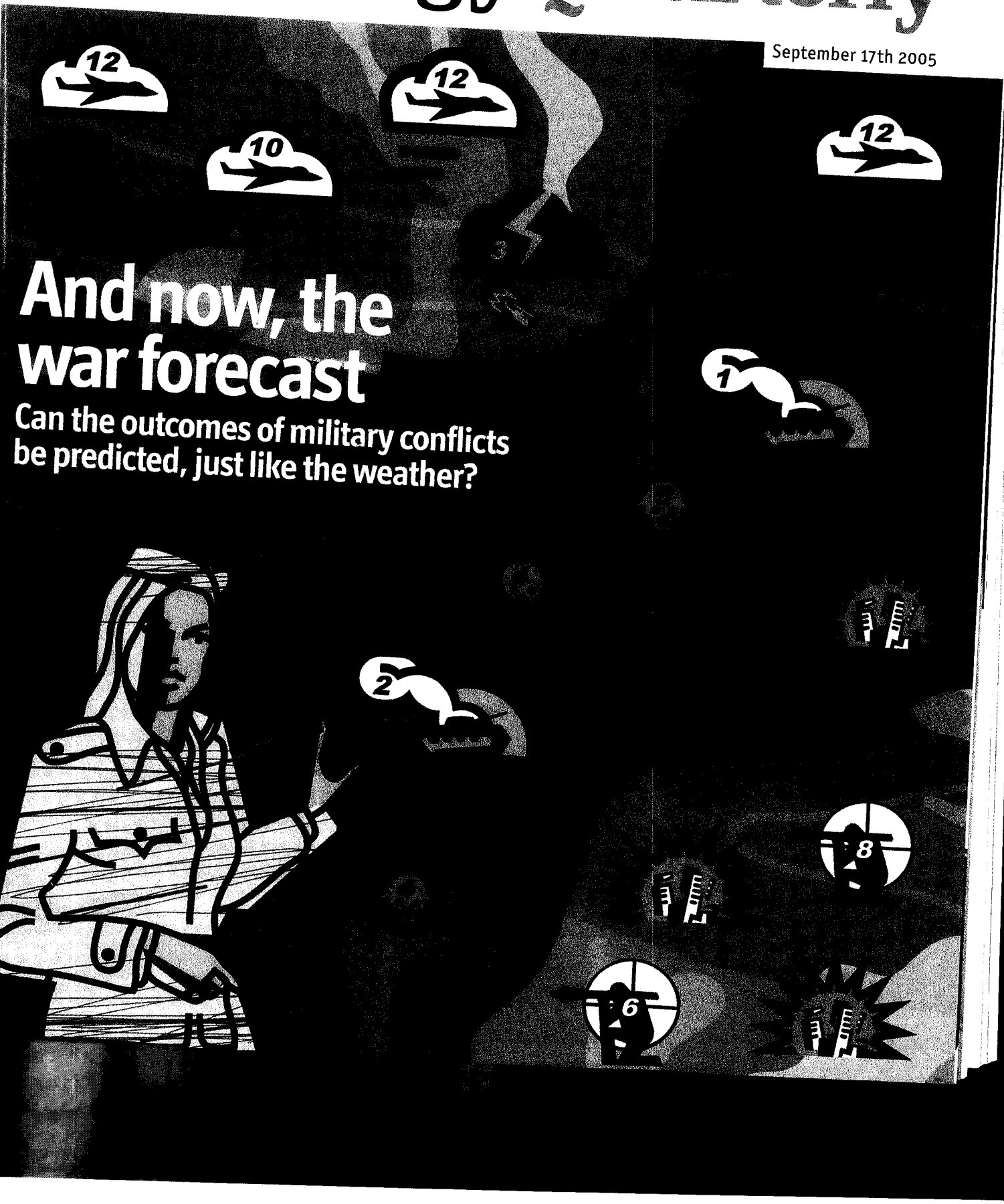
The Economist

Technology Quarterly

September 17th 2005

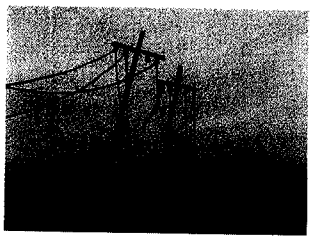


And now, the war forecast

Can the outcomes of military conflicts be predicted, just like the weather?

How the internet killed the phone business

Almost-free internet phone calls herald the slow death of traditional telephony



THE term "disruptive technology" is popular, but is widely misused. It refers not simply to a clever new technology, but to one that undermines an existing technology—and which therefore makes life very difficult for the many businesses which depend on the existing way of doing things. Twenty years ago, the personal computer was a classic example. It swept aside an older mainframe-based style of computing, and eventually brought IBM, one of the world's mightiest firms at the time, to its knees. This week has been a coming-out party of sorts for another disruptive technology, "voice over internet protocol" (VOIP), which promises to be even more disruptive, and of even greater benefit to consumers, than personal computers (see pages 73-75).

VOIP's leading proponent is Skype, a small firm whose software allows people to make free calls to other Skype users over the internet, and very cheap calls to traditional telephones—all of which spells trouble for incumbent telecoms operators. On September 12th, eBay, the leading online auction-house, announced that it was buying Skype for $2.6 billion, plus an additional $1.5 billion if Skype hits certain performance targets in coming years.

