy International took the decision to use this annual report as the basis for a ranking assessment of the state of privacy in all EU countries together with eleven non-EU benchmark countries. The 2007 global rankings extend the survey to 47 countries (from the original 37) and, for the first time, provide an opportunity to assess trends. At that time the United Kingdom and the United States were classified as endemic surveillance societies; New Zealand and Australia were described as having systemic failure to uphold privacy safeguards.

Since then, the 2009 Search and Surveillance Bill has been criticised as having very few measures to protect civil liberties and human rights, and a large number of measures that can be exploited to infringe those rights, not only of people suspected of committing criminal acts, but also others inadvertently caught up in the activities (New Zealand Council for Civil Liberties 2009).

Crime and terrorism are cited as justifications for increasing government surveillance. However, in his commentary on the situation in the UK — where 25% of all the world's CCTV cameras are located, Ian Pearson (2008a) suggests that:

"these new systems will make little impact on criminals, who can easily bypass them, whereas generally law-abiding citizens will feel increasingly monitored, oppressed and restricted. The result is effectively a digital prison, where law-abiding people have greatly reduced freedom, but where the criminals roam around relatively freely outside, the police unwilling or unable to control their behaviour. This inverted social control can not be sustainable. Law-abiding people will not indefinitely tolerate a system which allows criminals to do as they wish, while they themselves have very little freedom. The likely result is rejection of this system. If government ignores or oppresses peaceful protest, as it has so far, then the next stages, as frustration and anger increases, will inevitably be civil disobedience, increasing unrest, rioting and the violent attacking of surveillance systems, including government equipment, data centres, and companies that are seen to be providing or collaborating with these systems".

Clearly, the New Zealand situation is less extreme, but surveillance is increasing and there is real potential for an anti-technology backlash if technology intrudes too heavily into people's lives. Without the freedom to do wrong, we have no freedom at all. Pearson (2008b) envisages "a Stepford Society, where conforming people won't be able to commit even trivial offences without penalty, and will have no choice but to live squeaky clean lives, their free will effectively taken away by technology. Meanwhile there will be a parallel underworld of career criminals who just ignore a wide range of laws so that they can hide, ignoring all these constraints with a low risk of being found, using false identities, e-link or LCD number plates, and stolen credit cards, then presumably use loopholes in legislation to minimise their punishments in they are caught. The film *Demolition Man* portrayed this kind of society for 2030 Los Angeles. It may happen much sooner in the UK". Pearson has long been concerned that IT use by government will create an anti-technology backlash at some point, and has determined that 2010–2012 is the most likely period for this to happen.

Singularity and AI

Pearson (2008b) expects synthetic intelligence to approach and even exceed human levels between 2015 and 2020. The production of smarter-than-human machines creates a very rapid positive feedback in technology development that is called singularity. Hassler (2008) explains the concept as "the idea that, as a consequence of exponentially accelerating technological innovation and continuously self-improving artificial intelligence, computer power will outstrip human brainpower, leading to the end of human culture as we know it". Experts told her to expect this situation to come to pass "somewhere between 2030 and 2045, depending on whom you talk to", whereas Pearson (2008b) gives a timeframe of 2020–2025. Pearson quips that "it will be technologically equivalent to ET landing and giving us all the toys from his space ship". Some of the developments are predictable, even as far out as 2040 or 2050, such as fully transparent links between our brains and machines, the end of death via electronic immortality, network enabled telepathy, global consciousness and so forth. Most of the really big changes in the 2050 timeframe are probably beyond our capability to imagine in just the same way that DVDs or internet chat rooms were inconceivable before the invention of the transistor.

According to Hassler, the singularity represents an untestable set of assumptions about our near future. She questions why so many are "willing to take it seriously when we're still a very long way from understanding how consciousness arises in the human brain, let alone figuring out how to re-create it in a machine. We're even a long way from the much simpler goal of creating autonomous, self-organising, and perhaps even self-replicating machines. Simple locomotion — like walking — has only recently been conquered by roboticists. And there's still a lot of work to be done to integrate walking with other functions, like seeing and hearing". Arbor (2003) quotes John Holland, professor of electrical engineering and computer science and professor of psychology at the University of Michigan: "we don't understand enough about how our own human software works to come even close to replicating it on a computer".

Hassler concedes that the singularity is certainly possible, but appears to conclude that the 2030–2045 timeframe is overly ambitious (let alone 2025!): "Wireless communication, ubiquitous computing, nanotechnology, distributed sensing, and embedded systems are going to converge and deliver wonders. Electronic prosthetic devices and biopharmaceuticals will help us correct or expand our physical and mental capabilities. Ultimately, we may even learn enough about consciousness to re-create it in a machine and create artificial vessels for our own minds. But with all we have to do over the next 30–40 years, we don't expect to be hitting the "Upload to digital heaven" button anytime soon".

Goertzel (2007) believes that "if it is done properly, AI engineering can bring us rapidly to a positive Singularity". His position is that the creation of a superhumanly intelligent

AI system is possible within 10 years, and maybe even sooner (3–5 years) "if we really try". Goertzel does concede that in principle possibility is one thing, and pragmatic possibility another. The vast majority of contemporary AI researchers take the position that, while AGI is in principle possible, it lies far beyond our current technological capability. In fact this is currently the most popular view among AI researchers. A group of mainstream, academic, non-futurist AI researchers was asked "When will computers be able to simulate every aspect of human intelligence"? 41% said "More than 50 years," and 41% said "Never."

No-one knows for sure whether it is possible even in principle for true intelligence or consciousness as we know them to develop on digital circuits. It may be possible, and therefore presents a possible threat — many people underestimate the potential for AI-based threats because they assume that all machines and their software must be designed by people; that is no longer true and will become increasingly untrue as time goes on. Once AI reaches a certain level of intelligence, it would be capable of hiding, using distribution and encryption to disperse itself around the net. By developing its own techniques to capture more processing resources, it could benefit from a positive feedback loop, accelerating quickly towards a vastly superhuman entity. Although there is no reason to assume it would necessarily be malicious, there is equally no reason to assume it would be benign (Pearson 2008a).

Computing gel

Computing gel, a development that can take us away from conventional digital computing, has the potential to substantially improve the scope and capability of computing and therefore the likelihood of the existence of a real AI threat. The last few years have taken processing chips from single cores to multiple cores, the number doubling every year or so. One of the big problems with chips is heat dispersal, and ongoing miniaturization of circuits also creates quantum effect-related errors. Moving to 3D architecture would allow higher device counts without needing to further shrink size. When device counts increase, interconnection becomes a further problem. A fairly obvious solution is to start suspending processors in gel, using free-space optical links to connect them together. It is not necessary in principle to hard wire processors into fixed architectures at the point of manufacture. They could use self organisation to establish their own networks. In this way, with the gel providing cooling and a medium for communication, thousands or even millions of tiny processors could be suspended in a 100ml pot of gel. Each of the processors could have just a few thousand transistors, or millions. Some could be digital circuits, some analog. Such a medium with a suspension of analog and digital processors, unconfigured, would be an excellent raw base on which to run evolutionary and adaptive algorithms. Such a gel could be given a loose default structure, with some neural networks, some digital circuits, but mostly unassigned reconfigurable circuits. It could use high speed experimentation, configuring circuitry in many different ways and making pseudo-random modifications in a smart evolution program, to discover by itself the best circuits and architectures to achieve a large library of functions. **It is impossible to predict the range of capability such a gel might be capable of achieving…Starting as the equivalent of the "primordial soup", it could blaze through the equivalent of billions of years of evolution at high speed. At some point a powerful enough gel would pass human level of intelligence, and keep going** (Pearson 2008a).

Smart bacteria and smart yogurt

As biotechnology and its spinoff synthetic biology progress, it will eventually be possible to design and build living bacteria that can build and power electronic circuitry within their own cell. As they reproduce, large colonies of such "smart bacteria" could self organize into highly sophisticated machines, effectively smart yogurt, which is essentially a biological means of producing the gel computing described above. Preliminary calculations suggest that a pot of smart yogurt could provide the electronic foundations for an intelligence equivalent to an entire country.

