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The rise and rise of computer animation

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Breaking the sound barrier—again

Transport: A new breed of supersonic business jets, without Concorde's drawbacks, could soon be taking to the skies

IMAGINE being able to cross the Atlantic in less than three and a half hours. You could fly from London to New York for a meeting and still be home in time for dinner. It used to be possible, before the demise of Concorde, of course. But while Concorde has passed into history, the dream of supersonic travel is alive and well. Several firms are now racing to develop a new breed of supersonic passenger aircraft. These planes will use new technology to ensure that they are quieter, more efficient and capable of turning a profit—something Concorde struggled to do throughout its 27-year lifespan. The new aircraft will differ in another way, too. To start with, at least, they will probably not be airliners, but much smaller business jets.

That is because business-jet users are most likely to value time over money, says Preston Henne of Gulfstream Aerospace, a big business-jet manufacturer based in Savannah, Georgia. Supersonic business jets make sense from an engineering and financial point of view, too. "Historically, if you go back and look at how today's aeroplane systems evolved, it started with smaller aircraft and affluent customers," says Mr Henne. Concorde was an exception to this rule, which may explain why it failed.

That said, those rushing to build supersonic business jets fall into two camps, taking two very different approaches. Those in the first camp, which includes Gulfstream, are aiming to overcome what was arguably Concorde's biggest drawback: the sonic boom it created during supersonic flight. The resulting noise pollution ultimately led to international regulations banning commercial aircraft from flying supersonic over land. This in turn severely restricted the flight paths Concorde could follow, since it was so inefficient at subsonic speeds that routes had to be designed to minimise the distance flown over land. Gulfstream plans to tackle this problem head on, by getting rid of the sonic boom. It sounds ambitious, but 40 years of research suggests that it should in fact be possible.

According to a theory developed by two researchers at Cornell University, Richard Seebass and Albert George, the sonic boom can be minimised by altering the shape of the plane to redistribute the shockwaves that cause it. Sonic booms actually consist of two parts, each caused by a shockwave—one at the front of the aircraft and the other at the tail. The shockwaves arise when the plane is travelling faster than the sound waves it is producing. Unable to dissipate, these sound waves build up instead and form a shockwave. Dr Seebass's theory suggested that shaping the fuselage appropriately could reduce the boom by

causing the sound waves to spread out, or better still by causing them to interfere with each other, so that some sound waves cancel others out.

But it was only in 2003 that these theories were finally shown to be correct. The complex shapes required to reduce the boom proved to be very difficult to design by hand. Eventually engineers at America's space agency, NASA, used a supercomputer to simulate the airflow around an F-5 fighter jet and determined how to alter its shape to reduce the sonic boom. In flight tests, the modified F-5—often likened to a "pregnant pelican"—proved that it was indeed possible to reduce the first part of the sonic boom by 25%. Mr Henne believes that Gulfstream can reduce the second part of the boom too, and so drastically reduce the "sonic signature" of a supersonic plane passing overhead. Supersonic flight over land might then become a possibility.

Of course, it is not quite that simple. It will be necessary to persuade regulators—the Federal Aviation Administration and the International Civil Aviation Organisation (ICAO)—to reconsider the current ban. Furthermore, to make the new aircraft commercially viable, there would also have to be changes in the way that supersonic aircraft are handled when coming in to land at airports. There is little point in having a supersonic aircraft if it gets put into a holding pattern for an hour when it arrives at its destination. These are ambitious goals which might seem foolhardy if Gulfstream were the only firm pushing for them, but it is not alone. Also looking for reform is an alliance of ten large aeronautical firms—including Lockheed Martin, Boeing Phantom Works, Raytheon and Rolls-Royce—collectively known as the Supersonic Cruise Industry Alliance (SCIA). This group is working with NASA to build a prototype supersonic aircraft.

But with NASA and SCIA having only just begun their partnership earlier this year, such an aircraft still seems a long way off. Developing the technology will take time, as will lobbying to get the regulations changed. For companies such as Gulfstream or SAI (which is taking a similar approach, in conjunction with Lockheed Martin), there is a danger that other firms could take to the skies first.

That is because those in the second camp are taking a different approach, designing aircraft that fly at supersonic speeds over sea and subsonic speeds over land, but far more efficiently than Concorde once did. Leading the pack is Aerion, based in Reno, Nevada. It hopes to have its supersonic business jets airborne by 2010 or 2011, by which time SCIA is unlikely even to have made a dent in the ICAO regulations.

Aerion's approach is based on the massive improvements in engine and airframe design since Concorde, says Richard Tracy, the company's chief technology officer. Its aircraft will be powered by two Pratt & Whitney engines, normally found on far larger aircraft, that can be reconfigured to optimise their performance for both subsonic and supersonic flight. The aircraft will meet airport noise requirements—Concorde used to make a huge amount of noise on take-off and landing—and will also produce a smaller sonic boom than would normally be expected for a plane of its size. That is an unexpected benefit of putting the engines close to the fuselage and above the wings, explains Mr Tracy, which means that most of the sonic boom is directed upwards, not down.

So, which camp is right? Perhaps both. Mr Henne admits that the first camp could lose out to rivals that are not dependent on changes to the current rules. But he is adamant that deregulating supersonic flight is the way to go. According to a survey carried out by Gulfstream, only a quarter of all journeys by business jets are over water. This, says Mr Henne, severely limits Aerion's market. Aerion does not dispute that figure, but argues that the 25% of flights that are over water are still a significant market. Indeed, notes Mr Tracy, the market is big enough that Gulfstream has developed long-range subsonic aircraft to service it, so there should be room for supersonics too.

Nor is Aerion alone in this belief. Earlier this year an agreement was signed between the Society of Japanese Aerospace Companies (SJAC) and France's Aerospace Industries Association to develop technologies jointly that could be used to produce supersonic airliners. Like Aerion, this partnership is concentrating on adapting existing technology to produce a supersonic aircraft that can fly subsonic over land, in accordance with existing regulations. The aim is to have an airliner capable of carrying 300 passengers 6,000 nautical miles, equivalent to the distance from Tokyo to New York.

It is still early days for this joint-venture, but it seems to mean business. In October, researchers at Japan's space agency, JAXA, carried out flight tests of a prototype airframe in Woomera, Australia. It achieved speeds in excess of Mach 2.5, or two and a half times the speed of sound. That said, Akira Yanagida, general manager of engineering at SJAC, says that at speeds above Mach 1.6 the economics simply do not work. As a result, none of the runners in the new supersonic race aims to fly faster than Concorde, which used to cruise at Mach 2. Whoever wins the race, this much seems clear: supersonic aircraft are about to stage some sort of a comeback. And this time they will be here to stay. ■

Walk this way

Transport: New moving walkways have been given a speed boost. But will pedestrians in airports and shopping centres be able to cope?

ALONG with vast space cruisers and laser weapons, they are a science-fiction staple described by authors including Robert Heinlein and Isaac Asimov: sleek conveyor belts that whisk passengers around futuristic cities at breakneck speeds. Yet the moving walkways that criss-cross many of today's airports and shopping centres travel at a sober 3kph, which is slower than most people walk. The idea of "travelators" is to accelerate foot traffic by boosting your walking speed, but many users regard moving walkways as an excuse to stop walking altogether. So why not increase the speed of the walkways, as the sci-fi authors suggest?

Engineering firms have tried for decades to realise the high-speed dream, but without much success. Recent history is littered with abandoned attempts by companies such as Fujitec, Boeing and Mitsubishi Heavy Industries. Moving walkways grew out of the mining and bulk transport industries, and the first high-speed version debuted in 1900 at the Exposition Universelle in Paris. But the sloping charms of the equally novel escalator proved more attractive to the flourishing department-store business, and the high-speed moving walkway

went into limbo.

So the launch in 2002 of the Trottoir Roulant Rapide in Paris marked a belated revival for the technology. Also called the Gateway, this 185-metre conveyor moves 110,000 people a day through Montparnasse station at about 5kph, or twice the usual speed. Yet it also marks something of a retreat. The original speeds of 9-12kph proved too fast, and a series of injuries led to the brief closure of the walkway soon after it opened. Three years on, orders for more Gateways remain elusive, though CNIM, the French engineering firm behind the project, says it is negotiating with some potential customers.

Most recent high-speed systems work on the same basic principle: riders step on to a short section of track that slowly accelerates, and then deposits riders on to the high-speed stretch. (Getting part of the track to accelerate can be done in two ways: either by using a series of belts rolling at gradually increasing speeds, or by varying the distance between overlapping sections of track, which allows different parts of a single walkway to move at different speeds.) At the end of the journey, a decelerating section reverses the process. Flashing lights, recorded messages and contrasting colours mark the transition zones.

The need for a new kind of high-speed people mover seems obvious enough in theory. As airports and shopping malls grow ever larger, so too does the time taken to walk from one end to the other. Fast walkways are cheaper and smaller than monorails, and anything that shaves even a few minutes off a dreary commute is bound to find favour with the public. In practice, however, high-speed walkways must grapple with stiletto heels and litigious pedestrians. Another problem is cost: Mitsubishi estimated that its Speedwalk system would cost up to 50% more than a conventional walkway.

But still the engineers keep trying. The latest entry in the field is the TurboTrack, which runs at 7kph and was recently unveiled by ThyssenKrupp, a German industrial conglomerate. Rembert Horstmann, a company spokesman, insists the market is ripe: today's worldwide total of 260,000 moving walkways and escalators is growing by about 22,000 per year, he says, with 15,000 of those in Asia. Walkways and escalators now transport millions of people every year with very few injuries, he notes. ThyssenKrupp regards the new airports being built across the Middle East as a promising market.

Besides, the aversion to risk has arguably gone too far. John Loder, an Australian urban-planning expert, reckons that if conventional escalators were invented today, regulators would not allow them. The high-speed Loderway system he designed in the early 1990s encapsulates the bumpy history of rapid walkways. It enjoyed successful trials at two Australian airports and a two-year run in Melbourne's central railway station, all without incident. But an unlucky confluence of misfortunes, including the Asian economic crisis, caused investors to abandon the project.

Despite the setbacks, Mr Loder is still optimistic about the technology's long-term prospects. People will gradually adapt to faster walkways, he believes. After all, even escalators were initially regarded as terrifying: when Harrods, a London department store, introduced its first escalator in 1898, smelling salts and brandy were provided to revive customers overcome by the experience. But now nobody thinks twice about stepping on to an escalator. So perhaps it is too soon to dismiss the dream of rapid walkways as science fiction. ■

Odd bedfellows, striking results

Health care: Video games, often denounced for their supposed ill effects, actually have a surprising range of therapeutic uses

MICHAEL KELLEHER was turning right in his car on a country road near Rylane, Ireland, five years ago when another car rammed him from behind, thrusting him forward and pushing his foot on to the accelerator pedal. Mr Kelleher's car shot across the road and crumpled into a wall. His wife, the only other person in the vehicle, suffered a chipped vertebra, which has since healed. Mr Kelleher's neck and back pain soon disappeared. What didn't go away was his fear of cars, especially those tailing him. "It was almost to the stage of panic," he says. He took to pulling over when cars appeared in his rear-view mirror. Ridicule from his children didn't help.

But then last year, a trauma psychiatrist from St Stephen's Hospital in Cork put Mr Kelleher back behind the wheel—not in a real car, but in a video game called "London Racer". He was coached through a dozen sessions of "graduated exposure" to virtual traffic. "It gave me confidence," says Mr Kelleher, who now happily drives in motorway fast lanes.

Other examples abound of the therapeutic uses of video games. To regain movement in partially paralysed limbs, for example, stroke victims must spend long hours making repetitive movements. "You get bored," says Dr Sung You of Hampton University in Virginia. He bought two "immersive" video games, "Snowboarding" and "Sharkbait", that use a small camera to incorporate the player's image into the game. During physical therapy, stroke victims twist and

turn as they tear up the slopes or avoid sharks. "It's just fun," says Dr You, who found that the greater motivation and focus of gamers meant they recovered more co-ordination than patients in a control group. He reported his results in May in *Stroke*, a journal published by the American Heart Association.

Eric Styffe, a 22-year-old carpenter who lives in Thalwil, Switzerland, used to suffer from severe attention-deficit disorder (ADD). But then a therapist taught him how to play "neurofeedback" video games designed to sharpen concentration in ADD patients and autistics. With electrodes fixed to his skull, Mr Styffe fixed his mind on game characters, such as a juggler or a Pac-Man-like blob fleeing ghosts in a maze. When his mind wandered, the virtual characters dropped dead. "It felt weird," says Mr Styffe. But after just two weeks of daily game therapy, he stopped taking Ritalin, a prescription amphetamine. Mr Styffe, who now plays once a month to avoid relapse, says the results are "amazing".

The American military, which has used video games to train soldiers for some time, is now investigating their therapeutic uses as well. This year the Office of Naval Research, which co-ordinates scientific research for both the Navy and the Marine Corps, allocated $4m among three groups to study video therapies. One of the groups, the Institute for Creative Technologies at the University of Southern California, modified the game "Full Spectrum Warrior" to treat veterans of the Iraq war suffering from post-traumatic stress disorder. Patients, coached by a therapist, recreate disturbing combat situations but have the power to change the outcome by, say, making enemy bombs explode farther away. "Habituation leads to dissipation," explains Albert Rizzo, the project's leader.

Similarly, an Israeli team at the University of Haifa recently built a disturbingly realistic virtual world of suicide bus-bombings to treat attack survivors. Patients, who wear a head-mounted display, control virtual blasts that incorporate amateur video of real explosions. "The old therapies don't work very well," says Tamar Weiss, the team's leader.

Phobias may represent the biggest market for video-game and virtual-reality therapy, and clinics are popping up worldwide. Many are writing their own software from scratch. For example, the recently opened Tokyo Cyber Clinic is developing, with help from Waseda University, a virtual Tokyo subway (overcrowded for realism) to treat people who panic when surrounded or touched by others. But most clinics buy games off the shelf—sometimes from firms whose main business is making entertainment games. IREX, a Toronto-based developer of more than 100 video games, has modified a quarter of them for use in health care. (Tweaking games typically entails deleting some competitive elements and adding commands to let patients control exposure to whatever provokes anxiety.)