This seems a vast sum to pay for a company that has only $60m in revenues and has yet to turn a profit. Yet eBay was not the only company interested in buying Skype. Microsoft, Yahoo!, News Corporation and Google were all said to have also considered the idea. Perhaps eBay, rather like some overexcited bidder in one of its own auctions, has paid too much. The company says it plans to use Skype's technology to make it easier for buyers and sellers to communicate, and to offer new "click to call" advertisements, but many analysts are sceptical that eBay is the best owner of Skype. Whatever the merits of the deal, however, the fuss over Skype in recent weeks has highlighted the significance of VOIP, and the enormous threat it poses to incumbent telecoms operators.

For the rise of Skype and other VOIP services means nothing less than the death of the traditional telephone business, established over a century ago. Skype is merely the most visible manifestation of a dramatic shift in the telecoms industry, as voice calling becomes just another data service delivered via high-speed internet connections. Skype, which has over 54m users, has received the most attention, but other firms routing calls partially or entirely over the internet have also signed up millions of customers.

A price of zero

The ability to make free or almost-free calls over a fast internet connection fatally undermines the existing pricing model for telephony. "We believe that you should not have to pay for making phone calls in future, just as you don't pay to send e-mail," says Skype's co-founder, Niklas Zennstrom. That means not just the end of distance and time-based pricing—it also means the slow death of the trillion-dollar voice telephony market, as the marginal price of making phone calls heads inexorably downwards.

VOIP makes possible more than just lower prices, however. It also means that, provided you have a broadband connection, you can choose from a number of providers of VOIP telephony and related add-on services, such as voicemail, conference calling or video. Many providers allow a VOIP account to be associated with a traditional telephone number—or with multiple numbers. So you can associate a San Francisco number, a New York number and a London number with your computer or VOIP phone—and then be reached via a local call by anyone in any of those cities.

Furthermore, your phone (or computer) will ring wherever you are in the world, as soon as it is plugged into the internet. So you can take your Madrid number with you to Mumbai, or your San Francisco number to Shanghai. Skype and other VOIP services, in other words, are leading to lower prices, more choice and greater flexibility. It is great news for consumers—but terrible for telecoms operators. What can they do?

Watching the elephants dance

As is always the case with a disruptive technology, the incumbents it threatens are dividing into those who are trying to block the new technology in the hope that it will simply go away, and those who are moving to embrace it even though it undermines their existing businesses. Since VOIP will cause revenue from voice calls to wither away, the most vulnerable operators are those that are most dependent on such revenue.

In particular, that means mobile operators, which have been struggling for years to get their subscribers to spend more on data services, but are still hugely dependent on voice. Worse, the very "third generation" (3G) networks that are supposed to provide future growth for these firms could now undermine them, because such networks make mobile VOIP possible too. Least vulnerable, by contrast, are those fixed-line operators that are now building new networks based on internet technology, which will enable such firms to benefit from the greater efficiency and lower cost of VOIP compared with traditional telephony.

These operators are taking an "if you can't beat 'em, join 'em" approach and getting into the VOIP business. While their voice revenues will slowly evaporate, they will then be well placed to offer fee-based add-on services over their new networks. Again, this is a common pattern with disruptive technologies: forward-looking incumbents can end up giving upstart innovators a run for their money.

It is now no longer a question of whether VOIP will wipe out traditional telephony, but a question of how quickly it will do so. People in the industry are already talking about the day, perhaps only five years away, when telephony will be a free service offered as part of a bundle of services as an incentive to buy other things such as broadband access or pay-TV services. VOIP, in short, is completely reshaping the telecoms landscape. And that is why so many people have been making such a fuss over Skype—a small company, yes, but one that symbolises a massive shift for a trillion-dollar industry. ■

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Software can predict the weather, but can it predict the outcome of a military conflict? The success of one war-forecasting system suggests that it can. But now the software must keep up with the changing nature of warfare and the rise of "asymmetrical" conflicts: pages 19-20

Watch this space

Consumer electronics: As mobile phones threaten to depose them as the most personal of technological devices, high-tech watches are fighting back

IT IS a tiny technological wonder that goes everywhere with you. Your choice of brand and model says a great deal about who you are and how you wish to be perceived by others. It may have a classic, bare-bones design, or its sleek casing may conceal a host of extra functions. Ten years ago, this described your wristwatch, which epitomised the combination of fashion and technology for over a century. But today it also describes your mobile phone, which for many people has already dethroned the wristwatch as the most personal of technological devices. Can watchmakers fight back? In recent years there have been several attempts to boost the appeal of watches by adding exotic new functions, from telephones and televisions to personal organisers. But so far, none of these super-watches has been a hit with consumers. Manufacturers, it seems, have tended to ignore obvious practical limitations, and have failed to exploit the unique position of the watch—right there on your wrist.