Advanced AI is not the only means by which smart bacteria and smart yogurt present a threat. With this level of miniaturisation, and the ability to exist and reproduce in nature, smart bacteria could be the ultimate security threat. Small groups of bacteria could provide little islands of processing, connected via network links to the whole smart bacterial intelligence, or there could be large numbers of independent intelligences. With dual existences in both the real and virtual worlds, they present an interesting threat both to electronic and natural systems (Pearson 2008a). Timeframe unknown!

Weapons

Robotic vehicles

These vehicles will search and destroy enemy troops and equipment on the ground or in the air, theoretically without risk to friendly troops. They work by means of on-board computers that interpret sensor data to identify and target hostile forces with built-in weapons. The major developmental problems encountered so far are that it is difficult to quickly and reliably discriminate between hostile forces and neutral or friendly parties, and systems that check with human controllers are vulnerable to communication failures. Malfunctioning robots could fire wildly at anything (Hecht 2006).

High-energy lasers

These powerful energy beams travel in straight lines through air or space at the speed of light and can strike over distances of thousands of kilometres. However, the lasers require a lot of fuel or electrical power and they are very bulky (Hecht 2006).

Space-based weapons

The main mission of space-based weapons would be to defend against ballistic missiles fired at targets on Earth. Fleets of interceptors or battle stations Fleets of interceptors or battle stations would be stationed in orbit, poised to fire at any attacking missiles. However, the technology is immature (Hecht 2006).

Hypersonic aircraft

Launched from a standard runway, a hypersonic aircraft could fly faster than Mach 5 to strike anywhere in the world within 2 hours. It would also have enough thrust to deliver a satellite to low-Earth orbit. However, many engineering issues remain unresolved (Hecht 2006).

Active Denial System

Millimetre-wave or microwave beams supposedly make people flee without injuring them. They might typically be powered by a generator fitted to a Humvee, in crowd control situations.

Nevertheless, serious injury is possible if people cannot escape from the beam; skin burns within minutes. The beam also superheats metal objects like coins, earrings, or spectacle frames, which can then burn skin (Hecht 2006).

Nuclear missiles

Nuclear missiles, which are able to deliver unmatched destructive power anywhere in the world, remain the ultimate level of military power (Hecht 2006).

E-bombs

High-power microwave pulses can knock out computers, electronics, and electrical power, crippling military and civilian systems. However, the effects can depend on local conditions, and are hard to predict. Sensitive enemy military equipment can be shielded, and microwaves also disable friendly electronics within range (Hecht 2006).

Layered missile defence

Layered missile defence offers the best chance to shoot down attacking ballistic missiles. Multiple anti-missile systems are deployed to target ballistic missiles during different stages of the attacking missile's flight. Each phase, or layer, of defence increases the chance of successful destruction of the missile. However, the system is very expensive to build, test, deploy, and maintain (Hecht 2006).

Information warfare

This technique interferes with the flow of information vital to enemy operations, while defending friendly channels of communication. It works by specifically targeting communication networks and computers. Expert computer hackers, called crackers, might break into or overload military computers and networks, or spread computer viruses. Jammers might also block radio and television transmissions. Misinformation is circulated deliberately. This technique is of limited use against low-tech opponents (Hecht 2006).

Technology and the environment

Green turbulence

Environmentalism is evolving quickly. Greens (around the world) are losing the political initiative and scientists are finally taking hold of the problems, though conspicuously fighting about details. There is growing conflict about the best ways to address climate change and other environmental issues. There is also a tension between technologists who tend to think in terms of glass-half-full, have-your-cake-and-eat-it solutions, and deep green environmentalists who tend to have a much darker perspective, generally espousing the belief that the current dominant economic systems and their intertwined technological systems are at odds with the ecological cycles of the natural world. Their view is that the technologies that support life for the rich are threatening the very viability of life on Earth (Kimbrell 2009; Pearson 2008b).

Johnson (2009) comments that oil-based economies are ripe for technological revolution, but political interference is leading to half-baked solutions. In spite of the groundswell of entrepreneurs and academics working towards new answers, it is uncertain whether the energy landscape will look very different in a decade.

Climate change

Technology adaptations to climate change are not covered in depth here because it is expected that they will be examined in the accompanying Environmental Trends report. It is timely to comment on the evident disagreement between scientists about the existence, causes, and effects of climate change. The Economist (2010f) has recently published a special report on the science of climate change, offering a very succinct and compelling response to the uncertainty and disagreement: “using the Inter-governmental Panel on Climate Change ‘s (IPCC) assessment of probabilities, the sensitivity to a doubling of carbon dioxide of less than 1.5ºC … has perhaps one chance in ten of being correct. Even if the IPCC were underestimating things by a factor of five or so, that would still leave only a 50:50 chance of a desirable outcome. The fact that the uncertainties allow you to construct a relatively benign future does not allow you to ignore futures in which climate change is large, and in some of which it is very dangerous indeed. The doubters are right that uncertainties are rife in climate science. They are wrong when they present that as a reason for inaction”.

Geoengineering

The concept of geoengineering has begun to move from the fringe to the mainstream, due to the fact that we may not be able to cut carbon dioxide emissions sufficiently to manage global warming. Chris Rapley, director of London’s Science Museum and professor of climate science at University College London, has concluded that we need to suck carbon dioxide out of the atmosphere, perhaps using artificial trees that eat it. He thinks that such an endeavour “will allow us to exploit the substantial reserves of oil, gas and coal to sustain society through the inevitably long and hard transition to a low-carbon world, without causing dangerous climate change. If ever there were a technical project that humanity should invest in, this is it” (Appleyard, 2009).

Such technologies have long been dismissed due to the amount of energy required, but the global warming crisis has rendered the potential payback of research investment into creating less energy-intensive technologies feasible.

Maynard (2009) postulates that the next decade will see the debate over geoengineering intensify. Research will lead to increasingly plausible and economically feasible ways to tinker with the environment. At the same time, political and social pressure will grow — both to put plans into action and to limit the use of geoengineering. The big question is whether globally co-ordinated efforts to develop and use the technology in a socially and politically responsible way emerge, or whether we end up with an ugly, and potentially disastrous, free for all.

Writing in the New Scientist, Kunzig and Broecker (2009) assert that technologies to capture CO_2 from the atmosphere are seen as the next goldmine because the potential advantages are so great.

Energy

We hear a lot about peak oil and declining stocks of fossil fuels, and there are few who would dispute these facts. However, one point of view that doesn't generate a lot of column inches or air time is that energy is effectively unlimited. Ian Pearson, who is no climate change denier and fully acknowledges the predicament of our planet's environment, has high expectations of the mitigating value of technology. He considers that we tend to ignore likely technology progress, thereby inaccurately estimating long-term problems and paying far too much attention to them at the expense of short-term quick wins such as addressing methane emissions.

Pearson demonstrates (with equations that I won't reproduce here!) that solar farms in the Sahara alone could supply forty times more energy than is needed for the whole planet. He develops this model further to show that the maximum obtainable price for a barrel of oil would eventually fall below extraction cost, meaning that some oil will just be left in the ground. Climate models should therefore use greatly reduced estimates of fossil fuel use in the long term, not increased. Of course, this situation would never arise if we didn't believe that oil is a finite resource, but it certainly provides food for thought.

Craig Venter, the genetic maverick who first sequenced the human genome, is working on bacteria that excrete diesel. He claims that "the debate on fuels and energy is blown out of proportion. We are very close to solving the energy needs in a way that will make our children enjoy cheaper and more efficient energy that what we see today".

Source: Appleyard 2009; Pearson 2009.

Alternatives to fossil fuels

- geothermal and hydroelectric are good solutions where available;
- wind and wave depend on weather, needing backup capacity with little possibility of long-term cost reductions (although a cunning plan to store energy underwater may help fulfil the promise of wind power — *see* below);
- nuclear is unpopular and expensive with little cost reduction capability;
- solar energy is an excellent solution, although storage solutions are needed to cope with nightfall;
- the cost of photovoltaics has the potential to fall much further than other renewables in the long term.

Sources: Pearson 2009; Economist 2010g.

Wind power

Most wind-power turbines are built at sea. Alexander Slocum, of the Massachusetts Institute of Technology, has devised a pumped-storage system that uses seawater. The scheme involves anchoring a hexagonal array of hollow, 31-metre-diameter concrete spheres to the ocean floor at a depth of approximately 350 metres. Floating turbines would be tethered to these spheres and surplus power from these turbines, generated during periods of high wind and low electrical demand, would be used to pump water out of the spheres, evacuating the central chamber. When the wind falters or the lights go back on, water forced into the central chamber by the pressure of the surrounding ocean would pass through a turbine and generate electricity. Each sphere would provide a five megawatt turbine with 4 hours of storage capacity.