Some firms design games and virtual environments specifically for health-care applications. Virtually Better, based in Atlanta, Georgia, is arguably the world leader in therapeutic software, with a range of virtual environments (viewed using head-mounted displays) to treat problems as diverse as crack addiction, fear of storms and eating disorders. Poder Volar, a clinic in Buenos Aires, uses a Virtually Better environment called Virtual Airplane to help patients overcome fear of flying, by letting them gradually get used to the process in the safety of an office. "I was paralysed at the mere thought of flying," says Maureen Scanlan, the owner of a private school who recently completed a course of treatment at Poder Volar. Now she flies regularly.

Therapeutic video games developed at public research centres are sometimes made available for free downloading. The psychology department at the Université de Québec en Outaouais, for example, offers free downloads that modify the popular video games "Max Payne", "Unreal Tournament" and "Half-Life", turning them into treatments for phobias including arachnophobia, claustrophobia and fear of heights. (Clinics must first buy the game in question, then modify it by installing the free software.)

Ben Sawyer, organiser of the second annual Games for Health Conference, which took place in Baltimore in September, says the sector is growing dramatically, with especially rapid adoption of "pain-distraction" and "anxiety-reducing" games at hospitals. Dr Anuradha Patel, an anaesthesiologist at the New Jersey Medical School who offers children games before surgery, says the playtime is more effective at calming them down than reassurances from their parents. Dr Patel says that by diminishing pre-surgery anxiety, video games lower adrenaline levels and blood pressure before anaesthesia, easing the shock of waking and possibly speeding recovery. Similarly, video games have been used since the 1980s to provide "cognitive distraction" for children receiving chemotherapy. In a review article published in July, the *British Medical Journal* noted that a series of studies found that distracted patients suffered less from nausea and required fewer painkillers.

Critics denounce video games for promoting violence and destruction, despite the lack of solid evidence to support such claims. The evidence for gaming's curative and therapeutic benefits, by contrast, is rather more convincing. ■

A sight for sore thumbs?

Communications: Researchers are dreaming up some surprising new ways to enter text into mobile devices more quickly

PEOPLE who send text messages fall into two camps: the 50% or so who, according to surveys, like to have the "predictive" text-entry function on their handset switched on, and the other 50% who prefer the "multi-tap" method of tapping out one letter at a time. The problem with predictive text is that it often guesses the wrong word: invite a friend out for a "pint" (7468 on most keypads), and your phone may suggest "shot" and "riot" before guessing the correct word. The problem with multi-tap is all that tiresome clicking, which is why people often use abbreviations in their txt msgs. Neither method is anywhere near as fast as a conventional keyboard; and a mini-keyboard squeezed on to a small device (such as the BlackBerry and its imitators) is too fiddly for some users. So the search continues for a way to enter text into mobile devices with the speed of a full-sized keyboard, but without its bulk.

Ken Perlin of New York University's Centre for Advanced Technology began working on the problem in 1997. The result was Quikwriting, a stylus-based system that allows the user to enter text without ever lifting the stylus off the screen. Imagine a drawing of a flower, with eight petals around a stamen, on a touch-sensitive screen. Each petal contains up to eight letters, numbers and punctuation marks. Picking a character involves moving the stylus from the stamen into a petal, and then back to the stamen (in some cases via another petal). Each word forms a squiggle, and users soon learn the shapes of common words, ▸▸

as with shorthand.

To start with, Quikwriting attracted a small but devoted following among users of Palm handheld computers. But it has since been licensed by Microsoft, which is developing it (under the name XNav) for use in a range of devices, including mobile phones, television remote controls and its Xbox games consoles. It has done away with the stylus and built several prototypes based on a flower-shaped array of buttons. By running your thumb over the buttons in sequence, you can write text messages or e-mails with one hand.

IBM has also developed a squiggle-writing interface, called ShapeWriter, for use on tablet PCs. It relies on a specially developed on-screen keyboard, in which the letters are laid out in a hexagonal grid. As with Quikwriting, the user drags a stylus over the keyboard to pick out letters. Lifting the stylus indicates the end of a word. Each word has a distinctive squiggle shape (or "sokgraph", as Shumin Zhai, the developer of the system, calls them), which is identified by pattern-recognition software. As a result, ShapeWriter is very tolerant of straying styluses. In tests, users were able to reach speeds of 80 words per minute. ShapeWriter can be downloaded free from IBM's website (www.alphaworks.ibm.com/tech/sharktext), and Dr Zhai says he is now working on a smaller version of the software for use on handheld devices.

While these approaches move away from the old-fashioned "Qwerty" keyboard (which has been around since 1868), Howard Gutowitz of Eatoni Ergonomics is moving towards it. He says there is comfort in the familiar. "Quikwriting is elegant from a conceptual point of view, but I don't think it's mass market," he says. "If you want something mass market, it's got to be really simple to use." To this end, Eatoni has created the EQ3 (Eatoni Qwerty 3-column) keypad for mobile phones. While most handsets assign several letters to each number key in an ABC, DEF pattern, EQ3 assigns the letters in a way that looks similar to a Qwerty keyboard, but with a few letters moved around to avoid "collisions"—such as the confusion between "pint" and "riot". Collisions occur, on average, once every 27 words when using T9, the most widely used predictive-text system. Using EQ3, collisions occur, on average, once every 85 words.

For BlackBerry-type devices, which have a larger number of keys, Eatoni has developed EQ6 (Eatoni Qwerty 6-column). In this scheme, the Qwerty-like arrangement is spread over six columns, so that fewer letters are assigned to each key, further reducing collisions to an average rate of once every 1,800 words. The BlackBerry has ten keys in each row; reducing the number of keys in each row to six, notes Mr Gutowitz, means you can make the keys bigger, or the device smaller. Unfortunately for Eatoni, Research in Motion (RIM), the firm behind the BlackBerry, has developed a similar scheme, which appears on its 7100 series of smartphones. Eatoni has launched a patent-infringement lawsuit against RIM as a result. Evidently the fate of these new text-entry methods depends on more than just ease of use. ■

Breaking up is hard to do

Environment: The low-tech graveyards where ships are picked apart by hand could give way to a greener, more high-tech alternative

PLACES such as Chittagong and Alang have become synonymous with the ship-breaking industry. On beaches in India, Pakistan and Bangladesh, low-wage workers, often young and equipped with little more than crowbars and flashlights, dismantle hundreds of ships every year. Many die from explosions and falls, not to mention long-term disease from exposure to toxic substances. The trade also does grave environmental damage. Hazardous materials such as asbestos, arsenic, mercury and PCBs end up buried in the sand, burned in the open or dumped at sea. Yet the ships also contain tonnes of valuable steel, which is why governments are keen to keep the business alive, despite growing concern.

But now Ecodock, a company based in the Netherlands, wants to bring some ship-breaking back to European shores, where it was widespread until the 1970s, when environmental regulations and rising wages sent it abroad. Ecodock's aim is to build a global network of 30-40 "green" ship-breaking facilities that can safely dispose of the 700-odd large ships decommissioned every year—90% of them in South Asia, China and Turkey.

Using sophisticated cranes, workers would first remove the toxic substances and then take the ships apart, all the while scouring for recyclable parts. Doebren Mulder, Ecodock's founder, says the firm has secured funding for its first facility in Eemshaven, in the Netherlands. The 320-metre dry-dock, big enough to accommodate the largest vessels and even disused drilling platforms, is due to open in early 2007. Ecodock claims that its high-tech system can break down a ship in just over three weeks, as opposed to three months in China or six to eight months in Bangladesh, India or Pakistan.

The venture has regulatory wind in its sails. The European Commission and International Maritime Organisation have ruled that single-hulled tankers must be taken out of service by 2010—the original deadline of 2015 was brought forward after the *Prestige* oil spill in 2002—which means that at least 1,400 tankers will need to be broken up. The regulations also stipulate that the ships must be dismantled in an environmentally responsible way, which bodes well for Ecodock.

The new approach should also appeal to the shipping industry, for a number of reasons. For a start, it could mean good rather than bad publicity. With today's high fuel costs, sending empty ships

On the graveyard shift

across the world for dismantling is needlessly expensive, especially if it can be done closer to home. Building the new facilities will create jobs and mollify politicians in the wake of the *Prestige* and *Erika* oil-spills, and the debacle of the *Tricolor*, which sank in the North Sea in 2002 with 2,862 cars on board, and was subsequently struck by two other vessels.

Furthermore, the shippers will be able to make money from the recycled parts. Typically 95% of a ship's structure is reusable, most of it valuable steel. Brass, cables, refrigerators and plumbing fixtures can also be reused. In contrast to the current business model, where the ship-breakers buy the vessels from the owners outright and then sell the salvaged bits themselves, Ecodock is offering to split the proceeds with shipowners.

Some obstacles remain. The countries where ship-breaking now takes place sorely need that income and steel it generates, and can largely ignore nettlesome safety regulations. And the shipping firms want to keep their fleets in service for as long as possible, which could have a curious side-effect: as the decommissioning deadline approaches, companies will rush to dispose of their tankers at the last moment, overburdening whatever green facilities then exist, and leaving no alternative but to keep sending ships to the graveyard beaches of Asia. ■

Market, market, on the wall

Technology trends: If prediction markets are so good at making forecasts, why not use them to identify emerging technologies?

THE technology industry loves a prediction, and keeps legions of forecasters and futurists in business. But many predictions are wrong, technologies often arrive late, and very few live up to the hype. Why, then, are technology firms not keen users of internal prediction markets? These harness the collective brainpower of employees by giving them virtual trading accounts and virtual money, and letting them buy and sell "shares" in such things as project schedules or next quarter's sales. What are, in effect, elaborate computer games might help tech firms spot trends and make more accurate forecasts. Yet, oddly, hardly anyone is using them in this way.

Hewlett-Packard and Intel pioneered the corporate use of prediction markets, but neither seems to be using them other

than experimentally. Todd Proebsting of Microsoft says the software giant has run a dozen or so such markets, and that they quickly and cheaply capture employee sentiment on project deadlines or software quality more accurately than any other measure. Google recently said it is also using internal prediction markets. But such markets are typically used to predict internal matters, rather than to divine broader technology trends—which is, some argue, a missed opportunity. "At the moment, it's a fad that companies are trying out," grumbles Robin Hanson, an economist at George Mason University who popularised the concept of corporate prediction markets and believes they could be a powerful tool.

But can prediction markets really spot broader industry trends? There have been some attempts to find out. Perhaps the oldest technology-oriented public prediction market is the Foresight Exchange (www.ideosphere.com), which launched in 1994. Ken Kittlitz, one of its co-founders, says it has an accuracy rate of about 70% on technology questions. Among its best calls: it said a computer would beat Garry Kasparov at chess two years before it happened. But it was too bullish on demand for videophones.

Another prediction market, operated by NewsFutures, ran for a while on the website of *Technology Review*. Most of its predictions, says Emile Servan-Schreiber, NewsFutures' boss, concerned financial matters. But the market did make a few accurate predictions about technology trends: it concluded that products based on ultrawideband technology would not be commercially available by July 2004, and correctly forecast the take-up rate for internet telephony.

Even so, says Justin Wolfers, an economist at the Wharton School at the University of Pennsylvania, it is still unclear whether prediction markets really can spot tech trends. That is why he is among those closely watching the latest experiment, being carried out by Yahoo!, a big internet portal and search engine, in conjunction with O'Reilly & Associates, a publisher of technical books and organiser of technology conferences.

In March, the two firms launched the Tech Buzz Game, "a fantasy prediction market for high-tech products, concepts and trends". Users buy shares in technologies they think will do well; the share price of a technology depends on the frequency with which Yahoo! users perform web searches for it. Yahoo! hopes to use the answers to predict search trends that will be popular in future, so that it can sell advertising against them. O'Reilly wants an inside track on hot topics for future books and conferences. In the spring, the market identified "Ruby on Rails", a programming environment, and Flickr, a photo-sharing site, as hot picks. But the game has not yet been around long enough to assess its track record for longer-term prediction, says David Pennock, a senior researcher at Yahoo!

The most important thing about the Tech Buzz Game, says Mr Wolfers, may be that people are actually playing it, because it is so well designed. Encouraging employees to use prediction markets has always been a challenge. Mr Proebsting says he believes it is just a matter of time before Microsoft starts using predictive markets to predict external as well as internal events. Perhaps he could use the technology to estimate when. ■

Fingerprints for car parts

Security: People have fingerprints, but objects do not—unless you spray them on in the form of thousands of tiny microdots, that is

WHILE "smart dust" remains a technological fantasy, a distant cousin is already being used to protect valuable items around the world. The "microdots" produced by DataDot Technology, an Australian firm, are tiny polyester particles, just one millimetre wide, that can be sprayed on to valuable items such as car parts. Under ultraviolet light and a magnifying glass, any one of these thousands of dots can reveal the host vehicle's unique identity number. Of course, a car thief could try to scrape off the microdots, but their sheer number makes that impractical; a single dot is enough to identify a stolen component. Warning stickers enhance the dots' deterrent effect.

And it seems to be working: according to a study published by Australia's National Motor Vehicle Theft Reduction

Council in 2004, thefts of BMWs are down more than 60% since the carmaker began using microdots in 2001; thefts of Subaru vehicles fell by more than 90%. Ford, Porsche, Audi and Lotus are also using the technique in Australia. And the idea is spreading. Mitsubishi and Volkswagen have been experimenting with the dots in Britain and Taiwan respectively, and Nissan uses them in America on some of its most expensive headlights. Microdots can also safeguard laptops, boats, farming equipment—almost anything, in fact. In 2004, police in Florida caught a corrupt parking-meter official using planted microdotted coins.

Though the idea of microdotting dates from the 1940s, it became economically viable only with the advent of laser etching in the 1990s. Las Vegas casinos were among the first to use the dots, in an effort to root out fake gambling chips. Australian investors then bought the rights, motivated in part by Australia's high rate of car crime. Even though steering-wheel locks, satellite tracking and immobilisers had helped to reduce car thefts, trade in stolen parts remained a problem. The use of microdots is changing that.

Creating the dots themselves is fairly straightforward. The hard part, says Ian Allen, DataDot's boss, has been convincing carmakers and insurance companies to adopt them. After all, the idea of spraying a car with dots sounds strange—but it is not as dotty as it seems. ■

The end is virtually nigh

Gaming: How the inhabitants of an online game are responding to their impending destruction and the end of their virtual world

THE end of the world is a favourite theme of storytellers and prophets, and with good reason: accounts of how a small band of intrepid adventurers tries to avert destruction, or sets out for a new and better world, make for exciting tales. But there will be no such stories for the inhabitants of Dereth, whose time will run out on December 30th. Dereth is the virtual world associated with "Asheron's Call 2", an online game. It has not attracted enough players for its publisher, Turbine Entertainment, to continue to support it. And so Dereth and all of its inhabitants will be destroyed.