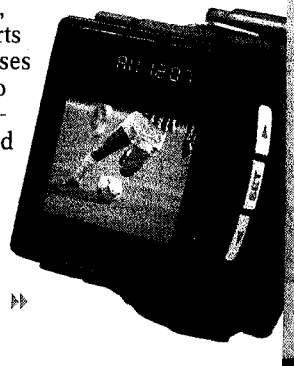
Consider, for example, the chequered history of attempts to develop a "Dick Tracy" watch with a built-in phone, as used by the 1930s comic-strip hero. Swatch, the Swiss pioneer of low-cost fashion watches, unveiled a prototype called Swatch Talk in 1998, but it has not been seen since. A similar fate befell a Samsung device that was previewed in 2003. In both cases, production plans were shelved when prototypes failed to impress users: holding your wrist to your ear during a conversation and keying in numbers with a toothpick simply look absurd. The Wristomo, a watch-phone made by NTT DoCoMo of Japan which actually made it to market in 2003, provides a partial solution by making the strap part of the phone. Watch and strap unfold into a normal sized phone, but this makes for a rather chunky watch, and the Wristomo has been a flop.

Watches, it seems, are simply the wrong shape for mobile telephony. But what about digital music? One snag is the inconvenience of wires from wrist to ears. The controls also tend to be rather fiddly, and because weight and volume are at a premium in watches, battery life is usually not competitive with larger, dedicated devices such as Apple's iPod. As a result, watch-based MP3 players have also failed to take off. Similar drawbacks have scuppered attempts to integrate personal organisers, digital cameras and other devices into watches.

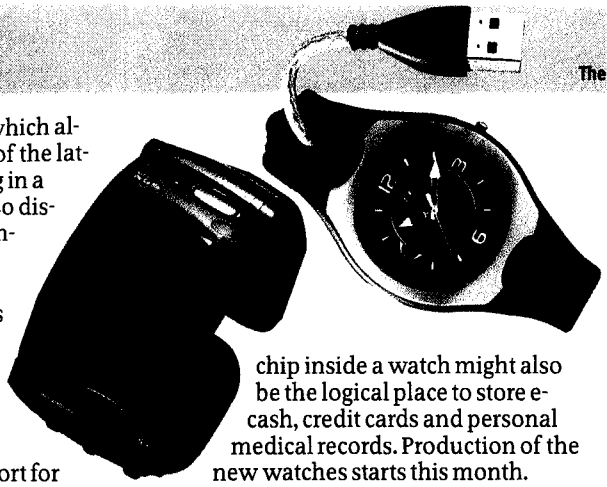
Yet still they come: gadget freaks can choose from a host of exotic models that would do James Bond proud. Want a wristwatch TV for your daily commute? No problem: NHJ of Japan makes one with a sharp, 1.5-inch colour screen—but the battery only lasts an hour. Still looking for those weapons of mass destruction in Iraq and need a radiation detector? The Gamma-Master watch has a handy built-in Geiger counter. Other watches incorporate ultraviolet radiation sensors and satellite-positioning systems.

But such watches appeal only to the geek fringe. Mobile phones, however, suggest that people will adopt new features on a device that originally just did one thing. Millions of people now use their mobile phones to send text messages, take pictures and play games. So perhaps watchmakers need to find new features that play to the strengths of watches. For example, unlike socially disruptive mobile phones, watches are far more discreet. They are also visible at a glance, without the need to fumble in a pocket or briefcase. Watchmakers dream of creating an iconic, breakthrough device that opens up an entirely new category, just as the iPod did.

Hence the launch last year, after many delays, of "smart" watches powered by Microsoft's MSN Direct service. This service, only available in parts of North America, uses an FM radio signal to send news, sports results, stock prices and other nuggets of information to the watch's screen. Many users have their favourite items, including the ▸▸



time, cycling continuously, which allows surreptitious scanning of the latest sports results while sitting in a meeting. The watches can also display alerts from Microsoft's instant-messaging service, and can synchronise calendars with a PC. Four watchmakers backed the initiative: Suunto of Finland, Fossil of Texas, and Tissot and Swatch, both members of the Swatch Group of Switzerland.



The Swatch Group's support for smart watches is significant, since this conglomerate of Swiss watchmakers accounts for some 25% of global watch sales by value. The decision to launch a smart watch under the Tissot brand is particularly revealing, says Pierre Maillard, a veteran observer of the Swiss watch industry and editor of *Europa Star*, a trade magazine. He notes that Tissot sits in the highly profitable mid-market segment which the Swiss have cornered, and is associated with Swiss quality, not cheap gadgetry. The Tissot "High T" smart watch, retailing at over $700, is aimed at status-conscious businessmen, not hip youngsters. Its novel touch-sensitive display is reminiscent of the iPod's nifty scroll wheel.

Most smart watches, however, are still quite chunky, in order to squeeze in the necessary electronics. The need to pay a $40 annual subscription charge is off-putting, too. And the technology has had teething troubles, so its future is unclear.

But whatever becomes of smart watches, the wristwatch still has potential in other areas. For example, because it is normally strapped to its owner, it is harder to misplace than a flash drive or memory stick. This has prompted LAKS, an Austrian firm, to launch a watch with built-in flash memory and a standard USB connector in its strap to enable it to be plugged into a PC. Previously better known for its chic Klimt-inspired watches than for high-tech gadgets, LAKS has seen its sales more than double as a result.