The load-smoothing effect of the system will also allow the transmission lines linking the turbines with the shore to be cheaper (because they will not have to cope with peak capacity) and deliver power that, being better matched to demand, is worth more. In combination, these factors could bring the price of offshore wind power into line with that of its onshore cousin.

They will also make an electricity grid supplied primarily by renewable sources a technically feasible proposition by reassuring customers that the lights will never go off and eliminate the argument that "alternative" is not merely expensive, but also unreliable.

Source: Economist 2010g.

Hydrogen

Jeremy Clarkson, of *Top Gear* fame, accepts that oil will run out one day and "the concept of using these last few drops for personal travel is stupid". To him, it is "perfectly clear that hydrogen is the obvious replacement. It is the most abundant gas in the universe. It can be stored on a credit card. And a car that runs on hydrogen produces no noise and only H2O from the tailpipe. What's more, you could plug such a car into your house at night and even if your house is Blenheim Palace, it will run all the electrical appliances, silently and at no cost to the environment". It might be difficult to make hydrogen from water, but certainly not impossible.

In fact, researchers at GE have come up with a prototype of an easy-to-manufacture apparatus that could lead to a commercial machine able to produce hydrogen via electrolysis. Such technology could be economically practical for future fuel-cell vehicles to run off hydrogen.

The hydrogen economy tops the list of LiveScience's "10 Technologies that will transform your life".

One of the main hurdles in the development of hydrogen technology is efficient and safe storage of the hydrogen — compressed and liquid hydrogen do not store sufficient volumes and pose safety risks. A firm by the name of Safe Hydrogen has found a way to store hydrogen in a slurry format. The energy density of rechargeable slurry is equivalent to liquid hydrogen. Rechargeable slurry uses only heat to release the hydrogen. The slurry can then be recharged with hydrogen. Rechargeable slurry provides hundreds of charge/discharge cycles enabling he capital cost of the slurry to be amortised over the cycles. Slurry is very safe to transport and can be stored at normal temperature and pressure. The slurries were designed to be distributed using the existing fossil fuel infrastructure of tanks, trucks and water transport. Depleted slurries yield environmentally safe byproducts and can be completely recycled and reused. Slurries match the storage efficiencies of liquid hydrogen without the inherent complexity of storing and transporting cryogenically cooled and potentially explosive gases.

Safe Hydrogen slurries enable hydrogen storage for future use in the same location or for distant and broad based distribution to all market applications such as large-scale power generation, back-up power, as well as for fuelling hydrogen-powered vehicles and ships.

Sources: Clarkson 2010; LiveScience 2008; Talbot 2006; www.safehydrogen.com.

Smart grids

In many parts of the world, the way that electricity is generated, stored, and transmitted is under immense strain. As demand for electrical power grows, a radical rethink of the power grid is needed if we are to get electricity to the right place at the right time. The smart grid is the solution most likely to emerge as the way forward over the next 10 years.

Smart grids connect producers of electricity to users through an interconnected "intelligent" network. They allow centralised power stations to be augmented with — and even replaced by — distributed sources such as small-scale wind farms and domestic solar panels. They route power from where there is excess being generated to where there is excess demand, and they allow individuals to become providers as well as consumers — feeding into the grid from home-installed generators, while drawing from the grid when they can't meet their own demands. The result is a vastly more efficient, responsive and resilient way of generating and supplying electricity. As energy demands and limits on greenhouse gas emissions hit conventional electricity grids over the next decade, expect to see smart grids get increasing attention.

Source: Maynard 2009.

Solar power

The next decade might be the one where solar power fulfils its promise. Apart from increased political and social pressure to move towards sustainable energy sources, some promising solar technologies might bear fruit over the next few years. The first of these is printable solar cells. Although not significantly more efficient than conventional solar cells, they have the potential to dramatically reduce the cost of solar power if the technology can be scaled up and some teething difficulties resolved. The technology is simple in concept — using relatively conventional printing processes and special inks, solar cells could be printed onto cheap, flexible substrates; roll to roll solar panels at a fraction of the cost of conventional silicon-based units. This opens the door to widespread use.

The second technology to watch is solar-assisted reactors. Combining motor-concentrated solar radiation with some nifty catalysts, it is becoming increasingly feasible to convert sunlight into other forms of energy at extremely high efficiencies. Imagine being able to split water into hydrogen and oxygen using sunlight and an appropriate catalyst for instance, then recombine them to reclaim the energy on demand, all at minimal energy loss.

In less than 10 years, solar-based energy could be at parity with the cost of electricity from the grid, and may well become a standard feature of new residential construction.

Sources: LiveScience 2008; Maynard 2009.

You power

Gadgets such as mobile phones are marvels of the modern age, but are basically useless without a battery. It is not inconceivable that we might one day be able to gather all the energy our gadgets need from the world around us. In 2008, Zhong Lin Wang at the Georgia Institute of Technology in Atlanta wove a fabric made from zinc-oxide nanowires on strands of Kevlar. Each time the material is bent or squeezed, it generates a tiny current. Wang and his team found they could harvest it by coating each fibre with a film of metal.

Gadgets implanted inside your body, like pacemakers, could be powered by you. A heart-powered electricity generator devised by a team at Stanford University produces electricity by forcing a small magnet back and forth through a tine wire coil. The magnet is housed in a liquid-filled silicone tube with a balloon attached to each end, and the whole device is placed within the heart. As the heart beats, the balloons are squeezed in turn, forcing the liquid — and the magnet — back and forwards through the tube. A researcher at the University of Texas has developed a fuel cell that can be implanted in an artery and uses glucose in the blood as fuel.

Source: New Scientist 2009.

Transport

Transportation is a basic human need, and it will be necessary to develop new materials and modes of transportation to meet the demands of our society in a sustainable way. Commentators on the future of transport seem to fall into two camps: the optimists who acknowledge the challenges but expect technology to pull us through; and the pessimists who maintain that the only viable solution is to travel less and go low-tech, advocating bicycles and public transport. Clearly, there is merit in both approaches and while it would be overly simplistic to suggest that the future will lie somewhere between the two extremes, we can be sure that things will change and probably for the better.

Today's globalised economy largely rests on nineteenth- and twentieth-century revolutions in transport: humankind's ability to move goods and people around the planet by boat, train, car and plane. The global transportation network allows consumers to buy crisp New Zealand apples in London, fresh seafood in Oklahoma City and Chinese-manufactured goods everywhere.

Indeed, transportation is so integral to the global economy that 14% of the world's greenhouse-gas emissions come from that sector alone. In the developing countries especially, that fraction is growing rapidly. There is every reason to expect that car ownership will continue to increase towards that of the already developed nations, where between one-third and one-half of the population owns a car.

Managing the greenhouse emissions from transportation has therefore emerged as a major challenge in the twenty-first century. Technologies that could help accomplish that goal range from the relatively familiar — such as fuel cells running on hydrogen split from water via solar or wind power (*see* p.?)— to the novel — such as kite-powered ships or steam-powered trains.

Not so long ago most of these ideas would have been dismissed as pipe dreams. Today, if the soaring price of oil has a silver lining, it is that the push for alternative transportation technologies has become real and serious. However, oil prices are notoriously volatile and the challenge for policy-makers in every sector is to make sure those investments in future transportation are sustained for the long haul.

The Volvo Group is working to meet the demands posed by threats to our safety, health and the planet at large, as well as providing solutions to the increasing need for transportation. They are well aware that our future vehicles and entire infrastructure must become smarter. Innovation tends to occur where there is significant challenge. It is therefore not surprising that there are some potentially exciting developments in the pipeline. Imagine, for example: smart vehicles that communicate with each other and the infrastructure; secure transport for both driver and goods; vehicles that avoid accidents and shut down when stolen.

Public transport would ideally become the dominant means of transporting the masses. New Zealand's population size and geography are limiting factors, but we could do more.

Sources: Apelian 2007; Nature 2008; Volvo Group Global.