"Asheron's Call 2" is an example of a "massively multiplayer online role-playing game" (MMORPG), a booming genre of games, many of which are set in Tolkeinesque virtual worlds. Players control individual characters which may or may not be human as they fight monsters, complete quests and acquire new equipment, money, skills and special powers. MMORPGs can attract hundreds of thousands of players—the current top dog, "World of Warcraft", has just passed 4m subscribers—and are particularly popular in Asia. Players pay an upfront fee for the basic game software, which they install on a PC, and then pay a monthly access fee, typically $12-15.

Devoted MMORPG fans spend dozens of hours a month building up their characters, and live what is, in effect, a parallel life in another world. (One MMORPG is even called "Second Life".) Part of the attraction is that such games are inherently social—as well as chatting with in-game friends, players can team up to accomplish particular missions or defeat powerful monsters. The resulting sense of community and social cohesion means that MMORPGs have loyal populations. The original "Asheron's Call" is still going, as are "EverQuest" and "Ultima Online", which launched in 1997. But "Asheron's Call 2" failed to achieve critical mass. Its population, once over 50,000, has now fallen below 15,000, making the game economically unviable.

The citizens of Dereth responded to news of their imminent demise in a number of ways. Many simply expressed their sorrow in postings on the game's online discussion board. "How do I tell my nine-year-old that he won't be able to run around Dereth anymore?" lamented one parent. Other players posted bilious attacks on Turbine's management team. "Last one out, please punch Jeff Anderson in the back of the head," wrote one, referring to Turbine's chief executive. "A big fat middle finger to the execs in charge of this decision," wrote another.

Some players took the "if we are all going to die, we might as well have some fun" position, and called upon the game's omnipotent overlords to grant them extra powers and abilities for the remainder of their virtual lives, and lower the prices of upgrade items. Turbine responded by making it easier to advance to higher levels. But some players complained that this was unfair on those who had worked so hard to build up their powers the hard way. "The game may be ending but you still don't deserve stuff handed to you on a silver platter," grumbled one.

There have been several cases, in other MMORPGs, where players have staged in-game protests to complain about unfair rules or policies. There have even been in-game riots. But there have been no such protests in Dereth. Edward Castronova, a gaming expert at Indiana University and the author of "Synthetic Worlds", a book about MMORPGs, says this is not surprising. "The only influence players have on the developer is to leave the game," he says. When thousands of players threaten to leave, developers take notice. But when the game is shutting down anyway, such protests are futile.

What of escaping to another world? Some inhabitants of "Asheron's Call 2" plan to do just that. "I have met so many people, many of whom will continue as life-long friends," wrote a player called Princess Death Song. She announced a plan to set up a website where she and her friends could decide which other MMORPG to move to, "so that we can continue that journey of friendship". But it would not be any MMORPG run by Turbine, she declared.

The company could have mounted the equivalent of an evacuation, by moving the population of "Asheron's Call 2" to another world. The original "Asheron's Call" game is still running on its servers, for example. It also has two new and potentially lucrative games under development, based on the "Dungeons and Dragons" and "Lord of the Rings" franchises. Offering the citizens of Dereth characters in these new worlds might have enabled Turbine to retain their goodwill. Instead, they may now decide to steer clear of the company and its new worlds. Whether Turbine's closure of "Asheron's Call 2" will hurt the prospects for its new games will not become apparent until they are launched next year, but it seems unlikely, since both are based on such strong brands.

Another option would have been to throw open the world to the open-source community and let the players run it themselves. Mr Castronova, for one, favoured this approach, but a Turbine spokesman has ruled it out. Instead, Dereth will simply vanish without trace. There will not even be a puff of smoke. ■

Darkness falls over Dereth

And the winners are...

Innovation Awards: Our annual prizes recognise successful innovators in seven categories. Here are this year's winners

THIS newspaper was established in 1843 to take part in "a severe contest between intelligence, which presses forward, and an unworthy, timid ignorance obstructing our progress". One of the chief ways in which intelligence presses forward is through innovation, which is now recognised as one of the most important contributors to economic growth. Innovation, in turn, depends on the creative individuals who dream up new ideas and turn them into reality.

The Economist recognises these talented people through our annual Innovation Awards, presented in seven fields: bioscience, computing and communications, energy and the environment, social and economic innovation, business-process innovation, consumer products, and a special "no boundaries" category. The awards were presented at a ceremony in London on November 14th by Bill Emmott, editor-in-chief of *The Economist*. And the winners were:

• Bioscience: **Herbert Boyer**, co-founder and director of Genentech, and **Stanley Cohen**, professor of genetics and medicine at the Stanford University School of Medicine, for developing **recombinant DNA** technology. This is the fundamental innovation that allows genetic material from two sources to be combined, making possible the use of bacteria as drug factories and the genetic engineering of plants and animals. The two men had the idea while eating pastrami and corned-beef sandwiches when attending a conference in Hawaii.

• Computing and communications: **Sergey Brin** and **Larry Page**, co-founders of Google for the commercialisation of **search technology**. Few companies become so integrated into everyday life that their names become verbs, and none has done so as quickly as Google, which combined a superior method of ranking search results with an advertising-based business model to pay the bills. The firm is widely seen as the new Microsoft—which is both an accolade and a warning.

• Energy and the environment: **Stanford Ovshinsky**, president and chief scientist and technologist, Energy Conversion Devices, for developing the **nickel-metal-hydride battery**. This is the battery technology found in hybrid cars, laptop computers and many other devices, and is just one of the many innovations devised by Mr Ovshinsky, a self-taught inventor who pioneered the field of amorphous materials in the 1950s. He is now focusing on solar panels and hydrogen-powered cars.

A Hale and healthy winner

• Social and economic innovation: **Victoria Hale**, chairman and chief executive, Institute for OneWorld Health, for her work promoting the development of **pharmaceuticals for the developing world**. In 2000, Dr Hale founded the non-profit pharmaceutical company to develop treatments for "orphan" diseases neglected by traditional drugmakers. OneWorld develops drugs based on donated or royalty-free intellectual property, and is in final-stage testing of a promising new therapy to cure visceral leishmaniasis in India.

• Business-process innovation: **Alpheus Bingham**, chairman, InnoCentive, for his work developing a **web-based problem-solving community**. InnoCentive is an online forum that brings "solution seekers", who post descriptions of technical problems they need to solve, together with "problem solvers" who try to solve them in order to win an associated bounty. Around $1.6m in potential rewards are currently listed on the innocentive.com website, which is used by over 80,000 researchers.

• Consumer product: **the iPod team** at Apple for the development of the **iPod** digital-music player. When Apple launched the iPod in October 2001, it was widely derided. Who would buy such an expensive device, and why did Apple think it could take on Sony? But Apple had the last laugh. The iPod became an iconic product, and Apple has stayed ahead of its rivals with further innovations such as the iTunes Music Store, the click wheel and video iPod.

• No boundaries: **Fujio Masuoka**, professor, Tohoku University for the invention of **flash memory**. In 1984, Dr Masuoka invented the low-cost, low-power, non-volatile storage technology that can today be found inside mobile phones, music players and many other devices. He is now suing Toshiba, his employer at the time, for $9m, which he believes is his fair share of the $180m the firm has earned from his work.

We extend our congratulations to the winners, and our thanks to the judges: Simon Best, chairman, Ardana Bioscience; Denise Caruso, executive director, the Hybrid Vigor Institute; Martin Cooper, chairman and chief executive, ArrayComm; Larry Downes, professor, School of Information Management and Systems, University of California, Berkeley; Shereen El Feki, bioscience correspondent, *The Economist*; Rodney Ferguson, managing director, J.P. Morgan Partners; Daniel Franklin, editorial director, Economist Intelligence Unit; Lisa Gansky, director, Dos Margaritas, co-founder, Ofoto; David Goeddel, vice-president of research, Amgen; François Grey, head of IT communications, CERN; Georges Haour, professor of technology and innovation management, IMD; Vic Hayes, former chair, IEEE 802.11 working group; Leroy Hood, director, Institute for Systems Biology; Louis Monier, former director of advanced technologies, eBay; Shuji Nakamura, director, Centre for Solid State Lighting and Displays, University of California, Santa Barbara; Andrew Odlyzko, professor of mathematics and director, Digital Technology Centre, University of Minnesota; Navi Radjou, vice-president, enterprise applications, Forrester Research; Rinaldo Rinolfi, executive vice-president, Fiat Research; Paul Romer, professor of economics, Graduate School of Business, Stanford University; Paul Saffo, director, Institute for the Future; Tom Standage, technology editor, *The Economist*; Vijay Vaitheeswaran, energy and environment correspondent, *The Economist*; Carl-Jochen Winter, professor of energy and engineering, University of Stuttgart; Muhammad Yunus, managing director, Grameen Bank. ■

A matter of definition

Consumer electronics: The switch to high-definition (HD) television will gather pace in 2006—but beware the jargon

COLOUR television, which first emerged in America in the mid-1950s, was not an overnight success. There were fights over competing standards, the first colour sets cost a fortune, and for years there were very few colour broadcasts. Only in 1972 did sales of colour sets outstrip black-and-white.

Now a similar transition is under way with the switch to "high-definition" television (HDTV) which, as its name suggests, offers sharper, more detailed pictures. It is still early days: while there are around 1.5 billion televisions on earth, the number of HDTV households grew from around 8m to around 14m during 2005, according to IMS Research, a consultancy. HDTV broadcasts have been available for some time in America and Japan, have recently launched in France and Germany, and will reach Britain and the Netherlands early in 2006. But unlike the switch to colour, the process of switching to HDTV is rather difficult to explain without descending into jargon.

Conventional television is broadcast in an "interlaced" format, in which the screen is divided into several hundred horizontal lines. Half of these lines (the odd-numbered lines) are redrawn, then the even-numbered lines, then the odd-numbered ones again, and so on. The American NTSC system, for example, divides the screen into 480 lines, half of which are updated every 60th of a second (an approach known as 480i). This allows smooth movement to be depicted, while using half as much transmission capacity as updating the whole screen every frame: 60 half-frames per second looks smoother than 30 full frames per second. Most European countries use another interlaced format, called PAL, which divides the screen into 576 lines. The extra lines, together with PAL's more accurate rendition of colour, explain why American TV looks grainy in comparison: 576i looks better than 480i.

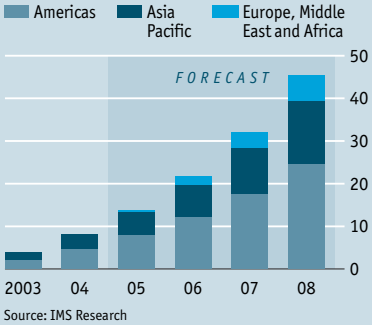
HDTV involves increasing the number of lines even further; the two main formats are 1080i and 720p. 1080i is an interlaced format with 1080 lines. 720p increases the number of lines to 720 and improves quality further by doing away with interlacing, updating the whole screen every frame instead—a technique called "progressive scan". This results in much smoother images, particularly of fast-moving subjects. To qualify as an HD set, a television must be capable of displaying both 1080i and 720p signals, as well as existing formats.

But then things get more confusing. An "HD Ready" set, marked with a special logo in Europe, is one capable of displaying HD signals from external sources. In America, "HD capable" refers to HDTVs with built-in tuners that can decode terrestrial HDTV signals; while a "digital cable ready" HDTV set contains a decoder for HDTV signals delivered via cable.

All of this gobbledegook helps to explain HDTV's dirty little secret: that around 80% of HDTV sets are not receiving HDTV broadcasts. In many cases, this is because consumers are unaware of the distinction; they buy a big new flat-panel HDTV and plug it into their existing cable or satellite tuner. The picture gets bigger, but does not get any sharper. "I have known people who say 'Look at my new HDTV', and I have to tell them they are watching regular broadcasts," says Anna Hunt of IMS. Admittedly, some people are buying HDTVs to use them with "progressive scan" DVD players, which produce a 480p signal. This looks much better than a 480i signal, though it is still not technically HD. But watching television in HD quality requires access to a source of HDTV broadcasting. The trouble is, not much HDTV programming is available: of the hundreds of channels available to most satellite and cable viewers, only a few dozen are available in HD.

Tuning in

Worldwide HDTV households, m



Source: IMS Research

The launch during 2006 of two rival HD disc formats, HD-DVD and Blu-ray, and the ability of new games consoles to produce HD signals, could boost adoption. And the industry hopes that the football World Cup, which will be broadcast in HD, will increase awareness of the distinction between HD and conventional broadcasts, particularly in Europe. The idea is that people will watch a World Cup match in HD at a pub or a friend's house, and then decide to upgrade.

Just how quickly HD will take off in Europe is unclear. For one thing, the superiority of HD images over European 576i broadcasts is visible only on 30-inch or larger screens—but Europeans have not embraced big flat-panel TVs in the way Americans have, notes James Healey of Datamonitor, a consultancy. Most European cable networks have not been upgraded to handle HD, and terrestrial HDTV broadcasts can begin in earnest only after 2010 or so, when analogue broadcasts end, freeing up the airwaves for HDTV. In America, cable networks have already been upgraded, and only 15% of households receive terrestrial signals; most rely on cable or satellite, which are better able to deliver HDTV.

Declaring 2006 the "year of HDTV", then, as some in the industry have, is overdoing it. Several previous years have also been declared the "year of HDTV" too, so scepticism is warranted. More consumer education and more HDTV content are needed; prices will have to fall too. The real tipping point, says Mr Healey, could be the 2008 Olympics or the 2010 World Cup. You will hear a lot about HDTV in 2006, but the transition, as with the switch to colour, will take many years. ■

Sunrise for renewable energy?

Energy: Renewable energy may not appear to be competitive with oil and gas at the moment, but the gap is closing

A SPECTACULAR sea snake has been spotted slithering around Scotland's northern waters. Though it is fiery red in colour, and some 100 metres in length, the writhing beastie has not sent the locals of Orkney running for the hills. That is because it is actually an innovative new device designed to produce electricity by capturing energy from the ocean's waves. Pelamis, manufactured by Ocean Power Delivery, a British firm, is at the vanguard of the next energy revolution. Or at least that is what proponents of renewable energy would have you believe. Orkney is home to the European Union's main marine-energy test centre, and local politicians and academics like to boast that Scotland, ideally suited to wave and wind-power projects, will become "the Saudi Arabia of renewable energy".