Lucas Alexander Karl Scheybal, the head of the firm that bears his initials, believes this sort of watch has huge potential in e-commerce. Its latest twist on the memory watch, called SmartTransaction, integrates both the USB connector and a secure smart-card chip, like those used in credit cards, with a contactless interface developed by Philips, a Dutch electronics giant. By plugging the watch into a PC, funds or travel tickets can be downloaded to the chip without the need for a special smart-card reader. Being wrist-mounted, a watch is always close at hand, which makes it particularly convenient when operating contactless readers on public-transport systems (such as those used by London's Oyster system). A contactless chip inside a watch might also be the logical place to store e-cash, credit cards and personal medical records. Production of the new watches starts this month.

Swatch also sees great potential for watches as contactless digital wallets. Its Swatch Access contactless technology, launched way back in 1996, has since found several niche applications, including use as an electronic ski pass at hundreds of resorts. Christoph Winkelmann of Swatch says the Access technology is making a big comeback in this year's product line, as the company targets new applications. In July, 64,000 Swatch Access watches functioned as tickets to the opening events of the new Swiss national football stadium in Bern. So perhaps there is a role for the high-tech watch after all. Time will tell. ■

Mashing the web

Software: Programmers are combining data from different websites to create "mash-up" sites with entirely new capabilities

ARMED with a stack of house-listing printouts from Craigslist.com, a popular website, Paul Rademacher was driving around Silicon Valley late last year looking for a place to live. It was not until he was about to park that he looked up and realised he had already visited the same house earlier. Surely, he thought, there had to be a better way to evaluate and visualise a list of housing options.

And so there was. In February, Mr Rademacher—who by day was a software engineer at DreamWorks Animation—began building a website that combines the mapping capabilities of Google's search engine with housing listings from Craigslist. The result, HousingMaps.com, creates maps showing houses or apartments in a particular city within a designated price range. The site went live in April, and is a leading example of one of the latest internet trends: the web mash-up. HousingMaps instantly attracted a crowd and has since been visited by more than 850,000 people.

The term mash-up is borrowed from the world of music, where it refers to the unauthorised combination of the vocal from one song with the musical backing of another, usually from a completely different genre. Web mash-ups do the same sort of thing, combining websites to produce useful hybrid sites and illustrating the internet's underlying philosophy: that open standards allow and promote unexpected forms of innovation.

"Mash-ups are emblematic of the direction of the web," says Paul Levine, the general manager of Yahoo! Local, a subsidiary of one of the web's most popular sites. "This is about participants in the web community opening up their systems." It may also be about good business. By building their sites using open standards, and so making it easier for customers and developers to build other sites that plug into them, companies can both encourage innovation and boost their own popularity. "When you lower the barriers to entry, interesting things happen," says Tim O'Reilly, president of O'Reilly & Associates, a firm based in Sebastopol, California that publishes programming handbooks. "The players who figure this out will wield a great deal of economic power."

As often happens online, this trend is being driven from the bottom up, by users. Most mash-ups happen without the sites that supply the data even knowing about it. For example, Greg Sadesky, a programmer based in Quebec City, grabbed textual data from Yahoo! Traffic and map data from Google without consulting either firm, to create a mash-up (see traffic.poly9.com) that produces traffic maps. Similarly, Chris Smoak, who lives in Seattle, has mashed together several traffic, web-cam, transport-information and map sites to create Seattle Bus Monster, a public-transit site for the Seattle area (see www.busmonster.com). The rise of online journals, or blogs, has spurred the mash-up trend by bringing programmers together to discuss new ideas and tricks. Mr Sadesky credits the inspiration for his traffic-map mash-up to the blog run by John Resig (ejohn.org), which explains how to extract traffic data from Yahoo!'s website.

Mashing is getting easier for these after-hours programmers as big websites start to cater to their needs. ChicagoCrime.org, a mash-up that lets visitors view crime data by street, date, type and zip code on a map of Chicago, for example, said at the end of June that Google's decision to release an official method for linking to its maps had made the site far more reliable. Yahoo! opened up its map data in a similar way in June, and in July Microsoft unveiled a pre-release version of its mapping site, MSN Virtual Earth. It includes a "Community" button to help ▸▸

programmers create websites that incorporate data from Virtual Earth.

Such firms are happy to see their sites get mashed. At the Where 2.0 conference in San Francisco this summer, Brett Taylor, the product manager of Google Maps, noted that "everyone is doing it already"—so why fight it? "A mash-up lets a company like Google tap into the creativity of the world's programmers," says Nathan Torkington of O'Reilly Media, who was the conference chairman.

So will mash-ups march on? Only if they lead to revenue, some predict. "Something has to evolve," says Craig Donato, the founder of Oodle, a site with local buying, selling and donation listings. If the information being mashed is useful, he says, it is probably expensive for the originated sites to put on the web in the first place. At the Where 2.0 conference, Mr Taylor of Google said that programmers were free to use Google maps for mash-ups that were "free to consumers"—but added that his firm reserved the right to deliver maps with advertisements on them in future. Dave McClure of Simply Hired, a recruitment site based in Silicon Valley, says he expects the mash-up scene to change, just as the blogging scene did when Google's advertisement-placing service, AdSense, first appeared and "turned free content into a monetisable data source".

There are already signs that mash-ups have commercial potential. Simply Hired and the social-networking site LinkedIn, for example, have already mashed themselves together. If you are a member of LinkedIn and go searching for a job on Simply Hired, you can link from a job listing to a list of LinkedIn contacts who could get you an introduction at the company in question. As well as helping users to land a job, this mash-up should help the two websites to boost their traffic. And in August, Salesforce.com, a pioneering provider of business software that runs inside web browsers, announced Smashforce, an initiative to make it easier to incorporate its software into mash-ups. A firm could, for example, combine a list of sales prospects with a map, to help a salesman plan his route.