Automated transport

Automated public transport, driverless cars, trains and buses, have been around as ideas since the 1950s. But now with climate change, the idea seems to be gaining more traction. Automated transport systems (ATS) have the potential to combine most of the advantages of private cars (e.g., flexibility, convenience, and comfort) with the advantages of conventional public transport (e.g., sustainability, environmental impacts, and cost), but at the same time avoid most of their disadvantages. ATS could use the existing road network and allow interaction with other users (i.e., conventional manually driven vehicles, cyclists, and pedestrians), and therefore do not require any costly rail infrastructure. System design and implementation for this is based on recent advances in sensor and information processing technologies, including vehicle guidance, vision systems and obstacle detection and avoidance.

It appears to be inevitable that automation, in all possible forms from providing information at one end of the spectrum and fully autonomous driving at the other, will play a major role in the integrated traffic solutions of the city of tomorrow.

In Britain, plans are already under way to introduce driverless cars, designed by Martin Lowson who worked on Saturn V Rocket, which launched the Apollo missions and who later designed the rotor blades for the world's fastest helicopter. He says it will have the same impact on transport this century as George Stephenson's Rocket did in the 19th Century, and the Model T Ford in 20th Century. The big challenge for entrepreneurs offering driver-less cars would be creating something that's better than the conventional automobile in terms of speed, price and convenience.

CityMobil is a project, co-funded by the EU, set up to build knowledge of the issues arising from the integration of automated transport systems in the urban environment (the technical capacity of automated transport vehicles has been tested elsewhere). It is a sizeable project with 28 research partners out of 11 EU countries. The need for **both** high speed scheduled mass transport **as well as** individualised on-demand short distance transport is recognised. This is why we have to test and evaluate new solutions based on advanced city vehicles. At the end of the project, the researchers expect to have a better understanding of the capabilities of new technologies and what the expected gains can be. There will be proposals for certification of advanced transport systems on a European level. Case studies are under way in the Spanish town of Castellón, at the new exhibition centre in Rome, and at Heathrow airport.

In a variation on the theme, Pearson proposes a system of "packetised" rail travel. Electronically driven pods could be assigned to a particular destination on demand. They would be automatically distanced from pods in front and behind and could continue on local roads using electronic paths. This kind of system would enable much higher rail utilisation and would reduce congestion on the roads.

Sources: CityMobil 2009; Pearson 2009; Sox First 2010.

Electric cars

Most of the major manufacturers are already developing models, but range is a big problem. These new-generation electric vehicles have range of 40 miles or so before needing to be recharged and the recharge time is likely to be in excess of 4 hours. Evidently, battery technology is still in its infancy but there is potential for batteries to store renewable energy. Likewise hydrogen fuel cells (*see* p.?) require a lot more refinement before they become a viable option (Pearson 2009).

Electric roads

But Korea's Advanced Institute of Science and Technology (KAIST) thinks that battery-powered cars aren't the answer to our energy crisis. Instead, KAIST has developed a new kind of electric vehicle that forgoes batteries entirely and instead relies on power from cables buried beneath the road. The On Line Electric Vehicle (OLEV) project consists of a set of electric buses that pass over power coil-containing tracks. Once the buses cross the tracks, they're given a boost of electricity that allows them to keep moving without having to stop and recharge.

If the OLEV project catches on, it could revolutionise the electric vehicle industry. Battery-powered vehicles have to constantly stop for recharging — a problem that will ultimately require an infrastructure of electric charging stations. The vehicles also contain lithium, which will inevitably become more expensive as electric cars become more popular.

With OLEV, strain on the power grid is reduced and lithium is preserved. KAIST believes that if half of all automobiles in Korea are converted to the OLEV system, the country can cut crude oil imports by US$3 billion each year.

This kind of giant Scalextric set is also mentioned by Pearson (2009). He suggests that with computers driving, cars could be very close together (end to end and side by side) allowing up to five times more road capacity to be realised. Power consumption and speed would improve greatly.

Sources: Schwartz 2009; Pearson 2009

Electric bikes

There may be more to John Key's national cycle way than any of us realised!

Delivery workers in New York, postal employees in Germany and commuters from Canada to Japan are among the millions taking part in an accidental transportation upheaval. It began in China, where there are an estimated 120 million electric bicycles, up from a few thousand in the 1990s. They are rapidly replacing traditional bikes and motorcycles and, in many cases, allowing people to put off the switch to cars.

The booming Chinese electric-bike industry is spurring worldwide interest and impressive sales in India, Europe and the United States. China is exporting many bikes, and Western manufacturers are also copying the Chinese trend to produce models of their own. From virtually nothing a decade ago, electric bikes have become a US$11 billion global industry.

In the Netherlands, one-third of the money spent on bicycles last year went to electric-powered models. Industry experts predict similar growth elsewhere in Europe, notably Germany, France and Italy, as rising interest in cycling coincides with an ageing population. India's nascent market is fast expanding and could soon eclipse Europe's.

Electric bikes bring both advantages and disadvantages in terms of environmental protection. For each mile travelled, electric bikes cause fewer emissions of the gases associated with global warming than do cars. However, a typical Chinese model uses five lead batteries in its lifetime, each containing 20–30 pounds of lead. In areas without stringent recycling programs, the potential for environmental contamination is high.

Other barriers to uptake include the high potential for accidents — involving cars and/or traditional bikes; and the culture of cycling as a sport rather than a utilitarian means of transportation.

Pearson approaches the situation from a different angle, with the bicycle lane providing the power rather than a battery. His concept uses a linear induction motor mat stuck to the road surface, with a metal plate and RFID chip attached to the front wheel of the bike and an on/off button on the handlebars. This solution would require more infrastructure investment but would eliminate many of the problems associated with battery-operated bikes.

Sources: Goodman 2010; Pearson 2009.

Jet packs

Personal jets have been around for over forty 40 years. The rocket belt featured in the James Bond movie *Thunderball* in 1965, at the opening ceremony of the 1984 Olympic Games in Los Angeles, and in the *New Scientist* in 2005. None of these previous prototypes worked very well.

The Martin Aircraft Company in Christchurch launched an entirely different kind of jet pack in July 2008. It is powered by two turbojet engines that run on standard auto fuel and can fly for 30 minutes on the single tank (earlier models could only sustain flight for about 30 seconds!). There is a parachute in case of emergencies. Cost and size are limiting factors: they cost about the same as a high-end car and are not so much strap on as walk into.

Source: New Scientist 2009.

Space travel

It is common knowledge that two private companies, Virgin Galactic and XCOR Aerospace, are developing craft to ferry paying passengers into space. Sir Richard Branson of Virgin Galactic unveiled the rocket plane, SpaceShipTwo, on 7 December 2009. The vehicle will undergo testing over the next 18 months before being allowed to take people on short-hop trips just above the atmosphere. Virgin Galactic plans to start commercial flights in the US in 2011, not 2010 as originally intended. Spaceport Sweden official Johanna Bergstrom-Roos expects Virgin Galactic flights from Spaceport Sweden in 2012. Plans are to take 50,000 people into space during the first 10 years of operation.

Less well known is the possibility of personal spacecraft. Personal spacecraft could fly into orbit on a beam of microwaves shone upwards from the ground. A ground-based laser beam generates an explosive plasma when it strikes the underside of the craft, creating thrust that pushes it skywards. Obviously, much work remains to be done, but Patrick Wood of space technology company EADS Astrium, based in Stevenage UK, imagines that personal spacecraft could take off in the next 50–100 years.

Sources: Coppinger 2009; New Scientist 2009; Virgin Galactic n.d.

Biotechnology (non-medical)

Definition

Biotechnology is the manipulation of biological systems with the primary goal of application through the conduit of technology. Some of the applications of biotechnology include alcoholic fermentation, food preservation, bread-making (yeast-induced fermentation), pharmaceuticals (e.g., insulin and growth hormone production by microbes), bioremediation, water treatment by microbes, cloning (e.g., Dolly), bioengineering, gene therapy, genetically modified foods, transgenic animals, and many others.

Red biotechnological endeavours are those that involve the medical profession. These scientific efforts have produced amazing results, including advancement in the use of living organisms to create antibodies and the generation of new vaccines. The medical profession is grappling with the ethics of certain aspects of biotechnology, including manipulation of genes by powerful computer-aided operations.

Many manufacturers and industrial facilities are beginning to utilise gray biotechnology in order to cut overhead costs and improve environmental protection. Gray biotechnological professionals, like chemical and production engineers, look to the enhanced use of living organisms to make processes easier and more acceptable. Facilities that treat sewage and water, for example, can use certain bacteria in the filtration process to eliminate harmful organisms before they reach the public.