If such claims sound a bit over the top, they are entirely in keeping with the euphoria now sweeping through the renewable-energy sector. Money is pouring in as venture-capital firms, including many not previously interested in renewable energy, throw money at renewables. BP and Royal Dutch/Shell, two oil giants, have big renewables divisions. GE has unveiled "Eco-magination", an initiative focused on clean energy. High oil prices, environmental concerns, a desire for greater energy security and improved technologies "are combining to create the best investing environment ever for renewable power", observed Terry Pratt, a credit analyst at Standard & Poor's, in a report published in October. The International Energy Agency (IEA), a quasi-governmental agency not known for excessive greenery, forecasts that over $1 trillion will be invested in non-hydro renewable technologies worldwide by 2030. By then, the IEA predicts, such technologies will triple their share of the world's power generation to 6%. In some regions, such as western Europe and California, the share could top 20%.

Yet such predictions are met with scepticism by those who remember what happened after the oil shocks of the 1970s. Back then, high oil prices and concerns over scarcity led many firms to bet heavily on alternative-energy technologies. Most of them lost those bets when oil and gas prices fell in the late 1980s. One of the biggest losers was Exxon. Its current boss, Lee Raymond, has vowed not to spend another penny of his shareholders' money on renewables, which he calls "a complete waste of money".

The chief drawback of renewables is their cost compared with conventional energy sources. The cost of generating electricity from wind turbines is at least 5 cents per kilowatt hour (kwh), for example. Solar or wave power cost at least 18 or 20 cents per kwh. The cost of electricity from conventional sources, in contrast, is typically much lower—as little as 3 to 5 cents per kwh. Barring some dramatic breakthrough, renewable sources cannot, on the face of it, possibly compete.

Changing the rules

But look beyond the headline figures and a different picture emerges. Renewable energy has regulatory, commercial and technological trends on its side, all of which are working to close the cost gap with conventional sources. Taken together, they promise a far more sustainable, market-driven basis for investment in renewables than yesterday's faith in high oil prices—and suggest that renewable energy's cheerleaders could be on to something after all.

First, consider regulatory and policy ▸▸

"Pricing schemes that favour renewable energy are being made possible by 'smart' meters."

trends. Critics have long complained that renewables have survived only because of government subsidies. They are right—but every form of energy is subsidised. America's huge Energy Act, signed into law by President Bush in August, hands most of its $80 billion or so of largesse not to wind or solar, but to well-entrenched industries such as oil, coal and nuclear. Germany and Spain handed out cash to their coal industries even as they subsidised windmills.

Yet many governments, striving to reduce carbon emissions, are now embracing policies that promise more enduring and politically palatable support for renewable energy than subsidies: "externalities" pricing. In some countries, especially in Europe, action has come in the form of direct taxes on carbon emissions—which, of course, greatly benefit renewable energy. Japan is phasing out its solar subsidies altogether next year. Tax is a four-letter word in America, so policymakers there have instead adopted a mix of regulations, rather than a carbon tax, to boost clean energy. These include such measures as tax credits and "renewable portfolio standards" that require a certain proportion of energy production within a particular state to come from renewables.

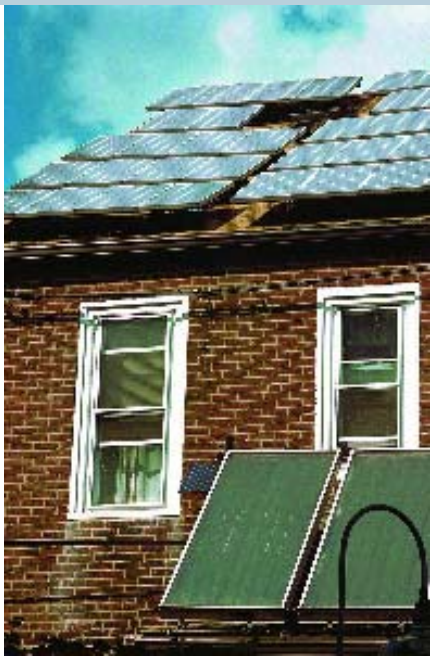
Second, these policy measures are being accompanied by the arrival of innovative business models built around renewables. A good example is Actus Lend Lease, an American firm, which is developing the world's largest solar-powered residential community in Hawaii to provide housing for American soldiers. "This is a business decision—there is no subsidy," says Chris Sherwood of Actus. Lenders were worried about the volatility of electricity prices, since Hawaii generates most of its electricity by burning imported oil, and the community's residents will pay a fixed rent, including utility bills, that is set by the army and adjusted only once a year. A sudden spike in the electricity price might have meant that the firm running the project would have been unable to make its debt repayments. Solar panels, in contrast, produce electricity at a known price for the lifetime of the panels. Reducing the uncertainty over energy costs, says Mr Sherwood, made it possible for the developers to borrow more.

Similarly, Sun Edison, an American start-up backed by Goldman Sachs and BP, has devised a clever new business model that overcomes a number of the real-world obstacles that have hitherto stymied renewable-energy projects. Simply put, it offers big retailers (such as Whole Foods and Staples) long-term, fixed-price electricity contracts in return for being able to set up solar panels on their rooftops. The retailers benefit from stable power prices, but do not have to buy or run the panels themselves; Goldman Sachs, which finances the panels, benefits from the associated tax credits and other offsets; BP sells more solar panels; and solar power has a better chance of taking off. Meanwhile, other ventures are looking to wind energy for a hedge. Several firms are putting together hybrid financial products that combine the output of wind farms in America's mid-west with that of natural gas-fired plants—thus hedging the volatility of both.

Pricing schemes that favour renewable energy are also being made possible by the arrival of new technologies such as "smart" meters, which allow for hour-by-hour variation in power prices. These make it possible for utilities to charge much more for power during the sweltering midday peak than early in the morning or late at night. Since solar panels produce their greatest power output in the middle of the day—just when prices are at their peak under a variable-pricing regime—Tim Woodward of Nth Power, a venture-capital firm specialising in energy, thinks smart meters with this type of "time of use" or "critical peak" pricing will make solar power far more attractive. "We see a groundswell toward this," he says. Several American states, led by California, are moving towards variable pricing, and the Energy Act encourages utilities to adopt it. Enel, Italy's national energy company, is rolling out smart meters to 30m customers across the country, and there are plans to make smart meters mandatory across the European Union, whenever a meter is installed or replaced.

Boxing clever

In the mean time, GridPoint, an American firm, is selling a "black box" at retailers such as Home Depot that its boss, Peter Corsell, claims will "solve the last-mile problem of the stupid grid". Usually, solar panels need a complex tangle of wires, inverters, batteries and other equipment to be installed to make them work. His firm replaces that with a "plug and play" device that also provides backup power. It even uses predictive software and an internet connection to juggle weather forecasts and utility pricing plans to decide when to sell power back on to the grid.



Coming soon to a roof near you?

All of this is making renewables more attractive, even without advances in the generating technologies themselves. But those technologies are not standing still either. Wind energy is now a commercially viable business, without subsidies, in a number of places around the world. (The crucial factor is the "wind potential" of the site; even the best sites for wind turbines produce power only 30-40% of the time, and the average across all of Germany's wind turbines, for example, is just 11%.) Of course, government helped the industry get to this point. Denmark, for example, is home to world-class turbine manufacturers, such as NEG Micron and Vestas, thanks to early state aid. And tax credits and other subsidies help wind operators in Germany and elsewhere.

The key to wind's success in becoming commercially viable has been technologies that have allowed turbine size to grow from an average of 10 metres in diameter in the mid-1970s to over 80 metres today. To build and run such monstrous turbines, companies have devised new composites for the blades, variable-pitch blades that catch the slightest of breezes, variable-speed drive motors and other advances. A doubling of wind speed means about an eight-fold gain in a windmill's energy output, so making windmills taller makes sense, as winds tend to be stronger and more stable higher off the ground. Of course, there are practical limits: make a turbine too big and you cannot deliver it to a field or a windy mountaintop. But offshore, where turbines can be moved by ship, that is not a constraint. Experts expect offshore wind to take off dramatically, especially in Europe, which has both plenty of wind and lots of protesters who object to land-based turbines. Robert

"Talisman, an oil company, has decided to put up two windmills on top of one of its gas platforms."

Kleiburg of Shell muses that the industry may need to rethink turbine design for offshore environments, however.

The prospects are also good for improvements in solar power. Ever since Bell Labs patented its design for a photovoltaic cell in 1954, crystalline silicon—the same stuff that is used to make computer chips—has been the dominant technology for such cells, thanks to its high reliability and conversion efficiency (at least compared with rival technologies). Silicon-based systems typically convert about 15% of the sun's energy into useful electricity. That may seem low, but since the fuel is free, the efficiency of conversion matters less than the overall cost per kilowatt of power delivered.

Alas, silicon photovoltaic cells are now victims of their own success. The solar industry has sucked up so much crystalline silicon that there is a global shortage, and prices have shot up. But crisis breeds invention. "In the old days, we'd get the garbage after the IT industry got the good stuff," says Rhone Resch of America's Solar Industries Association. But now half a dozen silicon-wafer plants are going up around the world dedicated solely to providing silicon for solar energy. "This is a watershed for the silicon industry," says Christopher O'Brien of Sharp Solar.

One firm hoping to capitalise on the silicon shortage is Evergreen Solar. It uses conventional crystalline silicon, but in an unusually frugal fashion. From crucibles of molten silicon, ribbons of the stuff are continuously pulled out. This "string-pulling" uses 30% less silicon than the usual sawing-and-etching method does, with further improvements in sight. But others are betting on a rival technology: thin films. Rather than etch wafers, various firms are creating solar panels on rolls of stainless steel (ECD Ovonics), plate glass (GE's Astropower division), and other materials amenable to continuous manufacturing processes. That means costs can be greatly reduced once full-scale plants are built and perfected, which would compensate for thin films' lower conversion efficiency.

"I'm betting against silicon," says Arno Penzias, a Nobel-winning scientist who is now with NEA, a venture-capital firm. Instead, he favours a flavour of thin-film solar technology known as "CIGS"—a sandwich of thin layers of copper, indium and gallium selenide pioneered at America's National Renewable Energy Laboratory (NREL). His firm invests in HelioVolt, which is trying to commercialise this technology; the firm claims that it can already achieve efficiencies close to those of silicon in the laboratory but using just one-hundredth the material. Billy Stanbery, HelioVolt's boss, thinks this technology could allow solar panels to be built into roofing materials, rather than installed on top. Shell's solar division, which is developing a thin film similar to CIGS, thinks it could reduce the cost of solar panels by more than 50% by 2012.

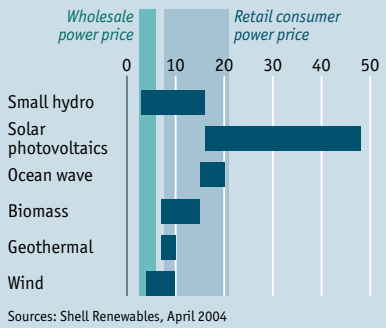
Another promising, but tricky, approach is organic solar panels. Konarka, whose founder won a Nobel prize for pioneering organic solar cells, is leading the charge in this area—but even one insider admits that commercialisation of its optical organic PV cells "is a long way off". Other researchers are applying nanotechnology and molecular chemistry to solar power, with the aim of mimicking photosynthesis. Most pundits think that is a long way off too. But a paper published by a team from the NREL in May raises a tantalising possibility: it found that tiny nanocrystals known as "quantum dots" could, in theory, make possible solar cells with around 70% efficiency. So the future for solar power could be bright indeed.

Follow the money

But what is most striking is that figures compiled by Shell Renewables in April 2004, when the oil price stood at $40 a barrel—it is currently closer to $60—found that wind turbines and solar panels could close the cost gap with conventional energy sources. Provided they are large enough and are sited in suitable locations, the most efficient modern wind turbines can produce electricity at a wholesale price (the price at which electricity producers buy and sell power on the grid) competitive with non-renewable sources.

Not so dear

Cost competitiveness of selected renewable-power technologies, unit cost ranges, cents/kWh



Sources: Shell Renewables, April 2004

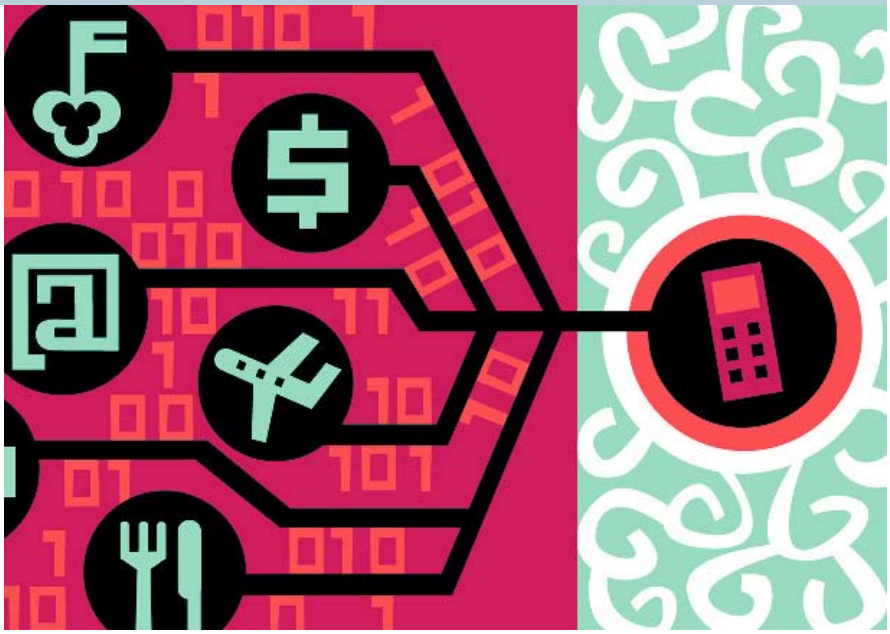
Solar panels cannot produce power at such low cost, but comparing their cost-per-kwh with wholesale prices is arguably not the most relevant comparison. That is because in general, solar panels are used not by electricity producers selling power to the grid at wholesale prices, but by consumers who use solar power to supplement or replace power bought from utility companies at retail prices (typically 8 to 20 cents per kWh). So solar power need only match these higher retail prices in order for homeowners and businesses to start to consider it as a viable alternative. And it turns out that the most efficient of today's solar panels do indeed match the retail price of electricity in some parts of the world with high retail prices, such as Japan (which is now phasing out its solar subsidies).