All told, the urge to mix things up should keep companies and programmers busy for the foreseeable future—too busy, sometimes, even to use their own mash-ups. Mr Smoak, who created his mash-up during evenings and weekends, says he never gets up early enough to take the bus to his day job, at Amazon. "I'm not an early riser," he says. "But if I stay up late I can do projects like this." And what of Mr Rademacher's housing search? The popularity of his website helped land him a job at Google, but has also kept him so busy that he has not had time for any more house-hunting. ■

Sailing ships with a new twist

Transport: Giant kites that act like sails could bring wind propulsion back to ocean-going ships, reducing emissions and saving on fuel costs

IN THE first half of the 19th century, ships began to adopt steam engines, first alongside and then instead of sails. Today, wind propulsion is for sportsmen and romantics, not shipping firms trying to make money. But the high price of oil and stricter pollution regulations are strong forces working to turn back the clock. Wind propulsion is coming back in a new form: kites, not sails. Next year, SkySails, a German firm based in Hamburg, will begin outfitting cargo ships with massive kites designed to tug vessels and reduce their diesel consumption. The firm estimates that these kites will reduce fuel consumption by about one-third—a big saving, given that fuel accounts for about 60% of shipping costs.

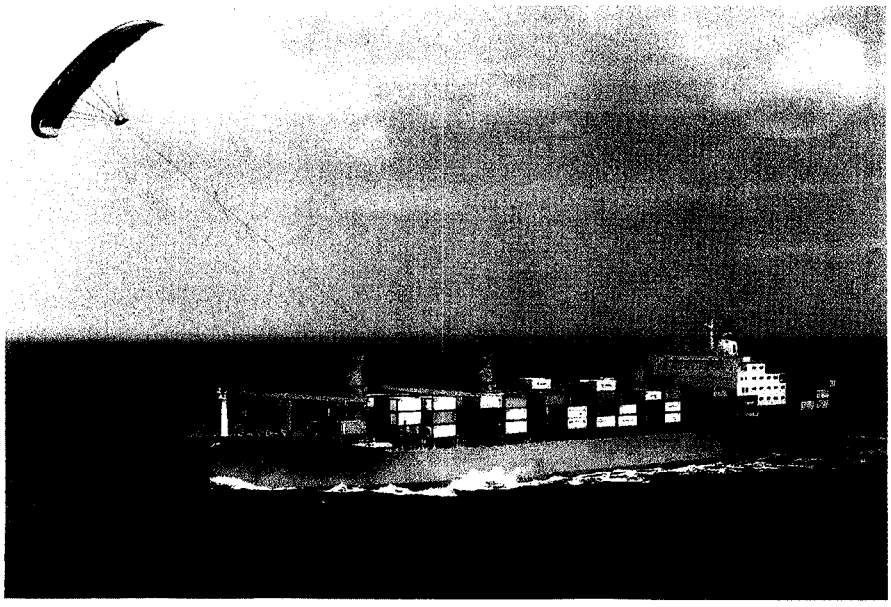
The idea of reintroducing sails to modern ships is not new. A Japanese consortium tried it in the 1970s, but got nowhere. In the 1990s, the Danish government launched Project WindShip, but it was scuttled in 1998. Other teams met failure, too. The insurmountable problem in each case proved to be the mast.

In unfavourable winds, large masts create a lot of drag. In gales, masts cause ships to heel, sometimes dangerously. Masts and their pivoting sails take up valuable container space on the deck. Loading and unloading is more expensive, since the cranes that lift containers must work around the masts. Engineers designed taller (and more expensive) masts, some exceeding 100 metres in height, to reduce their number and limit the loss of storage space. But the Panama Canal limits masts to 60 metres, and collapsible masts would be prohibitively expensive to build, operate and service.

Knud E. Hansen, the naval engineering firm based in Copenhagen that led Project WindShip, designed high-tensile steel masts with foldable carbon-fibre sails, known as vertical aerofoils because they generate horizontal thrust just as aeroplane wings create lift. The cost of retrofitting a cargo ship with a row of masts, and strengthening its hull and deck to dissipate the additional stress, was estimated at €10m ($12.5m). So the sails would have taken around 15 years to recoup their costs through fuel savings.

But the SkySails approach does away with masts and is much cheaper. The firm says it can outfit a ship with a kite system for between €400,000 and €2.5m, depending on the vessel's size. Stephan Wrage, the boss of SkySails, says fuel savings will recoup these costs in just four or five years, assuming oil prices of $50 a barrel. Jesper Kanstrup, a senior naval architect at Knud E. Hansen, says the idea of pulling a ship with an inexpensive kite—attached to the structurally solid bow like a tugboat—had never occurred to him. "It's a good idea," he says.

SkySails' kites are made of a type of nylon similar to that used in the sails of modern windjammers, but they fly between 100 and 300 metres above sea level, where winds are less turbulent and, on average, more than 50% stronger than the winds that sails capture. An autopilot ▸▸



Masts? Who needs them?

computer adjusts the height and angle of the kite, the surface area of which can range from 760 to 5,000 square metres. When the wind blows too strongly, one end of the rectangular kite is released so that the kite flaps like a flag. A powerful winch retrieves the kite when necessary.