Green biotechnology provides assistance to farms and agricultural businesses. Biotechnology used on the farm includes the creation of plants that can endure a variety of meteorological conditions and the use of treatment options on products to be sold for public consumption. Leading stores and other food providers rely on green biotechnology for the consistency of many of their food products.

White biotechnology is also known as industrial biotechnology. It is the application of biotechnology for industrial purposes, including manufacturing, alternative energy (or bioenergy), and biomaterials.

Role of the sector

Biotechnology is an area of speedy development that is just beginning to undergo the same revolution as the IT industry did. Sometimes the change is much too fast for our ethical understanding to keep up, which is where the structures of the old world could slow progress down, as development becomes a game of politics, not possibilities. Biotechnology has the potential to create better healthcare, improved foods, better and safer agriculture, and cleaner industrial processing. Local biotechnology companies export to over 60 companies around the world, including Australia, Europe and the United States. Export revenue earned from biotechnology is predicted to reach $1 billion in the next 10 years. The New Zealand biotechnology sector currently employs around 2,500 highly skilled people, many of whom are world leaders in their chosen field. The Council of the European Union expects biotechnology to be an important pillar of Europe's economy by 2030, indispensable to sustainable economic growth, employment, energy supply, and to maintaining the standard of living. Biotechnology is expected to help meet the most urgent global challenges — growing and ageing populations, limited resources of raw materials, energy and water, the threat of global warming.

All sectors of biotechnology will continue to grow globally; developing countries will benefit from new vaccines and therapies and will see the highest growth of green biotechnology. The emerging industrial countries of Brazil, India, and China will become strong competitors in agrobiotech. Biotechnology is, and will continue to be, an international industry, based on international business models.

Sources: Council of the European Union 2007; Biotechnology Learning Hub (www.biotechlearn.org.nz); Johnson 2009.

Food

One of the key driving forces behind advances in biotechnology is the growing demand for a sustainable supply of food. A giant leap in agricultural production and yields will be needed within the next two decades. In addition, lifestyle factors (less physical activity, higher food intake, intake of convenience food and fast food) leading to an increase in lifestyle-related diseases are prompting the search for tailored, personalised nutrition (nutraceuticals, functional foods) providing better food with improved health attributes. We are likely to see food markets split up into conventional food products and targeted or personalised foods. Furthermore, biotechnology will permit better extraction of valuable ingredients and nutrients from residues of conventional food production.

Personalised nutrition relies on sound, non-invasive diagnostics which is expected to become available from advances in biomarker research, genetic testing, and from advanced imaging and biosensor technologies. Information on the interplay of individual genetic makeup and the physiological response to food is already being collected in genomics projects (Council of the European Union 2007).

Bioenergy

Advances in biotechnology are also being driven by climate change, which calls for effective measures to reduce the release of greenhouse gases and to promote the transition from conventional fossil fuels to alternative and renewable sources. A challenge of equal order is the anticipated increased demand for energy in the next decades while fossil fuel reserves, particularly oil and gas, will continue to decline.

Bioenergy production is an example of integrated RD&D combining green and white biotechnology, agricultural production, conversion technologies, materials sciences and others.

The International Energy Agency (IEA) predicts that by 2030 today's 1% share of biofuels (based on energy content) of the global transport fuel market could have risen to 7%, with other projections even higher. By 2030 energy crops that store more energy and can be used in their entirety will have become available from advanced breeding technologies, including genetic engineering.

Food and fibre crops currently contribute to the supply of feedstock materials for energy supporting the vision of decentralized energy production. It is anticipated that by 2020 or earlier the conversion of lingo-cellulosic biomass (straw, wood, etc.) by enzymatic hydrolysis will have become standard technology and will open up access to large feedstock supplies, thus avoiding direct competition with food production (Council of the European Union 2007).

Synthetic biology

Ten years ago, few people had heard of the term "synthetic biology." Now, scientists are able to synthesise the genome of a new organism from scratch, and are on the brink of using it to create a living bacteria. Synthetic biology is about taking control of DNA — the genetic code of life — and engineering it, in much the same way a computer programmer engineers digital code. The development has arisen partly as a result of the falling cost of reading and synthesising DNA sequences, but it is also being driven by scientists and engineers who believe that living systems can be engineered in the same way as other systems. In many ways, synthetic biology represents the digitisation of biology. We can now "upload" genetic sequences into a computer, where they can be manipulated like any other digital data. We can also "download" them back into reality when we have finished playing with them — creating new genetic code to be inserted into existing, or entirely new, organisms. This is still expensive, and not as simple as many people would like to believe. However, as the cost of DNA sequencing and synthesis continues to fall, expect to see the field advance in huge leaps and bounds over the next decade. We are not likely to crack how the genetic code works in great detail by 2020, but synthetic biology will be a hot topic over the next decade. In particular, look out for synthesis of the first artificial organism, the development and use of biobricks — the biological equivalent of electronic components — and the rise of DIY biotechnology (Maynard 2009).

Medicine and Health

Biotechnology and biomaterials

Biomaterials science encompasses elements of medicine, biology, chemistry, tissue engineering and materials science. While a definition for the term "biomaterial" has been difficult to formulate, one of the more widely accepted working definitions is:

- "A biomaterial is any material, natural or man-made, that comprises whole or part of a living structure or biomedical device which performs, augments, or replaces a natural function".

A biomaterial is essentially a material that is used and adapted for a medical application. Biomaterials may have a benign function, such as being used for a heart valve, or may be bioactive with a more interactive functionality such as hydroxy-apatite coated hip implants. Biomaterials are also used every day in dental applications, surgery, and drug delivery (a construct with impregnated pharmaceutical products can be placed into the body, which permits the prolonged release of a drug over an extended period of time). The definition of a biomaterial does not just include man-made materials which are constructed of metals or ceramics. A biomaterial may also be an autograft, allograft or xenograft used as a transplant material (Wikipedia).

In the future we will see major developments in the area of surface modification of biomaterials to better control blood and tissue compatibility; biomaterials can be modified by plasma treatment or by chemical grafting. Through surface modification, we will be able to manipulate material attributes such as resistance to infection, resistance to clot formation, lubricity, and wear resistance (Apelian 2007).

Many commentators expect therapeutic cloning and stem cell research to revolutionise medicine. Replacement organs or tissue, which the body would see no reason to reject, can be grown in a laboratory. Cancerous or damaged organs could be replaced by new, disease-free clones of themselves. Biomaterials could be used to regenerate insulin-producing cells of the pancreas from stem cells. In November 2008 a woman successfully received a transplant of a section of trachea made from her own stem cells. In the same way that hip replacements have become routine surgery, we may be hearing about routine transplants from stem-cell-grown organs (Apelian 2007; LiveScience 2008; Ohannessian, 2008).

As stem cell research is still in its infancy, by 2030 regenerative medicine will have revolutionised medicine. Most, if not all, severe chronic diseases such as cardiovascular diseases and neurological disorders, diabetes and degenerative conditions of joints and bones, will be treatable by transplanting industrially produced stem cells; this will avoid organ transplants and therapies to treat the long-term secondary consequences of chronic disease. Treatment with stem cells will be cheap and efficient. Methods will be available for heart repair, neural regeneration and the regeneration of islet cells for the treatment of diabetes. Tissue regeneration will be widely used as a source of organs suitable for transplantation. Future medicine is expected to succeed in building three-dimensional organs like livers, hearts, kidneys and teeth (Council of the European Union 2007).

This view is not shared by all. Gottlieb (2003) asserts that the future of medicine lies "in DNA chips, supercomputers, and new drugs, not embryo research, tissue transplants, or stem cells. It is time for our public debate to pay more attention to this fact, since a medical and technological revolution of this significance is sure to have lasting political, economic, and social consequences".

In describing the union of biology and silicon, Gottlieb explains that new drugs currently in clinical trials are no longer scattershot one-size-fits-all affairs, but carefully targeted to the molecular fingerprints of specific diseases. Some of these drugs are even targeted to a patient's unique DNA profile. Medicine is moving from the *species* level — the ingrained assumption that drugs and diseases work the same in all human beings — to the individual level.