Renewables' growing competitiveness is not, in short, simply the result of sky-high oil prices. And that explains why Wall Street is at last getting interested. Not long ago, America's renewable-energy industry held a finance conference in New York at the Waldorf Astoria hotel. Brian Daly, a financier with the Trust Company of the West, stood up to make a presentation in the bejewelled grand ballroom. He observed: "When I made my first presentations in this industry, there were ten guys with ponytails and I had to flip charts myself." Now, he observed, the Waldorf ballroom was packed with besuited bankers—and his slides appeared on a high-tech screen.

If you still need persuading that something big and exciting is happening in renewable energy, head back to the frothy waters of the North Sea off Scotland. There, you will find the energy equivalent of beating swords into ploughshares: the planting of windmills on oil platforms. Talisman, an independent oil company, has decided to put up two windmills on top of one of its gas platforms. Building stable platforms accounts for around a third of the cost of offshore wind farms. But the oil and gas industry in the North Sea, now in decline, has plenty of platforms sitting around.

A Talisman official explains that, for the moment, the energy will be used only to power the platform's operations, but in future it may serve as a generating station, and send power ashore. "This will be the greenest platform in the world," he says. If even hardened oilmen can look to the winds for inspiration, perhaps the time really has come for renewable energy after all. ■

In the very near future



Communications: "Near-field communication" technology could fuse tickets, key cards and cash with mobile phones

NEW wireless technologies, from Wi-Fi to Bluetooth to 3G, generally promise to be faster, longer-range and more efficient than their predecessors. So a new technology, called "near-field communication" (NFC), is somewhat unusual. Compared with other, better known wireless standards, it operates over very short ranges—measured in mere centimetres—and it transfers data at a comparatively sluggish pace, not much faster than a dial-up modem.

But that does not mean that NFC is lacking in ambition. Quite the contrary. For rather than trying to displace existing wireless technologies, NFC's lofty goal is to supersede even older, more fundamental inventions: bank notes, coins, keys and tickets. It could also spice up advertising posters and make it easier to exchange data between mobile phones and other devices. How can such an apparently feeble technology hope to achieve so much? By bringing order to the growing field of contactless cards, and then, its proponents hope, by marching into other markets in conjunction with that all-conquering digital device, the mobile phone.

To start with, NFC is an attempt to unify the various contactless-card technologies that have been appearing all over the world. Hundreds of transport systems, from Hong Kong to Houston, are issuing tickets on contactless cards that can open turnstiles with the wave of a hand or the touch of a wallet, speeding access for commuters and reducing fraud and administration costs when compared with paper tickets. (Examples include Hong Kong's Octopus cards, London's Oyster cards and Japan's Suica cards.) In America, contactless payment cards and key fobs are used to speed up transactions at fast-food restaurants and petrol stations, and MasterCard recently began distributing PayPass contactless credit cards which can be accepted at 20,000 shops and restaurants. The firm expects to have issued 3m-5m cards by the year's end.

These contactless cards do not need batteries. Instead, when a card is placed close to a reader an electrical current is induced which powers up the card and enables it to exchange short bursts of data with the reader. Such induction happens only over very short distances, which is why close proximity between card and reader is required; some systems advise users to touch the card against the reader to ensure a successful connection, although contact is not actually required.

So far, this is all standard stuff. But now imagine putting a contactless chip and reader into a mobile phone. Since a phone has a screen, a keyboard and a connection to the internet, a number of new and useful things become possible. You could use your phone to see when your contactless train ticket was due to expire, for example, and top it up over the air. Alternatively, your phone could actually take the place of your contactless train ticket, and of other contactless cards, and act as the equivalent of a contactless wallet.

The combination of mobile phones and contactless cards can already be seen working in some countries. In Hong Kong, 50,000 phones with integral Octopus cards have been sold, while Japan's largest mobile operator, NTT DoCoMo, has sold over 4m "wallet phones" that contain a FeliCa contactless chip made by Sony. From next year, these phones will be able to double as Suica cards, since Suica cards are also based on FeliCa chips.

Such compatibility is the exception rather than the rule, however. The contactless card systems in use around the world employ several different and incompatible wireless technologies and software standards. But most of them operate in the same frequency range, around 13.56 MHz, so it is not too difficult to build a device that can talk to all of them.

And that is exactly what an NFC chip does. It is a device capable of acting as both a contactless card and a reader. It is compatible with FeliCa, the standard used in Japan and Hong Kong. It also works with a standard called ISO 14443, which forms the basis of the contactless payment systems used by MasterCard and Visa, and with Philips' Mifare technology, used in London's Oyster cards and in some 200 other ticketing projects around the world. (NFC itself was finalised as an industry standard in 2003.)

This means that an NFC-capable mobile phone can potentially function as an Octopus card in Hong Kong, a Suica ticket in Japan, and an Oyster card in London. Not many people would require such flexibility, admittedly. But a single, overarching global standard should lead to huge economies of scale. Nokia, the world's largest handset-maker and an early backer of NFC along with Sony and Philips, hopes to get the cost of NFC chips below $5, at which point they would be cheap enough for inclusion in even the most basic handsets. And that, in turn, would make possible many other uses.

Cash and carry

For a start, NFC-equipped mobile phones could double as electronic wallets, by taking the place of contactless credit cards. They could also give a much needed boost to electronic cash, an idea that has struggled for years to get off the ground. As Mondex, Visa Cash and a long list of other failed e-cash schemes have demonstrated, getting people to adopt high-tech alternatives to cash is extremely hard. Such schemes present a classic chicken-

"NFC could turn your mobile phone into a travel pass, wallet, cinema ticket, or even your door key."

and-egg problem: consumers will not adopt the technology until merchants do, and vice versa. As a result, e-cash has taken hold only in situations where adoption is mandatory, such as in university or business canteens.

The use of pre-paid credit for transport tickets offers a way out of this conundrum. Once large numbers of people start using contactless cards as tickets, retailers have an incentive to accept the cards as a means of paying for small items such as newspapers and snacks. This has already happened in Hong Kong, for example, where over 12m Octopus cards are in circulation. The same cards are also used for around 750,000 non-transport purchases per day, worth an average of HK$17 ($2.20) each. Similarly, the 10m Suica cards issued by the East Japan Railway Company can also be used for small purchases, and London's Oyster cards will follow suit next year. NFC-equipped mobile phones could further accelerate the adoption of e-cash, by making it possible to top-up funds over the air.

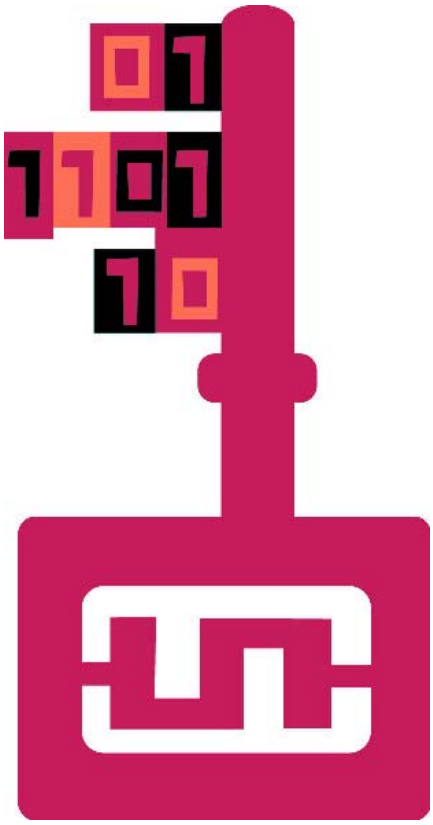
Near-field opportunities

As well as turning your mobile phone into a travel pass and a wallet, NFC could also allow it to function as a ticket to a cinema showing or sporting event, bought in advance via a mobile internet connection. And with access to offices, homes and schools increasingly controlled using contactless cards, NFC could enable phones to double as pass cards, too. Yet another possible application is in marketing. Smart posters could include an NFC chip, so that holding a mobile phone against the poster causes a related web page to pop up on the phone's browser. Ringtones or "wallpaper" graphics could even be downloaded straight from the poster. Similar promotional use has already been made of Bluetooth, but using NFC for the same purpose promises to be less fiddly and more secure, since initiating an NFC connection requires close proximity between phone and poster.

Indeed, handset-makers believe NFC could also provide a simple way around another problem: configuring devices to talk to each other over wireless connections. Both Wi-Fi and Bluetooth standards, which are commonly used for this purpose, have a range of several metres, which means that many possible devices could be in range, including those belonging to someone in a neighbouring office or apartment. To ensure a secure connection between two specific devices, users have to go through a fiddly set-up procedure. Since NFC works only over distances of a few centimetres, users could pair NFC devices simply by holding them against each other. Sebastian Nystrom of Nokia likens the process to initiating a conversation by walking up to someone and tapping them on the shoulder, rather than calling to them across a busy room.

Given its relatively slow transmission speed—a maximum of 424 kilobits per second, with early devices limited to half that data rate—NFC would not be very suitable for transferring, say, music files between a mobile phone and a computer. No problem, say NFC advocates: having established a secure pairing with NFC, the two devices can switch to a wireless technology with higher bandwidth, such as Bluetooth or Wi-Fi, which will also allow the devices to stay paired once they move out of direct proximity.

It all sounds great—in theory. But who is backing NFC in practice? An impressive group of companies, as it happens. The NFC Forum, an industry association, was founded by Nokia, Philips and Sony last year, and was joined in February by MasterCard, Matsushita, Microsoft, Motorola, NEC, Samsung, Texas Instruments and Visa. Other members who have joined since include American Express, LG, Intel, Siemens and SonyEricsson.



However, support from one crucial quarter is still muted—the mobile operators. It is not hard to see why their enthusiasm might be lukewarm. Mobile operators have a long backlog of technologies to sell, and many, such as picture messaging and videotelephony, have been coolly received by customers. And Simpay, a European mobile-payment project set up by Orange, T-Mobile, Telefónica and Vodafone, collapsed in June.

The support of the operators is important, since they have to decide which handsets, and hence which features, to make available to their subscribers. The operators might worry that if NFC makes it easier to connect mobile phones to other devices over short-range wireless links, this might discourage subscribers from sending data over the cellular networks. Conversely, as more functions converge on the mobile phone, NFC could offer operators a way to increase revenue and boost customer loyalty by offering new services. "We do see it as a way to boost network traffic," says Frank Zandee of KPN, a mobile operator based in the Netherlands that is testing NFC as a means of ticketing at a local football club. As mobile phones start to be used for financial transactions and ticket purchases, he says, operators stand to benefit.

Though it has not joined the NFC Forum, NTT DoCoMo regards the convergence of mobile phones and contactless cards as an opportunity to move into financial services. In April, it paid ¥98 billion ($900m) for a 34% stake in Sumitomo Mitsui Card Company, Japan's second-biggest credit-card issuer. By issuing its subscribers with credit cards embedded in their handsets, DoCoMo hopes to boost loyalty and create a new source of revenue. But this idea might not transfer to Europe, since it is predicated on the relatively undeveloped state of Japan's consumer-finance industry, notes Gerhard Fasol of Eurotechnology Japan, a consultancy based in Tokyo.

So if NFC does take off, it will not do so overnight. Coins have been in use since the seventh century BC. People are unlikely to give them up quickly. "It is only now that we are seeing the take-up of e-cash, after six years of operations," says Brian Chambers, international operations director of Hong Kong's Octopus scheme. "It takes a certain amount of time to change people's attitudes." ■

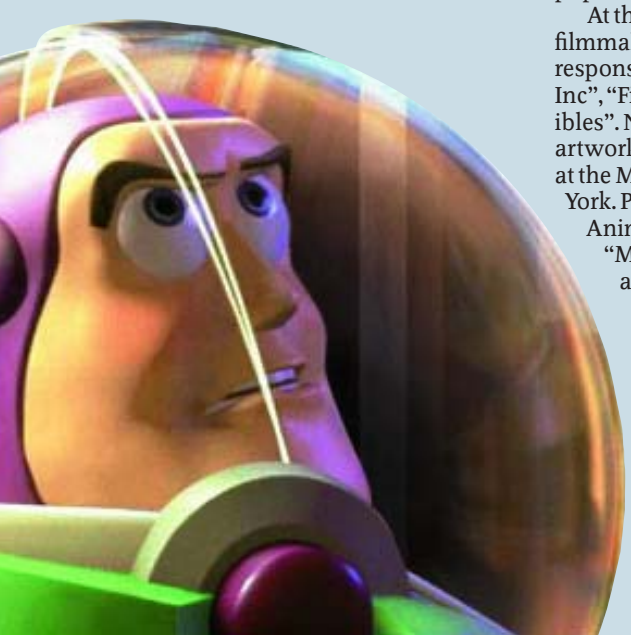
From "Toy Story" to "Chicken Little"

Computer animation:
The introduction of digital technology has transformed animated films. But will computer-animated humans ever look realistic on screen?

NOT by chance, the film that first introduced audiences to the story-telling flexibility and entertainment potential of computer animation was about toys. Buzz Lightyear the space-ranger, Woody the cowboy and the other playthings brought to life in Pixar's "Toy Story" (1995) were chosen not simply for their appeal to children—though that did no harm at the box office, of course. Toys were chosen also because they are relatively easy to model and animate on a computer. They do not have complicated features (such as fur or wavy hair), and nobody expects them to make fluid, lifelike movements. By the time "Toy Story 2" was released in 1999, however, the characters' motions were smoother, the lighting more realistic, and the humans (including Al, the greedy toy-collecting villain) were also more realistically depicted. Further improvements doubtless await in "Toy Story 3", which is already on its way. That is because some of the most vivid—and certainly the most entertaining—evidence of the plunging cost and growing power of computers is now to be found on the silver screen.