Regulators, as well as cost savings, could boost the technology. For while both Europe and America have strict regulations on vehicle pollution, ships have enjoyed something of a free ride. Moving one tonne of goods one kilometre by ship, for example, releases about 225 times as much sulphur as trucking the goods the same distance, according to the Secretariat on Acid Rain, a Swedish pressure group. Mario Dogliani, the head of research at RINA, an organisation based in Genoa that inspects and certifies ships, says European regulators are "really pushing" for tougher emission controls, backed up with stiff fines, for shipping. "We need to innovate," he says.

In May, the International Maritime Organisation's new rules on marine pollution took effect. They require many ships to switch to a low-sulphur fuel that costs 50% more than traditional (and highly polluting) fuel oil. And an increasing number of ports now offer discounts for ships with approval labels, called Green Passports, awarded by environmental groups. It all adds up to a favourable wind for SkySails. ■

The doctor in your pocket

Medical technology: Nearly everyone in the developed world carries a mobile phone—so why not use it to deliver health care?

GARY KATZ is a repeat offender. A few years ago, a nutritionist helped him to reduce his blood-cholesterol level from a troubling 286 to a reasonable 177. But after his annual check-up in April, Mr Katz found that his cholesterol was once again too high. The businessman turned to the same nutritionist as before, but now he and his food adviser have a secret weapon: the mobile phone.

Through a new service called MyFoodPhone, Mr Katz uses the camera built into his phone to take a picture of every meal. This is far easier than writing everything down in a food log, which the 44-year-old New Yorker did the last time he was fighting high cholesterol. At the end of each week, his nutritionist e-mails him a dietary critique. "I was never one

for the whole food-log thing," says Mr Katz, who owns a floor-covering business. "Now I'm doing better at keeping track of what I eat. I always have my phone with me—it's like having a conscience hanging on your waist."

The notion of procuring health care via phone is not new: when doctors routinely made house calls, medical help was just a phone call away. "Most healthcare services today are delivered inside medical premises," says José Lacal of MotoHealth, the health-telemetry project run by Motorola, the world's second-biggest mobile-phone manufacturer. "But with the mobile phone, you can take the services with you." HBS Consulting, a consultancy based in London, estimates that the global "telehealth" market—the use of telecommunications and information technology to deliver health care and related services—will grow to $7.7 billion in 2006, up from $3.2 billion in 2003.

So far, most mobile telehealth services, such as MyFoodPhone, simply use ordinary mobile phones to collect and transmit data. The next stage is to add specific medical sensors, which can even be incorporated directly into the handset. For example, LG, a South Korean handset-maker, started selling a phone with a built-in blood-glucose meter, for use by diabetics, in its home market last year. It can transmit blood-glucose readings to a doctor, parent or desktop computer for further analysis. Healthpia America, based in Newark, New Jersey, plans to launch the phone in America in January.

Motorola and Partners Telemedicine (a division of Partners HealthCare, a group of hospitals and health-care providers in Boston) have been testing devices that can transmit a patient's weight, blood pressure and other data. Weighing scales and blood-pressure monitors communicate via Bluetooth (a short-range radio technology) with the mobile phone, which then sends the data to the doctor. Clinical trials are under way in Barcelona and Boston, says Mr Lacal, with potential commercialisation as early as next year.

In Britain, a joint-venture between the Institute of Biomedical Engineering at Imperial College London, Toumaz Technology and Oracle, the world's second-largest software firm, has devised a "pervasive monitoring system" that will enter trials in 2006. A small sensor, attached using a sticking plaster, monitors the patient's heartbeat and detects irregularities. The resulting electrocardiogram data is sent wirelessly to a nearby mobile phone, which then transmits it to a monitoring centre, or directly to a doctor.

Mobile telehealth need not be so elaborate, however. SIMpill, a South African firm, makes a small device that clips on to a medication bottle and sends a text message to a central computer whenever the cap is removed. If no message arrives, the central computer sends a text-message reminder to the patient, or to a family member or carer. The system is now used by more than 2,000 people and can dramatically improve compliance, says SIMpill's founder, David Green. It has just been launched in America.

Many observers expect mobile telehealth to take off in mobile-loving South Korea and Japan, but to lag behind in America, where consumers are more likely to raise privacy concerns. But Donald Jones, head of mobile health care at Qualcomm, a wireless-technology firm based in San Diego, notes that phones' built-in security features make them far more secure than PCs.

Besides, the need for tools to improve the management of chronic health conditions cannot be overstated. According to America's Centres for Disease Control and Prevention, more than 90m Americans have a chronic illness, and they account for over 75% of the nation's $1.4 trillion annual spending on health care. So the mobile phone could be a useful tool to combat both chronic disease and runaway medical costs. Joseph Kvedar of Partners Telemedicine, who is also a professor at the Harvard Medical School, suggests that insurance companies might, for example, offer free phone minutes to customers who go for a walk every day. Their compliance would be monitored by a pedometer built into the handset.