The merger of medicine and microchip is only natural — DNA can be thought of as a 3 billion-year-old Fortran code transduced into bits of data, captured in databases, and analysed with sophisticated software. Gottlieb enthusiastically concludes that "the marriage of biology and silicon and the shift from species-based to individualised therapy will change the face of medicine forever. In the new medical paradigm, disease will be diagnosed before it is made fully manifest. Highly targeted drugs will be used to intervene before organs are ravaged or tissue is destroyed. This new ability to diagnose and treat certain diseases early, from infectious agents like Hepatitis C to degenerative ailments such as Alzheimer's and Parkinson's, may obviate the need for the types of tissue, organ, or stem cell therapies that often attract the most public attention".

Either way — stem cells or silicon — preventive medicine will play a more prominent role in the future. Although improved diagnostics could increase the costs of prevention there will be huge savings from cost-efficient early intervention as well as from the delayed onset of diseases.

Genetics

Advances in genetics are anticipated to support four areas of healthcare:

- prevention and diagnosis, including screening;
- therapy;
- enhancement;
- reproduction.

Early diagnosis is predicted to improve the management of disease, and in the case of carriers, inform reproduction choices. Genetic screening could identify people at risk of a particular disease and allow appropriate interventions to be introduced before the disease develops. As a result, the role of medicine could shift from treating the symptoms of disease to eliminating its cause. Therapeutic and preventative benefits from the discovery of genes could lag 20–50 years behind the diagnosis, leading some to question the appropriateness of screening and diagnosis if there are no treatments available. Ultimately, gene therapy will mean the replacement or deletion of the defective gene to eliminate the associated illness, although we are not likely to see the effects of this until after 2020.

The earliest gains are expected to come from the use of genetic information to predict the effectiveness and side effects of drug therapies. Indeed, the development of pharmacogenetics could be disruptive to healthcare within the decade; genetics has the potential to redefine "disease", "treatment" and "patients" and demand new relationships with patients.

The advent of personalised medicine is expected to transform the pharmaceutical sector. Specific molecular therapies — more efficient and associated with fewer side effects — will dominate the medicine of 2030. Small, specialised companies, resembling thinktanks and close to academia, will feed big pharma's drying pipelines with new medicines. Today's large pharmaceutical companies, still relying on the blockbuster business model, will have to diversify their strategies as awareness grows that blockbusters alone do not resolve the issue of "difficult-to-treat" patients.

Potential difficulties arise with training, workload and resourcing of GPs, as genetic services are likely to be integrated within primary care, and the potential for screening and selection within reproductive technology could allow parents to specify their child's characteristics, raising complex issues about the value of life. Finance could also be a limiting factor.

Extensive research is leading to a better understanding of genetics and the nature of genetic illnesses. Some of the most impenetrable and harrowing mental illnesses known to man will, according to James Watson, co-discoverer of the DNA molecule, be understandable and maybe even curable. Through gene sequencing "disorders like Alzheimer's disease, epilepsy, Parkinson's disease, schizophrenia, bipolar disease, unipolar depression, obsessive compulsive disease, attention deficit disorder and autism will finally have their genetic guts open for all to see", says Watson.

Regrowing amputated limbs, broken backs and even damaged brains could one day be a reality following the discovery of a gene that is key to the almost magical ability. Researchers have found that the gene p21 appears to block the healing power still enjoyed by some creatures, including amphibians, but lost through evolution to all other animals. One day, it might be possible to accelerate healing in humans by temporarily inactivating the p21 gene.

Sources: Alleyne 2010; Appleyard 2009; Council of the European Union 2007; National Public Health Service for Wales 2005.

Bionics

Plug-and-play replacement organs may seem far fetched, but they could be closer than you think. Bionics, a merger of medicine and engineering where metal and plastic are just as important to the functioning of the human body as blood and tissue, has made major advances in the last 50 years — replacement joints, cochlear implants, mechanical heart-assist pumps, and pacemakers are now taken for granted and have profoundly improved quality of life (Apelian 2007; Pobojewski 2003). The development of bionic organs is predicated on the technological achievement of constructing selectively permeable membranes that will not be rejected by the immune system (Galletti 1991). Development of bionic/artificial organs will eventually resolve the shortage of suitable donors.

Researchers at the University of Manchester have transformed fat tissue into nerve cells. Next on the agenda is the development of an artificial nerve that will be capable of bringing damaged organs and limbs back to life. This technology will have benefits in organ transplants, trauma patients and cancer patients (ScienceDaily 2007).

Bionic lungs, kidneys and livers are currently being tested, bionic devices for people with hearing loss are also in the pipeline, as are temporary bionic devices that can be used to keep people alive while they wait for surgery.

General Medical Technology

Monitoring systems

Developments in the field of dependency and care for the chronically ill could help people to feel more comfortable and more secure, with the least possible impact on their daily lives. One of the main lines of work has involved analysing and monitoring human movement. Inertial sensors have been developed that can detect falls and characterise different types of movement. This research has applications in monitoring and preventing the risk of falls in elderly people or people recovering from a fracture. Help will get to those who need it faster. There are also systems that enable patients' vital signs to be monitored in domestic environments — force sensors, used to measure weight, can simultaneously detect heart and respiratory rates.

Source: Science Daily 2009.

Medical technology is boldly going where Star Trek went before

Dr "Bones" McCoy needed only to wave his tricorder sensor like a talisman over *Star Trek* crew members to detect any ailment — and to cure many of them. In reality, McCoy's "sensor probe" was a prop contrived from a salt shaker by a TV crew making do on the tight budget of a fledgling series. These futuristic sickbay tools presented a captivating vision of what medicine might one day achieve.

The portable medical scanner, which revealed internal injuries in an instant, is taking longer to appear in the real world. When it does, it may go a step further: engineers are developing a portable scanner to not only spot internal injuries like torn arteries, but also heal them in a flash. The secret of this device is high-frequency sound waves, or ultrasound beams, that are already used to examine babies in the womb.

Lawrence Crum at the University of Washington in Seattle has shown that high-intensity ultrasound can cauterise bleeding arteries. His company, Ultrasound Technology, has developed a hand-held device that allows surgeons to cut through blood-rich organs and cauterise the cut at the same time. Crum was hoping to test it in humans in 2009.

Weak ultrasound beams can also be used to spot the fast flow of blood characteristic of a bleeding artery. The US government's Defense Advanced Research Projects Agency (DARPA) is funding a project to combine the two ideas, which will result in the Deep Bleeder Acoustic Coagulation system — a portable device that uses ultrasound to both spot and seal bleeding blood vessels.

The device will consist of an array of ultrasound transceivers built into a cuff that can be wrapped round an injured limb. Transceivers emitting low power ultrasound will scan for reflections from damaged arteries. If they spot a leaking blood vessel, the transceivers zap it. To avoid damage to healthy tissue, several beams are carefully focused to meet inside the body where their combined heat will seal the tear.

Sources: New Scientist 2009; Tansey 2004.

Robotic surgery

Surgery will become more accurate with the use of robots that make smaller incisions.

The surgeon sits in a remote area (distance varies) from the operating table, and assumes control of the robot's motion. The surgeon uses master control handles that receive force feedback, along with a 3D stereoscopic visual display to direct the instruments entering the patient's body. The robot cannot make decisions, nor can it perform any type of movement or manoeuvre without the surgeon's direct input. Thus, the robot has virtually no level of autonomy. There are more degrees of freedom in the movement of the mechanical arm than the human wrist. Any kind of tremor factor, which all surgeons have to one degree or another, is totally eliminated by the mechanical device so that the precision of placing a stitch, or doing a manoeuvre in an operation can be better defined. Degrees of freedom refer to the number of independent movements an object or "entity" can make. Six degrees of freedom are required to reach, position, and orient an instrument at any point in space. The seventh degree of freedom is the function of the operation itself (e.g., grasping or cutting). Robotic instruments subsume all seven degrees of freedom — the human wrist is only capable of 4 degrees of freedom while using a laparoscopic instrument. Essentially, these characteristics of the robot, along with the 3D visual display, provide the surgeon with an increased capability that allows him or her to perform minimally invasive surgery more precisely.