Computer animation has made enormous progress in a very short time. As recently as 1986, the year Pixar was founded, the use of the technology in films was in its infancy. Directors began by experimenting with special-effects sequences within live-action movies such as "The Abyss" (1989) and "Terminator 2" (1991). There were some short computer-generated (CG) films, but full-length animated films were still mainly hand-drawn and two-dimensional, with sparing use of CG imagery in some sequences, as in Disney's "Beauty and the Beast" (1991) and "Aladdin" (1992). Since then, CG effects have became cheaper and more realistic, and are now commonplace in live-action movies, many of which have come to rely heavily on them (think of the recent "Star Wars" or "Lord of the Rings" trilogies). The same technological progress also made full-length films feasible, and "Toy Story" and its many successors have now become a popular, profitable and innovative genre.

At the forefront of this revolution in filmmaking is Pixar, which has been responsible for such hits as "Monsters, Inc", "Finding Nemo" and "The Incredibles". Next week an exhibition of Pixar's artwork, designs and storyboards opens at the Museum of Modern Art in New York. Pixar's rivals include DreamWorks Animation (makers of "Shrek" and "Madagascar", among other films) and Blue Sky (makers of "Ice Age" and "Robots"). Tellingly, even Disney, which dominated the field of animated movies in the pre-digital era, has now belatedly embraced the technology. Having previously acted as the distributor for Pixar's films, last month Disney released "Chicken Little", its first all-CG film developed in-house.



Fewer than a dozen feature-length CG films have come out since "Toy Story", but several more will be released in 2006 alone, including "Ice Age 2" from Blue Sky, "Cars" from Pixar, "Over the Hedge" and "Flushed Away" from DreamWorks, and "Barnyard" and "Charlotte's Web" from Paramount. It all underscores the rapid rise to respectability of this new medium, an exciting fusion of art and technology. So how does it work?

The making of a monster

Putting a CG feature film together is very different from making a live-action movie using actors. That typically involves a director accumulating a dozen hours of footage (through multiple takes, shooting scenes from different angles, and so on) and then editing it down to a reasonable length. For CG films, the structure is generally fixed from the very beginning. The storyline is worked out, rough character sketches are produced and a detailed, scene-by-scene storyboard is put together. Then the characters' voices are recorded by actors, digital models of the characters are created, and the animators start to bring the characters to life in accordance with the dialogue. "So you see your picture slowly start to move," says Max Howard, a former Disney animation executive who is now at Exodus Film Group, an independent studio.

Initial pencil-and-paper sketches of

"For a full-length feature film, rendering can take more than a year of round-the-clock calculation using a vast amount of computing power."

the characters are turned into computer models consisting of a wireframe, or mesh, of hundreds of thousands of simple elements. To build a monster, for example, you might start off with a cylinder for each leg and perhaps a sphere for its body, says Jill Ramsay of Alias, a leading maker of animation and modelling software. Each of these elements is made up of tiny polygons, and any number of elements can be moulded together. "You can define any shape you want in 3D," she says, "but it is a long, slow process."

Once the wireframe monster has been created, the next stage is to make it move. To do this, the animator identifies the location of its joints and facial features and attaches a set of control points to them. This process, called "rigging", is akin to attaching strings and a control harness to a wooden puppet, but is far more complex. DreamWorks spent more than a year setting up the rigging for Shrek, the green ogre in the film of the same name. Such an elaborate character, says Ed Leonard, the firm's chief technology officer, typically has hundreds of controls for its rigs, to give it the necessary range of expressions and movements. Rigs can also be much smarter than the strings used to control wooden puppets: they can be configured so that if an animator moves a character's foot, for example, the knee bends in the appropriate manner.

With the control rigs in place, the animators can start to define the character's movements. There are 24 frames per second in a film, but the character's exact position does not have to be specified in each one. Instead, the animator positions the limbs of the character at particular points in time and defines how they are to move from one to the next. Animation software then interpolates between these positions to determine the position of each limb in each frame. The result can be viewed right away, in a simplified wireframe view that enables the animators to check their work as they go along.

This process sounds very mechanical. The magic comes from the animator's skill in bringing the character to life. "An animator and an actor are essentially the same kind of talent," says Alvy Ray Smith, a computer-graphics guru and one of the co-founders of Pixar. "I call it magic, because they convince us that a stack of polygons has emotions and is conscious." The computer does the actual animation, but does so according to the operator's instructions. This is, notes Dr Smith, not dissimilar to traditional hand-drawn cartoons, in which animators draw every second or third frame, and other artists called "in-betweeners" fill in the frames in between.

But there is more to animated films than walking wireframes, of course. So the next stage is to add colour and texture to the character models. In the case of Shrek, the character model is based on an "anatomically correct" representation (if that is possible for a fictitious monster) of bones, muscles and fat layers. Animators move the bones, and the muscles and fat layers respond in a realistic manner. This determines the shape of the outer layer of skin and clothes. Colour and texture are then defined using pieces of software called "shaders".

Each shader is a program that defines surface properties such as colour, texture, transparency, bumpiness, shadow colour, and so on. Different shaders can be attached to various parts of a character model to give it specific characteristics, corresponding to skin, hair, fabric and so on. Given a character model and its associated shaders, a specified viewpoint, and the defined position of one or more virtual light sources, it is then possible to "render" a view of the character. The light falling on to each polygon of the character's surface is calculated, and the appropriate shader then determines its colour and texture. After an enormous amount of computational effort, this produces a realistic, textured character. Throw in other characters, objects and background models, all with their associated shaders, and the result is a single movie frame.

For a full-length feature film, the rendering process can take more than a year of round-the-clock calculation using a vast amount of computing power. For "Madagascar"—which depicts the adventures of a zebra, hippo, lion and giraffe transplanted from a zoo into the wild—Mr Leonard says that DreamWorks' computer centre (or "render farm") ran seven days a week for a year and a half. At Pixar, a movie can also take between one and two years to render, says Dr Smith.

Special sauce

This basic process has not changed much since the days of "Toy Story", but the technology, both hardware and software, has advanced enormously. More powerful computers mean more elaborate modelling and rendering is possible, producing more realistic images. Animals now have fur and hair; lighting, fire and smoke effects are more subtle and sophisticated; and scenery can be more detailed. The bigger studios have spent years developing proprietary software that creates exactly the effects they want. DreamWorks, for example, has de-

The animator positions the character's limbs; flesh and clothes are overlaid on top; finally, lighting and textures are applied

Some viewers found the characters in "Polar Express" creepy

veloped its own lighting tool, called LIGHT, and its own rendering tool, called D-Render. Blue Sky's rendering software, called CGI Studio, uses proprietary techniques to render unusually life-like fur and grass. For "Ice Age 2", which will be released next March, Blue Sky has developed special software, based on the principle of "ray tracing", to render water and ice effects.

Ray tracing, a technique that has been around since the dawn of computer graphics, is capable of rendering reflective and translucent objects more realistically than a shader-based approach, but has the drawback of being far more computationally intensive. Where a shader-based approach calculates how light from virtual light sources affects the final colour of each point in the image, ray-tracing works the other way around: virtual rays of light are followed from the viewer back into the model, and are bounced off surfaces until they bounce back into a light source. (The traced rays thus actually travel in the opposite direction to real light rays.) Rays that encounter a partially transparent surface are split into two rays, one of which passes through the surface, while the other is reflected. Taking into account the way in which light bounces off and passes through surfaces in this way entails a lot of complex calculations, but greatly increases the realism of the resulting image.

Increasingly, ray-tracing is used in combination with shading, and various clever tricks have been devised to enable animators to make appropriate use of both approaches without too much of a performance penalty. Ray-tracing features have, for example, been incorporated into Pixar's RenderMan software, a shader-based rendering tool that is used internally, but which Pixar also sells to other companies. RenderMan was used by Disney in the creation of "Chicken Little", for example, and is widely used in special-effects work.

Faster computers make new tricks possible, but animators seem to have an insatiable appetite for more computer power. "Madagascar" could not have been made three years ago, says Mr Leonard, because modelling the jungle was so computationally intensive. Indeed, the increasing complexity of the films would appear to be slightly outstripping the growing speediness of computers. When "Shrek 2" was made, it required 10m render hours, versus 12.5m for "Madagascar", made just a year later.

Even so, technological hurdles remain, and there are still several areas with considerable room for improvement. An obvious one is fur. Since most fantasy characters in animated films are animals or monsters, depicting realistic fur is a priority for animation studios. But there are innumerable variations: long, short, thick, thin, wet, dry, matted. Fur must reflect light realistically, and long hair should wave around as the character moves. While there has been much progress in recent years, DreamWorks is promising a "completely new generation of fur" in next year's "Over the Hedge". Similarly, Carl Ludwig, technology chief of Blue Sky, is particularly proud of the new and improved fur in "Ice Age 2", which will also come out in 2006.

Then there is water, which is still "really hard" to model, says Ms Ramsay of Alias. It is a substance that reflects light, readily changes its degree of translucence, and must flow, splash and ripple realistically. But that has not stopped studios from plunging ahead, so to speak. "Ice Age" depicted life-like footprints and snow; next year's sequel will be set in a world of melting ice and floods, so characters must swim.

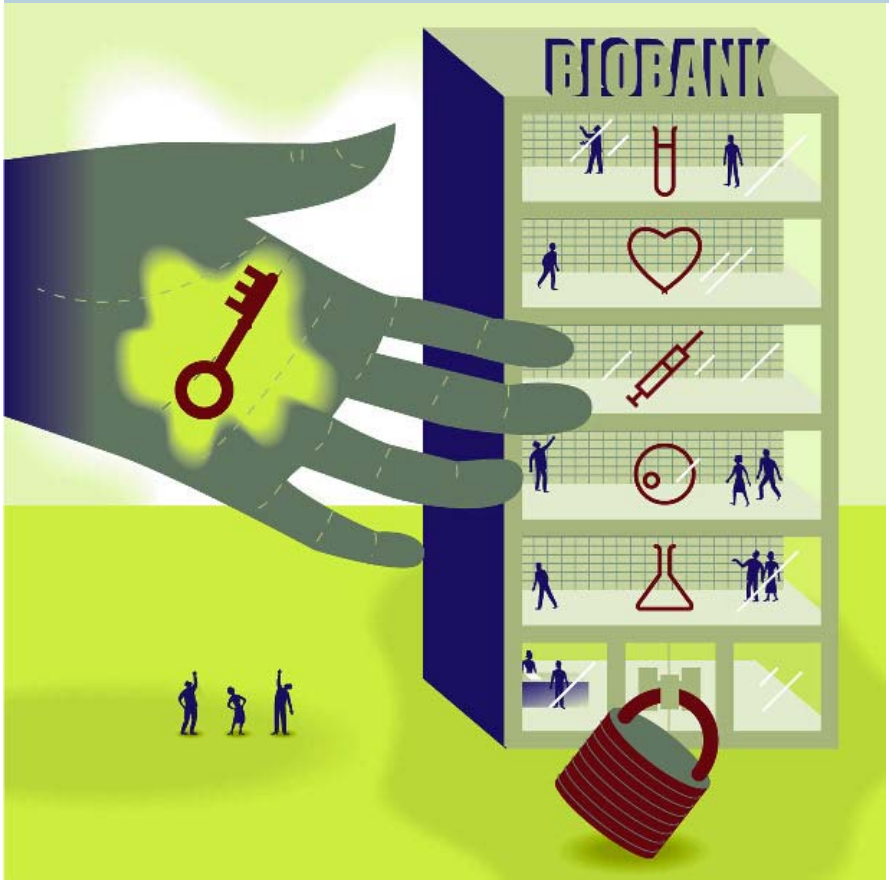
Imaginary animal, realistic fur

Another challenge is herds of animals, flocks of birds, or schools of fish. Animating large numbers of creatures is a challenge because "you can't hand-animate every single character," says Mr Leonard. Instead, a small number of characters are typically created and animated, and are then duplicated many times. The latest approach, says Mr Leonard, is to give groups of characters behavioural characteristics, and animate them as a coherent group, rather than separate individuals.

But by far the greatest challenge lies in the more realistic depiction of people. "The problem with human beings is the face," says Mr Ludwig. So familiar are audiences with subtle human movements and expressions, he says, that "the minute something is not there, we know it, and it feels dead or strange." That is not the case for fish or monsters. "Polar Express", which combined computer animation with motion-capture of performances from human actors, was one of the most ambitious attempts to render realistic humans. But many viewers found the results eerie or sinister.

Pixar has always chosen to depict people in a cartoon-like way in its films, notably "The Incredibles", rather than striving for realism. DreamWorks, in contrast, has taken a more realistic approach with the human characters in the "Shrek" films. There has been progress in the modelling of the way human skin scatters light, and hair is becoming more lifelike too. But such improvements, says Ms Ramsay, are "still costly" computationally.

Besides, ought the industry's objective really be making perfectly realistic humans—to have, as Mr Howard says, "Fred Astaire dancing again"? Despite DreamWorks' more realistic approach, Mr Leonard rejects any suggestion that total realism is the goal. Instead, he says, computer-generated characters, such as Princess Fiona in the "Shrek" films, need only be real enough to express recognisable emotions. "If you want to do perfectly real humans, then I suggest you get a camera and go shoot actors, because it's a lot cheaper," he says. After all, given animation technology's ability to depict almost anything that can be imagined, why should it limit itself to mere realism? ■



Medicine's new central bankers

Health care: Biobanks, which link tissue samples to patient data, are all the rage—but have drawbacks as well as benefits

WHAT do you get when you link a repository of tissue and DNA samples to a database of personal medical information and test results? A biobank. The combination is potent, because it can reveal things that tissue samples or medical records alone cannot. Drug companies and medical researchers can, for example, pick out samples from people with a particular disease, and determine its associated genetic variations to aid drug discovery. Public-health officials and epidemiologists should be able to identify disease patterns in subpopulations and ethnic groups far more quickly than is currently possible. And advocacy groups hope that disease-specific biobanks will accelerate research into disorders such as AIDS and breast cancer.

Nobody knows for sure, but there is a growing consensus that there are economically valuable and scientifically revealing deposits of biological samples and clinical data around the world, just waiting to be tapped. An oft-quoted research paper produced by RAND, a think-tank, in 1999 suggests that some 300m samples obtained through routine patient visits to clinics and hospitals are stored in America, at hundreds of public and private labs. The number and variety of samples that lie elsewhere in the world is unknown, but must be even larger.