Mobile phones' impact on health care could be even greater in the developing world, where mobiles far outnumber PCs. "For most of the world", says Mr Jones, "this is the only computer they are ever going to own. It's on the internet. And they carry it everywhere." Get ready for the doctor in your pocket. ■

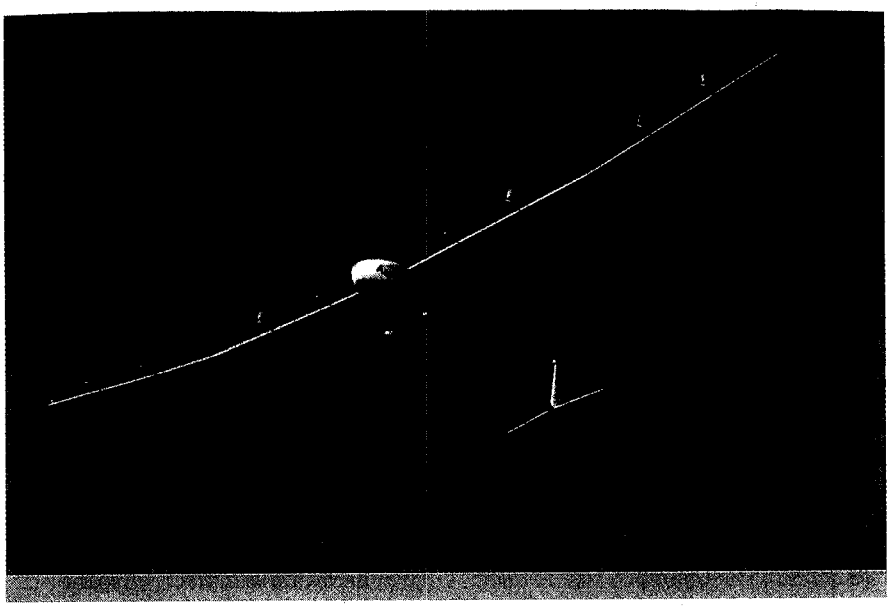
Summer camp for coders

"I'M A total geek all around," says Angela Byron, a 27-year-old computer programmer who has just graduated from Nova Scotia Community College. And yet, like many other students, she "never had the confidence" to approach any of the various open-source software communities on the internet—distributed teams of volunteers who collaborate to build software that is then made freely available. But thanks to Google, the world's most popular search engine and one of the biggest proponents of open-source software, Ms Byron spent the summer contributing code to Drupal, an open-source project that automates the management of websites. "It's awesome," she says.

Ms Byron is one of 419 students (out of 8,744 who applied) who were accepted for Google's "summer of code". While it sounds like a hyper-nerdy summer camp, the students neither went to Google's campus in Mountain View, California, nor to wherever their mentors at the 41 participating open-source projects happened to be located. Instead, Google acted as a matchmaker and sponsor. Each of the participating open-source projects received $500 for every student it took on; and each student received $4,500 ($500 right away, and $4,000 on completion of their work). Oh, and a T-shirt.

All of this is the idea of Chris DiBona, Google's open-source boss, who was brainstorming with Larry Page and Sergey Brin, Google's founders, last year. They realised that a lot of programming talent goes to waste every summer because students take summer jobs flipping burgers to make money, and let their coding skills degrade. "We want to make it better for students in the summer," says Mr DiBona, adding that it also helps the open-source community and thus, indirectly, Google, which uses lots of open-source software behind the scenes. Plus, says Mr DiBona, "it does become an opportunity for recruiting."

Elliot Cohen, a student at Berkeley, spent his summer writing a "Bayesian network toolbox" for Python, an open-source programming language. "I'm a pretty big fan of Google," he says. He has an interview scheduled with Microsoft, but "Google is the only big company that I would work at," he says. And if that doesn't work out, he now knows people in the open-source community, "and it's a lot less intimidating."



Held aloft by hydrogen

Aviation: An unmanned aircraft powered by hydrogen has taken to the air for the first time. Such aircraft could have both military and civilian uses

BLAME it on the Hindenburg. Ever since the hydrogen-filled German airship exploded in 1937, hydrogen and aviation have not had much to do with each other. But a new aircraft, which made its first flight in May, could change that. *Global Observer*, the world's first liquid-hydrogen powered, unmanned-aerial vehicle (UAV), is not an airship, but an aeroplane that uses hydrogen as a fuel. It was built by AeroVironment, a firm based in Monrovia, California, which announced at a UAV conference in June that *Global Observer* had made its first flight above the desert sands of Yuma, Arizona.

Having pioneered solar-powered flight in the 1990s with America's space agency, NASA, AeroVironment has since refocused its efforts towards fuelled UAVs. Solar-powered UAVs promise potentially unlimited hours in the sky, but they have limitations. At latitudes above 45°, and during the winter, the sun is too weak to keep the aircraft flying. Liquid hydrogen is an attractive fuel for a high-altitude, long-endurance vehicle, since it has around three times as much energy per unit of mass as conventional jet fuel. The difficulty is keeping it liquid, since hydrogen boils at -253°C. *Global Observer* has a special insulated storage tank that can hold enough liquid hydrogen to keep the plane aloft for 24 hours. The hydrogen is combined with oxygen from the air in a fuel cell, producing electricity that drives the aircraft's propellers and powers its onboard systems. The aircraft is a scaled-down version of a much larger aircraft that would be able to stay aloft for more than a week.