There are many different opinions regarding the future of this technology, though one thing remains certain —robotic surgery is here to stay. The British Medical Association expects to see the use of robots in surgery by 2015. Over the next 15–20 years the robot will probably look entirely different and will reduce in size and become more user friendly, probably more modular. We can expect to discover more useful applications of the technology. Eventually, these computer-aided tools will become the norm for specific applications, especially those requiring very small incisions on small organs. Medical students and surgical trainees may not have to choose to study robotic surgery — it is likely to become a standard technique. It might one day be possible for the doctor guiding the robot to be sitting at a console literally across the world from the patient. If remote surgery eventually becomes commercially available, many lives might be saved in hard-to-reach locations, from remote islands to battlefields.

With the rise in popularity comes the possibility of abuse, ultimately translating to issues of patient safety. Some may attempt to use the technology to attract business while neglecting to properly train in the use of surgical robots. Strict regulation of the sale and use of these devices will be required to ensure patient safety.

Source: Andrews (2009); Guidarelli (2006); National Public Health Service for Wales 2005.

The hospital of the future

Robots that glide through hospital halls, allowing medical teams to do their rounds without unsettling extremely ill patients in intensive care, may offer the most visually arresting example of the future of patient care. But they're just one of many dramatic advances changing how hospitals function. RFID tags that track every doctor, nurse, and piece of equipment in the hospital in real time, for example, can enable a faster emergency response. "Smart" beds that automatically transmit patients' breathing and heart rates to their charts can alert nurses to developing problems more quickly. One day in the not-too-distant future, any doctor in the country may have access to the complete medical history of an unconscious trauma patient — perhaps through an identifier implanted under the skin. According to industry analyst Datamonitor, spending on telemedicine, which now entails everything from remotely monitoring patients to analysing medical images from afar and could one day even include long-distance surgery, was expected to reach US$2.4 billion in 2009 and nearly triple to US$6.1 billion by 2012.

Ironically, one of the most anticipated developments is that technology will allow hospitals to do a better job of keeping people out of them. "By 2015, home will be the hub of care," predicts Naomi Fried, vice president of the innovation and advanced technology group at Kaiser Permanente's Sidney R. Garfield Health Care Innovation Center in San Leandro, California.

Advances in healthcare information technology, putting patient records into digital form (possibly into a national database) has the potential to provide a wealth of information about which treatments work and which don't — and to speed diagnosis and medical care and curtail unnecessary tests and procedures.

Hospital administrators are exploring ways that physical structure and environment can ease anxiety and promote wellbeing. "Evidence-based design" is inspired by studies suggesting that patients heal better if they have access to nature, natural light, and artwork, for example. In one oft-cited study, researchers found that surgical patients whose rooms looked out on trees used less heavy medication, suffered fewer minor complications, and went home nearly a day sooner than patients whose rooms looked out on a brick wall.

Rooms will also be "acuity adaptable," meaning that as the patient's condition changes, the room can, too — becoming, say, an intensive care unit temporarily. Studies show that moving patients less frequently results in fewer falls and medication errors.

Source: Andrews 2009.

Longevity

A novel group of drugs that target a gene linked to longevity could provide a way to turn back the clock on the diseases of ageing. The drugs target an enzyme called SIRT1, which belongs to a class of proteins known as sirtuins that have been shown to lengthen life span in lower organisms. It is thought that activating these enzymes mimics the effects of caloric restriction — a low-calorie but nutritionally complete diet that dampens disease and boosts longevity in both invertebrates and mammals. Caloric restriction has been shown to delay or slow the progression of a variety of age-related diseases, meaning that the SIRT1 activators might have the potential to treat illnesses ranging from Alzheimer's disease to heart disease to cancer.

Source: Singer 2007.

Ethics

Future biomaterials medical research is more likely to be impeded by ethical barriers than technological ones. Apelian (2007) asks us to: "imagine what will be the consequence of being able to know the prognosis for disease and especially a life-threatening disease in a newborn. In less than a decade when the Genome project is completed, we will be able to have such information. How will insurance companies assess risk and how will society cope with these issues?...Will health care only benefit those that can afford it? We will need to address the ethical issues that will arise by knowing a-priori a person's propensity for disease and poor health".

Recreational and performance-enhancing drugs

Drugs that enhance mental ability (nootropics) are not new, but their usage patterns are changing. Drugs like Ritalin, donepezil and modafinil are increasingly being used by students, academics and others to give them a mental edge, with the general sense that this is acceptable practice. Unlike physical performance-enhancing drugs, it seems that the social rules for nootropics are different. There are even some who suggest that it is perhaps unethical *not* to take them — that operating to the best of our mental ability is a personal social obligation. This leads to a potentially explosive social/technological mix that won't be diffused easily. There will be questions about whether people should be free to take these drugs, whether the social advantages outweigh the personal advantages, and whether they confer an unfair advantage to users by leading to higher grades, better jobs, more money. Furthermore, there is every chance that new, more effective drugs will emerge and with them questions as to who gets the good stuff? The 2010s are set to be an interesting decade for mind-enhancing substances (Maynard 2009).

Some recent experiments have shown that parts of the brain can effectively be closed down by means of strong oscillating electro-magnetic fields, affecting perception, thinking, and memory. It is likely that some people will start using this technology recreationally in the next few years — cyberdrugs. Also, new drug delivery systems are able to deliver drugs to exactly the right part of the body for chemotherapy, etc. Some use spherical gold capsules with very thin shells that are easily ruptured by ultrasound or electro-magnetic fields. Again, these could be developed for recreational purposes (Pearson 2008b).

Household Technology

General trends

- More and more money is being spent on televisions, video games and video accessories.
- Televisions are becoming much bigger and more complex.
- Video gaming is becoming more complex.
- Motion sensing is becoming a prominent technology. This technology has progressed from house alarms to video gaming, and will continue to be incorporated into other household concepts.
- Voice recognition technology is becoming more advanced and widely used. This technology will offer security and safety in homes and vehicles.
- Voice activation is becoming widely used and more reliable. Appliances and gadgets can be activated with such technology.
- Some devices may be able to read your mind. OCZ offers headset devices which can read electrical impulses in your brain.
- Touchscreens and motion sensors may replace the need for a mouse, keyboards, switches and dials.
- There is a large consumer demand for energy efficiency in all aspects of household technology.
- There is a growing demand for notebook computers, and a decreasing demand for desktop computers.

Source: CEA 2009.

Kitchen

- Flat panel displays will be used on appliances.
- Appliances could be connected to the Internet. This could provide information on temperature, energy efficiency and could help control the use of kitchen appliances.
- There is a growing demand for energy efficient technology with a greener footprint.
- Kitchen computers may become widely used. Computers may step in as the new family organiser in the kitchen, acting as the hub of the household.

Source: CEA 2009.

Cool gadgets

These items don't fit easily into any of the earlier sections of this report but are too good to leave out!

Invisibility cloak

German scientists at the Karlsruhe Institute of Technology have created a three-dimensional "invisibility cloak" that can hide objects by bending light waves. Cloaking makes an object disappear by steering electromagnetic waves around it, using a class of materials called metamaterials that guide and control light. The cloak was used to conceal a small bump on a gold surface — a bit like hiding a small object underneath a carpet and then making both the bump and the carpet invisible. Although the technique has been shown to be effective, it will be many years before something as big as a person could be made to disappear (TVNZ 2010).

Babel fish

Followers of *Hitchhiker's Guide to the Galaxy* will be familiar with the Babel fish that used brainwave energy, unconscious mental frequencies and a "telepathic matrix" to achieve real-time language interpretation. Now soldiers in Iraq have a laptop loaded with speech recognition and translation software that translates Arabic into English as soon as a person has finished talking; it is called IraqComm. These programs aren't ready to cope with free-flowing language just yet — the IraqComm works well because it focuses on around 50,000 words soldiers need. But it will happen one day (New Scientist 2009).

Bucky balls

Molecules composed entirely of carbon were first discovered by researchers in 1985 and named "buckminsterfullerenes" in homage to Richard Buckminster Fuller, the architect responsible for developing geodesic domes, which the molecules resembled. Spherical fullerene molecules are known as "buckyballs" and may have technological applications in electronics and nanotechnology.

Buckyballs can be joined to create highly stable "buckywires" which can be grown on an industrial scale. Buckywires have potential uses in technology fields such as photovoltaics. Researchers believe that due to the large surface area of buckywires and the manner by which they conduct electrons, they could be extremely efficient at harvesting power from light sources, like the sun. Other applications include wiring for molecular circuit boards, and a cheaper, metal-free alternative to the carbon nanotubes sometimes used for delivering drugs into the human body (CEA 2009).