The idea of biobanks is not new. But rising health-care costs, drug companies' desire to keep their development pipelines stocked, advances in data-mining technologies and a growing interest in the notion of "personalised" medicine have spurred a growing realisation, in both the health-care and information-technology sectors, that biobanking could be a very good business indeed. The result has been a growing level of activity in the field.

At a conference held in London in October, Britain and Norway announced a plan to co-operate on biobank-based research into the causes of attention-deficit hyperactivity disorder (ADHD), autism, schizophrenia and diabetes. With state-run health-care systems and strong research traditions, both countries are well placed in the field. Norway is collecting blood samples and health data from 200,000 citizens and from 100,000 pregnant women. Britain's project, called UK Biobank, will soon be gathering blood and urine samples and confidential lifestyle data from 500,000 volunteers aged 40-69, in an attempt to untangle the genetic and environmental causes of heart disease, Alzheimer's, diabetes and cancer. Participants will provide new samples and data for up to 30 years, allowing the development and course of different diseases to be tracked.

Similarly, the Karolinska Institute in Stockholm, which already runs one of the world's oldest university-based biobanks, plans to follow 500,000 Swedes for 30 years to gain new insights into depression, cancer and heart disease. There are numerous other examples such as Biobank Japan, the Estonian Genome Project, Singapore Tissue Network, Mexico's INMEGEN, and Quebec's CARTaGENE. Indeed, Sweden, Iceland, Quebec and Japan have been "banking" blood and tissue samples from their citizens for generations without attracting much attention. And all kinds of government institutes and university medical schools around the world have been collecting biological samples and clinical data as a matter of routine. These resources could now turn out to be extremely valuable.

Unanswered questions

But not everyone likes the idea. Bioethicists are quick to point out that the very thing that makes biobanks enticing and powerful to health-care professionals and drug companies makes them equally so to law enforcement, the insurance industry and government officials with a different agenda. This fear is not without foundation. The Swedish government, which created one of the world's first national biobanks in 1975—it now has at least a blood sample from all of its citizens—used a loophole to gain access to the biobank a couple of years ago, in order to track down a killer.

It was not, admittedly, a run-of-the-mill murder case. Anna Lindh, Sweden's popular foreign minister, was murdered in September 2003 at a department store. Although Lindh's murder was captured on closed-circuit television, it was ultimately a DNA match from the murder ▸▸

"While bioethical and regulatory worries about biobanks abound, lack of agreement on standards could prove to be a more immediate impediment."

weapon, a knife, that provided the basis on which the leading suspect, Mijailo Mijailovic, a 25-year-old Swedish Serb, was convicted. The DNA sample used to place Mr Mijailovic at the scene came from the country's national biobank, which—unlike many of the research biobanks now being established—is not anonymous.

Mr Mijailovic's conviction was later overturned on the basis that he suffers from a psychiatric disorder, but damage to the claim of confidentiality made by Sweden's biobank was done nevertheless. "This must never happen again," says Jan-Eric Litton of the Karolinska Institute biobank. "This is not and should not be the purpose of a biobank—the only purpose, and it is my great hope that all nations abide by and clarify this, is to understand disease and find ways to address it in all of its forms. Biobanks are the future—they are a unique opportunity if we manage them correctly."

But while limiting the use of biobanks to medical research sounds like a simple solution, grey areas abound. In January, Swedish lawmakers temporarily changed the law to allow access to the biobank in order to identify bodies of Swedish citizens killed in the Asian tsunami. That is arguably a non-medical use, but one that is harder to argue against: the samples were used to identify children, for whom dental records did not exist. As a biobank meeting held in Stockholm last May, and a follow-up meeting in Washington, DC, last month made clear, there is still no agreement about how to keep probing officials citing national security or other serious concerns out of the biobank vaults.

Equally difficult to resolve is the matter of consent. Speaking in Stockholm, Wolfgang Patsch of Paracelsus Private Medical University and Landeskliniken in Salzburg, and Chia Lin Wei of the Genome Institute of Singapore, highlighted the importance of creating a new consent model, engaging the public in dialogue about the promise and perils of biobanks, and ensuring accountability, transparency and confidentiality. Britain's UK Biobank, for example, will encrypt the identity of donors, so that only selected users will be able to link samples and data to particular individuals. Total anonymity raises problems of its own: it precludes the possibility of informing donors or their relatives if donated material reveals them to be at risk from a specific disease.

The question of confidentiality is bound up with another conundrum: who is going to pay for biobanks? The answer is unclear. One approach would be to make information freely available to academic and government researchers, but to charge drug companies and other commercial interests which stand to profit from their use of the data. That could make biobanks self-sustaining, or even profitable; it has even been suggested that donors should be given a share of the proceeds. But purists insist that biobanks should remain strictly non-commercial entities. The Genome Institute of Singapore forbids any commercialisation of its biobank data, for example, though so far it is the exception to the rule.

Further complicating matters is the question of scope. Should biobanks contain samples of blood, urine, tissues or stem cells? Should data from clinical trials

be included? And how far back in time should biobank collections go—to school, or even to new-born check-ups? Another challenge is that of quality control. It is vital that the millions of samples in a biobank are collected in a consistent and uniform way to avoid contamination or mislabelling of samples. As they come under increasing scrutiny from regulators, drug companies are already questioning the quality of biobank data. Before basing critical drug-development decisions on information from biobanks, they will need a high degree of confidence in its reliability.

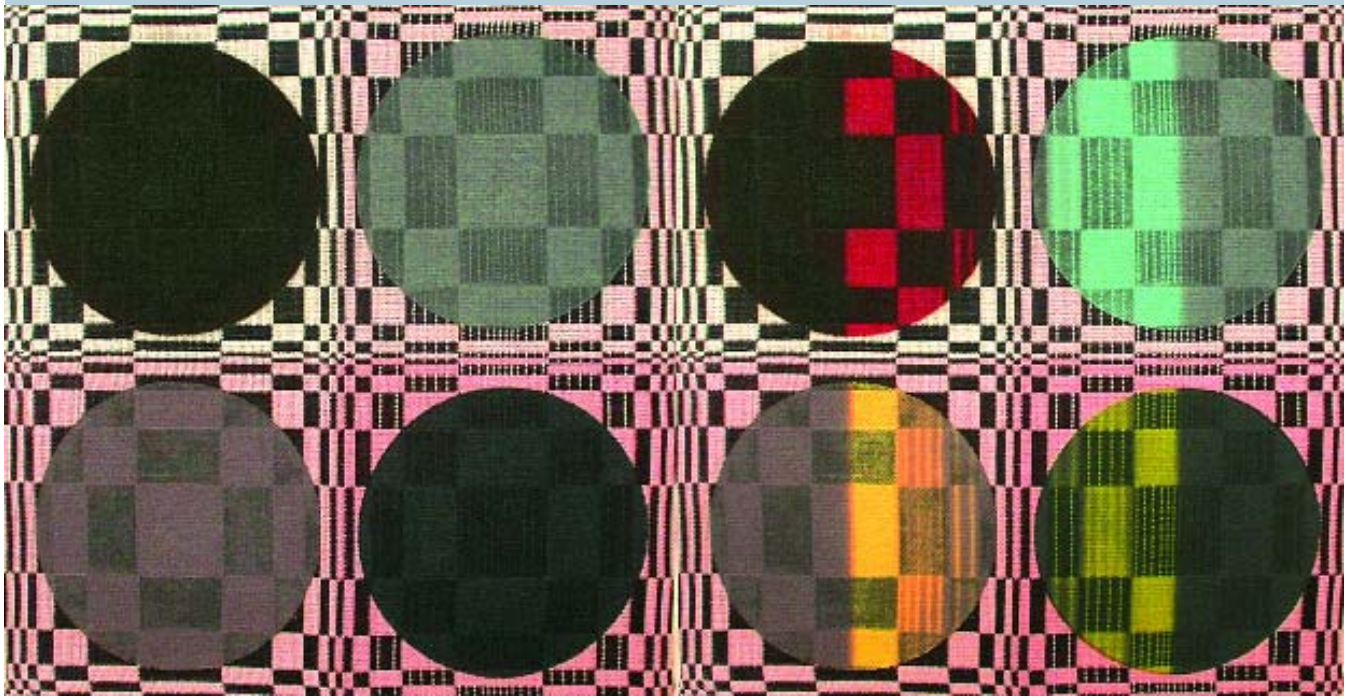
Money in the bank?

All of these objections must be weighed against biobanks' great potential to help in the development of new treatments, however. It is widely assumed that, in future, drug treatments will be tailored to each patient's unique genetic blueprint, so that two people with the same disease might be treated in very different ways. The hope is that personalised medicine could both make treatment more effective and reduce side-effects. Data in biobanks will play a crucial part in realising this vision, by revealing insights into disease progression and responses to standard therapies. That, in turn, will reduce the time needed to develop new personalised diagnostic tests and treatments.

According to Mike Svinte, head of IBM's information-based medicine initiative, "biobanking is becoming an essential part of the transformation to a personalised model of medicine." IBM certainly hopes so, as a proponent and backer of biobank initiatives around the world. Biobanks, with their mountains of associated data, require huge amounts of storage and processing power, and represent a daunting, yet potentially lucrative new market for the computer giant. Other technology companies such as Oracle, GE Healthcare and McKesson also stand to benefit if biobanks start to become widely adopted. There has already been much discussion about the standards and protocols that will be used to store biobank data, but these are still early days. When the debate begins in a more public fashion it will surely be heated.

Indeed, while bioethical and regulatory worries about biobanks abound, the lack of agreement on standards and procedures could turn out to be a more immediate impediment to their adoption and use. Martin Ferguson, senior vice-president for bioinformatics at Ardais Corporation, a firm that helps researchers assemble and maintain large repositories of clinical samples, argues that most of the technologies and standards that are needed already exist. "The main hurdle remains getting enough biobanks to actually agree upon and adopt a common set of systems for deployment, and thus become a sort of 'nucleation point' for a functioning biospecimen collection system," he says.

In other words, if the full potential of biobanks is to be met, there will have to be a standard way for researchers, whether in the public or private sector, to order and access samples and data from biobanks—just as the internet's common standards facilitated the free flow of information across digital networks, and made available previously untapped data. Only then will it be possible to fully exploit the mountains of samples, and reams of data, that are currently locked up in the world's hospitals, clinics, and laboratories. ■



Threads that think

Materials: The incorporation of sensors and controls into clothing is the first step towards a new realm of "smart fabrics"

IT COULD give the term "power suit" a whole new meaning. Getting dressed a few years from now, you may find yourself putting on more than mere fabric. Your clothes may by then sport electronic sensors and tiny computers. As you walk out of the door, you will be not just fashionably attired, but digitally enhanced—a living, breathing node on the internet. This prospect will delight some people and horrify others. But it could actually happen, if the field known variously as smart fabrics, electronic textiles or "washable computing" can achieve the breakthrough its proponents believe is just around the corner.

As recently as five years ago the idea of clothing, furniture and upholstery that combined fabric with electronics was a fantasy. Yet today the first examples of the technology are on sale, with more advanced products on the way. Current products are aimed at early adopters, but both hopeful start-ups and big firms such as Nike, DuPont and Philips are searching for an application that will carry the technology into the mainstream.

Smart fabrics look and feel like ordinary textiles, but can do extraordinary things: generate heat, monitor vital signs, act as switches or sensors, and even change colour. With so much fabric woven into daily life, proponents of smart fabrics see them as a natural way to increase the pervasiveness of today's gadgets and add snippets of intelligence to everyday items. Computing power is already being incorporated into cars, household appliances and entertainment systems, notes Stacey Burr, the boss of Textronics, a spin-off from DuPont based in Wilmington, Delaware, that is developing electronic textiles and clothing. So fabric, she argues, is a natural next step. "About 70% of the materials that people come in contact with are fabrics," she says. "We want to create fabrics that warm, illuminate, conduct, sense and respond." Smart fabrics will be particularly useful in the fields of medicine, sports, communications and personal security, Ms Burr predicts.

Material benefits

She is not alone in her enthusiasm. "There is a really big market," says John Collins of Eleksen, a British start-up that sells sensors based on smart fabrics that can be incorporated into clothing, accessories and furniture. Eleksen has so far sold 70,000 units, but already has firm orders for 600,000 units in 2006, and expects sales to rise tenfold again in 2007.

Smart fabrics can take many forms. The most basic kind is electrically conductive, such as Textronics' "textro-yarn", a slightly elastic material that resembles ordinary fabric. Because it conducts electricity, it can be used for heating (by passing a current through the fabric), as a radio antenna, for electromagnetic shielding, to provide power to other devices embedded into clothing, and even to make electrodes, for example to monitor vital signs. The company has just launched a sports bra that monitors the wearer's heart-rate and calorie consumption, and displays them on a wristwatch-sized screen.

Another of Textronics' smart materials is "textro-polymer". Its fibres have the useful property that their resistance changes when they are stretched. This can be used to detect bending, stretching or tugging, which can in turn reveal whether the wearer of a smart garment is moving or stationary, or whether a particular car seat or bed is occupied. In September, Textronics announced a deal with Konarka, a pioneer in flexible solar panels, with a view to making jackets that can recharge mobile phones and other devices.

International Fashion Machines (IFM), a firm based in Seattle, has just launched a range of light switches based on conductive yarns. Squeezing the fuzzy, pom-pom-shaped blob of material changes the amount of current flowing through it. This difference is detected by a control circuit that then turns lights on or off accordingly. Maggie Orth, IFM's founder, hopes ▸▸

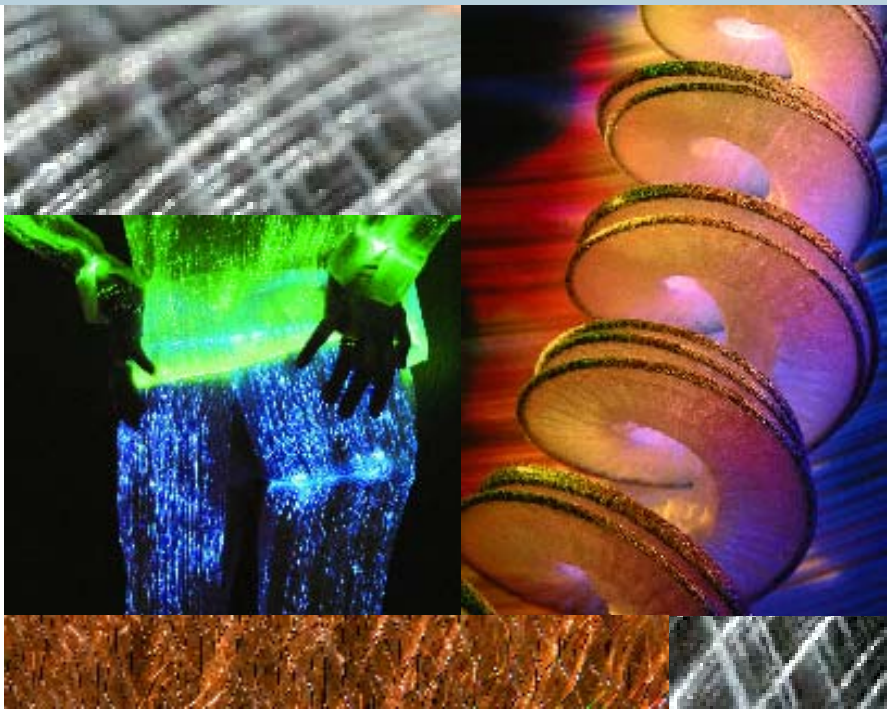
these playful switches will find use in children's playrooms and designer hotels.

The smart fabric made by Eleksen, called ElekTex, acts as a more elaborate touch sensor. It consists of three layers: a top and bottom layer of conductive material, and a middle layer that conducts electricity when it is compressed. Voltage gradients are applied across the top and bottom layers, at right angles to each other. When the fabric is pressed, current flows through the middle layer. By measuring the change in voltage across the top and bottom layers, it is possible to determine where (and roughly how hard) the fabric is being pressed. This means that sliding and tracing gestures, as well as individual presses, can be detected.

Eleksen claims that the fabric can survive being washed, crumpled, punctured and even driven over. It has already been used to make roll-up fabric keyboards for handheld computers, to control a heated jacket made by Innovative Sports, and to incorporate iPod controls into ski jackets made by Spyder, Kenpo and Westcomb. The iPod is popped into a special pocket and plugged into a control wire, and it can then be controlled using fabric sensors in the jacket's cuff or on its sleeve. Buttons start and stop playback and select tracks, and stroking a strip adjusts the volume.

In France, a cinema has experimented with using ElekTex to count the number of occupied seats; another proposed use is to incorporate television controls directly into the fabric of sofas. "The real value in our stuff is being able to keep the interface as soft as the thing it's going into," says Miles Jordan of Eleksen. The company has also devised a second form of smart fabric, again made up of several layers, which functions as a moisture sensor. The top two layers allow only a small proportion of incident moisture to reach the third, bottom layer, which contains a matrix of conductive fibres. The amount of moisture can be determined by measuring variations in the resistance of this layer. This smart fabric can be used for what Eleksen delicately calls "incontinence detection" in medicine, and to detect moisture in buildings.

A kinder, gentler light switch



Fancy fabrics, clever clothes

As well as acting as sensors and switches that gather information, smart fabrics can also function as output devices. One approach is that taken by Luminex, the result of a collaboration between Caen, an Italian electronics firm, and Stabio, a Swiss textiles company. Luminex is a fabric with fibre-optic strands woven into it, which are then illuminated using light-emitting diodes powered by a small battery pack. Luminex has already been incorporated into glowing clothes, safety garments, handbags and furniture, and even a wedding dress.

Electric Plaid, devised by IFM, takes a different approach. Rather than emitting light directly, it contains stainless-steel yarns coated with "thermochromic" inks that, as their name suggests, change colour depending on the temperature. Applying a current causes the yarns to heat up, which changes the ink's colour. This makes possible fabrics with slowly changing patterns (see photo on previous page), and even information displays: a wallhanging that changes colour depending on the weather forecast, for example.

As smart as these fabrics are, they still rely on separate control circuitry to detect pressure, motion or moisture, or change their appearance. Smart jackets based on ElekTex, for example, contain a small control unit to connect the touch sensors on the sleeve to an iPod. Rehmi Post, a researcher at the Centre for Bits and Atoms at the Massachusetts Institute of Technology (MIT), says the real breakthrough will come when the control electronics are not simply housed in clothing, but are woven directly into the fabric. Today's products, he points out, are a halfway-house in which the textiles and electronics are not fully integrated. "They aren't ambitious enough," he says.

Seamlessly weaving cloth, power and data, Dr Post admits, will be easier said than done. Many of the required technologies exist already, but overcoming problems such as electrical interference, programming and power supplies will not be trivial. "There are a few fundamental problems that have to be solved, but they are solvable," he says.

Integrating fabrics and electronics more closely will, Mr Collins predicts, make possible phones, music players and other portable devices that are part electronic and part fabric. They will, he says, be smaller, lighter, less power-hungry and more durable than today's devices.

Smart clothing could not only blur the lines between materials and electronics but, if items of clothing start to absorb previously discrete devices, between people and machines. "They will be a kind of second skin—functionality will blend into the background," says Ms Burr. Perhaps. But in the short term, at least, it seems more likely that smart clothing's appeal will be limited to particular, well-defined situations, such as skiing, policing and emergency rescue. That said, many people now refuse to go out without their mobile phones. The challenge for believers in smart fabrics is to make people feel similarly naked without them. ■

The computer will see you now

Larry Weed has spent his career trying to inject a dose of computing into health care—in the face of fierce opposition

WHEN asked to summarise the significance of Larry Weed's work, Charles Safran, a professor at Harvard Medical School, recalls a story from medical history. In the mid-19th century, the mortality rate from puerperal (or "childbed") fever at Vienna General Hospital's maternity ward was so high that many women, it is said, preferred to give birth in the street. Then a doctor called Ignaz Semmelweis achieved a dramatic reduction in deaths by insisting that doctors wash their hands between autopsies and obstetrical examinations. But other doctors refused to believe that their own hands transferred disease. Besides, they grumbled, hand-washing was far too time-consuming. Dr Semmelweis was widely ridiculed and eventually fired.

Today, Dr Weed is meeting similar opposition to his proposed reforms, which involve a far greater use of computers by doctors. As in 19th-century Vienna, many doctors today cannot believe that their inability to retain today's vast medical knowledge in their heads is harming patients, as Dr Weed contends. And they speculate that his notion of systematically using software to diagnose and care for patients could be, well, too time-consuming. "He's introduced something you have to call disruptive," says Dr Safran, who is also chairman of the American Medical Informatics Association. "It doesn't fit into the doctor's workflow."

But Dr Weed, who turns 82 this month, is the embodiment of indefatigability, devotion and determination. He has spent more than three decades devising software that matches a patient's symptoms and health history against an exhaustive catalogue of computerised medical knowledge. And he's no quack. He earned his medical degree in 1947 from New York's Columbia University and did his residency at Johns Hopkins Hospital in Baltimore. He has taught at a string of renowned medical schools, including that of Yale University in New Haven, Connecticut. In 1969, he changed the basics of health-care delivery with an innovation called the "problem-oriented medical record". And in 1995, he won the Institute of Medicine's Gustav O. Lienhard Award for outstanding achievement in improving American health care. "He is one of the giants of the last 500 years in medical thinking," says Don Detmer, a professor at the University of Virginia.

It's not hard to understand why Dr Weed thinks doctors need a dose of technology: there is simply too much new information to absorb and retain. Medline, a medical database, indexed 3,672 articles about adult coronary heart-disease studies in 2004, notes Elizabeth McGlynn, of RAND Health, part of the RAND think-tank. If a physician took 15 minutes to read each article, it would take 115 eight-hour days to read up on this one clinical area alone. As Dr McGlynn points out, most people need a list to remember five or more items when shopping. How, then, can doctors possibly retain information on some 12,000 known diseases in their heads? Practising medicine without computers is "like trying to send people up on the space shuttle with pencil and paper," says Charles Burger, a doctor based in Bangor, Maine who has been using Dr Weed's software since the 1980s. "There is no other profession that tries to operate in the fashion we do. We go on hallucinating about what we can do."

And it is a dangerous hallucination. Preventable medical errors kill between 44,000 and 98,000 people annually in America alone, according to a 1999 study from the Institute of Medicine, a non-governmental organisation in Washington, DC. But the problem is not uniquely American. Dr McGlynn says Canadian, British, Israeli and Scandinavian health-care quality is not much different. "Performance is consistently below the standards that one might hope for," she says.

A contagious idea

Dr Weed became interested in chemistry and biology as a teenager. He spent the second world war in the navy, and the GI Bill then helped finance his studies at medical school. But he says he cannot remember "in any precise way when or why I decided to be a doctor." And he is reticent to discuss any personal details that do not relate to his core message: that only by applying technology to health care can rigorous diagnosis and treatment be ensured. Dr Weed does remember that while teaching and doing microbial-genetics research at Yale in the 1950s, he was struck by the stark contrast between his well-ordered one-problem-at-a-time laboratory and the rapid-fire time spent in the hospital, dealing with

"As governments push for health-care automation, resistance to the use of IT could finally crumble."

patients' multiple problems. Plus, the files documenting those problems were a mess. "If you look at the old records, you had stream-of-consciousness notes that almost made it impossible to follow the patient's record," says Dr Burger.

The experience inspired Dr Weed to devise a new system—the "problem-oriented medical record", or POMR—in which each problem is itemised and monitored. Dr Weed applied his systematic approach first at East Maine General Hospital in Bangor in the late 1950s, and throughout the 1960s at Case Western Reserve University School of Medicine in Cleveland, Ohio and Cleveland Metropolitan General Hospital. Following a series of lectures, articles and a book on the topic, POMR was adopted in medical institutions, universities and doctors' offices in America, Britain and Japan.

"Long before it was obvious to anyone else, Larry looked at the situation in health care and saw a better way," says David Brailer, who is America's first National Health Information Technology Co-ordinator. "Saying that POMR was revolutionary almost understates it," adds Dr Safran. "There's probably no one who has more fundamentally affected the way we organise our work than Larry Weed. He fundamentally changed American medicine."

But as Dr Weed taught and used the POMR system, he longed to make it even more efficient. Why have secretaries type in all that health-history information if a computer could be made to do the work? In 1969, Dr Weed—who was by now raising four children with his wife, also a doctor—landed a government grant to build a minicomputer version of POMR known as PROMIS, for use on several wards at the Hospital of Vermont in Burlington. As a professor of medicine at the University of Vermont, Dr Weed was however unable to get the university to adopt the computer system. So he and his team left in 1982 to form the Problem-Knowledge Coupler Corporation (PKC) to create a new, PC-based version of the software.

Today, the company employs a staff of 70 in a former textile mill on the Winooski river in Burlington. PKC has built and continually updates software that does a startlingly good job of coupling patients' symptoms with the latest relevant medical information. The PKC software stands apart within the little-known niche of "diagnostic decision-support" software: with other diagnostic aids, doctors generally use software on an as-needed basis, such as during a complex case. But PKC takes patients and health-care providers through a thorough—and documented—question-and-answer routine at each encounter. PKC engages patients, who enter information about symptoms, family medical history and so forth. During or after the medical exam, the health professional enters physical findings and test results. PKC then returns a list of diagnoses and care options to consider, with links to journal articles on which the recommendations are based.

Doctors who have used PKC for years tell endless tales of improved office efficiencies, better patient involvement and diagnoses that they might otherwise have missed. A study from 2001 validates their experience, indicating that PKC's systematic approach can improve outcomes in chronic conditions such as diabetes. America's Department of Defence has been impressed enough to build PKC into its own Composite Health Care System, called CHCS II, so that Dr Weed's software helps to look after some 9m people. "PKC has a fairly unique capability to bounce a person's health record up against medical literature," says Colonel Bart Harmon, the army's chief medical information officer. He adds that PKC's list of potential diagnoses and care options are the opposite of the so-called "cookbook" medicine that many doctors fear will result from automation.

As with POMR, PKC's software has appeal outside America, too. "I would be very pleased if we could get all the general practitioners in Britain to use his software," says Brian Jarman, a professor emeritus at London's Imperial College School of Medicine and a former president of the British Medical Association. "It's virtually impossible for a doctor these days to remember everything. Computers don't let you forget things."

Medical complications

And yet the challenges for Dr Weed's software are significant. For starters, there's Dr Weed. Many agree that doctors are overwhelmed with information, yet far fewer agree with Dr Weed's vision of a completely revamped health-care system in which medical schools, as we know them, are dismantled. "The diplomas they grant and the licensing exams the states give could not possibly mean and guarantee what the public thinks they mean," says Dr Weed. Genius and dedication aside, the good doctor can be as caustic as he is charming, as bombastic as he is brilliant, as scathing as he is skilled. "He doesn't suffer fools gladly," notes Dr Detmer. "He's a totally consistent personality—this is a delight to those of us who find him inspiring, and tedious to those who wish he would go away."

Dr Weed says of his critics that "when you don't like the message, it's very easy to criticise the messenger. No one wants you to come to their house and tell them the floor is dirty and the food is lousy." But even if Dr Weed were a flatterer with a less bitter pill to swallow, there would still be a host of challenges blocking his health-care cure. There is huge resistance to diagnostic-decision support software as a category: doctors remain unconvinced of its benefits and believe it encroaches on their autonomy.

It is not unusual to hear doctors claim that they are far better diagnosticians than a computer could ever be. But this merely indicates that they do not understand that PKC does not purport to make diagnoses (in fact, none of the products in the category does), but rather guides doctors through a more exhaustive examination of all the possibilities than even gifted doctors could manage on their own. So for the time being, PKC is pursuing employers, rather than health-care providers, as potential customers. A firm can, for example, invite its employees to access PKC online and then share the results with their doctors.

And after decades of toil, things could finally be going Dr Weed's way. Governments and firms are struggling to improve the quality of health care, consumers are becoming more demanding and costs are rising, making health care's curious technophobia—IT spending per employee is lower than in the retail industry, for example—look increasingly unsustainable. As governments push for health-care automation, resistance to the use of IT could finally crumble. "If you look at medical errors, the cost of care, consumer frustration, bioterrorism—they all mean we need to have our health-information systems together," says Dr Brailer.

"It's impossible to keep up with the avalanche of knowledge," concludes Neil de Crescenzo, vice-president of global health care at IBM Business Consulting Services in San Francisco. "Therefore, it's important to use a valid diagnostic-decision aid like Larry's." In short, it is time for doctors to acknowledge the wisdom of washing their hands—this time, in a bit of computing power. ■