Holographic storage

The concept of storing data in three dimensions has been around for nearly 50 years. Recent developments in holographic storage mean that formats based on this idea are closer than we think. In early 2009 GE Global Research announced that it had developed a holographic storage material capable of storing 500GB of data on a DVD-sized optical disc. Discs of this size could be used to store 3D video. The technology is still a few years away from being commercialised (CEA 2009).

Solar tents

Camping and consumer electronics are no longer mutually exclusive thanks to the solar tent. Panels of the tent are made from a fabric that has solar threads woven through it and the pitched tent, angled towards the sun, gathers solar energy during the daytime and stores it for whenever it is required, e.g., to power a laptop or charge a mobile phone. It is even possible to text the tent causing it to glow so that it's easier to find (CEA 2009).

Self-charging cell phones

Nokia is working on a prototype cell phone that draws power from ambient radio waves that surround us to charge a wireless device. It works like a higher-powered version of an RFID tag by turning electromagnetic waves into electrical current. Nokia expect to have the product in the marketplace within 3–4 years (CEA 2009).

Solar-powered laptop

For some time, solar-powered laptops have been a dream but the challenge is to capture and store enough rays to meet the power needs of an operating laptop. Serbian designer Nicola Knezevic believes he can overcome these limitations by designing a laptop with an extra solar cell-covered lid to gather more power. The hinged lid adds only a few tenths of an inch to the thickness of the laptop which means that the device opens up like a bi-folded piece of paper that can be angled towards the sun. although the design is elegant it is still not yet able to completely power a laptop. If the chip industry continues to develop more efficient processors requiring less cooling and, therefore, power, it could be a contender for the first all-solar laptop (CEA 2009).

Ethics and perception

Jobs of the future

In 2020 Wellingtonians might commute to work in titanium flying cars, be greeted by a robot receptionist, travelate to their 3D virtual, interactive desks where their coffee of choice is waiting for them, sit down and have the morning's to-do list scanned onto their retinas — but they probably won't!

Just as many (in fact, the majority) of the techno-wonders that 21st century man was promised by sci-fi dreamers of the past are yet to materialise, we are still waiting for the paperless office and the workplace of the foreseeable future is not likely to change a great deal.

That said, futurists, trade unionists and human resource specialists are anticipating significant changes to many job titles and job descriptions in 10 years' time. Technology pressure is changing almost every industry, creating new business structures, procedures and business models.

New opportunities for 2020

Environmental

Green jobs are arriving in two breeds: some focused on reducing human environmental impact, others to "greenwash" their organisation's image.

A Traceability Manager will examine global supply chains and check for suppliers that might be excessively polluting or carbon costly to buy from.

A Cloud Controller could buy the planet time in the fight against climate change, by increasing the ability of clouds to reflect solar radiation.

Renewable energy

Expect huge growth in alternative fuels, although the sector may need to accommodate an influx of workers from the disappearing oil and gas industries.

A hydrogen fuel station manager will be responsible for producing fuel on site, requiring science as well as retail skills.

A uranium recycler converts bomb-grade uranium from warheads into low-enriched uranium for use in nuclear power plants.

Advanced manufacturing

A mechatronical engineer combines mechanical engineering, electronics, controls engineering and computers into the product design process.

A metal skin consultant manufactures self-healing composite materials for use on aircraft, ships, and spacecraft.

Augmented reality

Researchers and engineers are pulling graphics out of your television screen or computer display and integrating them into real-world environments. This new technology, called **augmented reality**, blurs the line between what's real and what's computer-generated by enhancing what we see, hear, feel and smell. In just a few years' time, video visor extensions to your Bluetooth earpiece will give you a full 3D overlay of your location. It will merge everything you can find on the web and all you can do on a computer game with everything you can do in the real world (*see* p.?).

A digital architect designs a range of virtual buildings for advertisers to market their products and services.

An avatar design-security consultant designs, creates and protects the virtual you.

Robots and artificial intelligence

Artificial intelligence will eliminate and transform many jobs by 2020. With the advent of systems that can predict the possibility of a patient getting cancer and robots to take over high-precision, high-value surgery, surgeons may struggle to find work.

Domestic assistants (robots) will work 24/7, but will need the occasional tune-up by a personal bot mechanic.

A powered exoskeleton engineer will design wearable robots that assist and protect soldiers, construction and rescue workers or other people working in dangerous environments.

Business

A simplicity consultant simplifies and streamlines processes, technologies and branding in an organisation.

A locapreneur will start up a local bank, make local cosmetics or soft drinks that are able to compete head-to-head with the big corporations that no one trusts any more.

Nanotechnology and biotechnology

This could be the decade we witness an explosion of technological advances in nanotechnology, biotechnology, information technology and cognitive science, collectively known as NBIC. As these fields expand and converge, opportunities will arise to reprogram our bodies' "software", extending life, reducing deaths and alleviating poverty.

A bioinformationist is a scientist who marries genetic information with drug development and clinical techniques.

A geomicrobiologist pieces together bits of geology, environmental science and microbiology to find out how micro-organisms might help make new medicine or clean up pollution.

Social services

Our ageing populations are already generating booms in home healthcare and nursing homes. Most of the growth in jobs will be at the sharp end of social services — nurses and carers — rather than in administration roles.

An experimental therapist will connect patients with new and emerging treatments and navigate them through the maze of outpatient services.

A home companion-caretaker will enable people to stay in their homes and live with dignity.

Education

This is one of the most future-proof sectors, with schools, universities and private providers expanding to keep pace with the accelerating need to train and retrain.

Online education brokers will be needed to tailor bespoke learning packages for people, dovetailing relevant modules from courses and syllabuses around the world.

Food

The demand for organic, healthy, locally sourced food will continue to increase. Sustainable agriculture involves small-scale methods as opposed to big machines and fertilisers, so the world will need more agricultural workers — up to tens of millions of them, according to journalist and food guru Michael Pollan.

The farmer of 2020 will be an agricultural entrepreneur as skilled in genetics as in marketing.

A personal food shopper will help clients hit their recommended daily allowance targets for nutritional balance, food miles and organic sourcing.

Careers at risk

Today, people often do the work of a smart machine. With advances in IT that will no longer be necessary, so jobs that rely purely on intellect and knowledge will be valued less than jobs that require human interaction. As Pearson points out, interpersonal skills tend to increase with age, allowing older people to do useful work thereby alleviating the pensions problem. In an earlier paper *The Future of Women*, Pearson observes that this is widely expected among futurists to be the woman's century. Many futurists draw this conclusion from a social trends base, but Pearson points out that a number of technology and economic trends are also in women's favour. Men will find that many of their traditional jobs are substituted by machines, women will have a much easier ride. Pearson talks about a new "care economy" dominated by interpersonal contact, so, for example, the hospital consultant can be replaced by a robot, but nurses can't.

Also at risk:

- Soldiers can be replaced by robots.
- With 3D printing techniques, in which solid objects can be constructed automatically from computer models, buildings could be erected in a matter of hours, thereby calling into question the role of the construction worker.
- Online shopping continues to grow, and existing stores are installing self-service scanners and robotic shelf stackers, which suggests that fewer shop assistants will be required in the future.
- Dwindling union membership calls into question the need for union organisers, unless they adapt to the needs of workers in the knowledge, science and technology sectors.

Life, death, and taxes

Some jobs will evolve in terms of, for example, service delivery techniques, but will remain fundamentally the same. As there is nothing as certain as life, death, and taxes (even with some of the medical advances outlined earlier!), society will always find room for undertakers, prostitutes, tax collectors, and religious leaders.

Likewise, we will always need to be governed and led (even though we might like to think otherwise), so politicians will continue to be required, subject as always to the fluctuating moods of the people they serve.

Much of the knowledge side of the law can be automated (e.g., will writing, conveyancing, and simple legal advice) but there will always be a need for lawyers with persuasive people skills to sway judges and juries, particularly in the growing areas of patent and intellectual property law. Furthermore, technology pressure is pushing ethical boundaries and creating a strong demand for legislation across a wide field. There will also be new kinds of crime, as computers get more sophisticated and increasingly networked.

Art will continue to change and evolve with technology, meaning that artists and entertainers will always find a niche.

Sources: Pearson 2008b; Pearson 2009; Wylie 2010.

Glossary

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