Such an aircraft would have a number of uses as a low-cost alternative to satellites. Equipped with wireless-broadband relays, imaging equipment or monitoring devices, it could be used for surveillance, weather monitoring and telecommunications. In 2002, AeroVironment demonstrated the use of a solar-powered UAV as a mobile-phone relay and a TV broadcasting platform, in conjunction with NEC, Toshiba and other Japanese firms.

Ted Wierzbanowski, AeroVironment's managing director, admits that many people were sceptical about the switch to hydrogen. "Building the prototype was the only way to put the hydrogen bogeyman to bed," he says. "We think this is a big paradigm shift in the aerospace and space industry." The prototype aircraft has a 15-metre wingspan, but he expects two production versions, with 46-metre and 76-metre wingspans. Loitering at altitudes of between 18,000 and 21,000 metres, they would work in threes: as one plane started to run out of fuel, another would take off, to ensure continuous broadband or TV coverage.

But several challenges remain. One of the biggest is reliability, according to John Del Frate, the former manager of NASA's Environmental Research Aircraft and Sensor Technology project. "Most commercial aircraft have to be inspected every 100 or 200 hours," he says. "In one flight of these hydrogen and solar-powered vehicles, we'll easily exceed that ▸▸

amount." Worse, the aircraft must be able to withstand ultraviolet radiation, freezing temperatures and high winds, says Mr Del Frate, though AeroVironment claims to have addressed these problems.

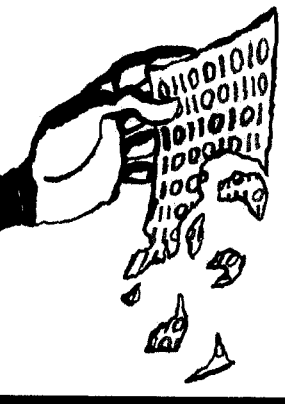
Then there is the small matter of convincing potential buyers, such as Colonel Patrick Rhodes, the commander in charge of America's Air Force Space Command "Battlelab", which tests new technologies for the military. For the moment, he says, "hydrogen-powered lighter-than-air and heavier-than-air vehicles that will provide significant persistence over an area are not there yet." But Major-General Douglas Fraser, director of air and space operations for Air Force Space Command, is optimistic that the new UAVs will eventually prove themselves.

The new aircraft also faces competition from rival technologies, such as the "Stratellite", a helium-filled airship being developed as a communications relay by GlobeTel Communications, a firm based in Florida. Mr Wierzbanowski reckons his approach has lower running costs, but airships can lift larger payloads. So there may be room in the stratosphere for both technologies. ■

A new way to stop digital decay

Computing: Could a "virtual computer", built from software, help to save today's digital documents for historians of the future?

WHEN future historians turn their attention to the early 21st century, electronic documents will be vital to their understanding of our times. Old web pages may not turn yellow and brittle like paper, but the digital documents of today's culture face a more serious threat: the disappearance of computers able to read them. Even a relatively simple electronic item, such as a picture, requires software to present it as a visible image, but 100 years from now, today's computers will have long since become obsolete. More complex items, like CD-ROMs or videos, will be unreadable even sooner.



In 1986, for example, 900 years after the Domesday book, the BBC launched a project to compile data about Britain, including maps, video and text. The results were recorded on laserdiscs that could only be read by a special system based around a BBC Micro home computer. But since the disks were unreadable on any other system, this pioneering example of multimedia was nearly lost for ever. It took two and a half years of patient work with one of the few surviving machines to move the data on to a modern PC (it can be seen online at www.domesday1986.com).

National libraries are just starting to grapple with this problem as part of their new mandate to preserve digital culture. "It is a major problem, but it is remarkable how little known it is," says Hilde van Wijngaarden, head of digital preservation at the National Library of the Netherlands. "People just accept that things no longer work after ten years."

Keeping working examples of all computer hardware is impractical, so the most popular preservation strategy is to copy files from one generation of hardware to the next. The problem is that today's word processors and web browsers, for example, do not always display files in the same way that older software did. An accumulation of subtle errors can eventually make the original item unreadable. An alternative approach, called emulation, uses software to simulate the old hardware on a modern computer, to allow old software to run. But today's emulators will need another emulator to run on the next generation of hardware, which will need another emulator for the next generation, and so on. This can also introduce errors.

So the National Library of the Netherlands is exploring a third option, using a simulated computer that exists only in software. It is called the Universal Virtual Computer (UVC) and is being developed by IBM, a computer giant. The researchers are writing programs to run on this virtual computer that decode different document formats. Future libraries will have to write software that emulates the virtual computer on each new generation of computer systems. But once that is done, they will be able to view all their stored documents using the decoders written for the virtual computer, which only have to be written once. "The decoder can be tested for correctness today, while the format is still readable," says Raymond van Diessen of IBM.

His team has written decoders for two common image formats, JPEG and GIF. They plan to move on to Adobe's PDF format. IBM is also talking to drug firms, which are required to store data from clinical trials for long periods. Ultimately, the aim is to be able to preserve anything from simple web pages to complex data sets. Ominously, some scientific data from the 1970s has already crumbled into unreadable digital bits. ■

The policeman on your dashboard

Transport: A new satellite-based driver-monitoring scheme could provide a glimpse of the Big Brotherish future of motoring

FOR years, traffic police and motorists have been engaged in an arms race. As the police have adopted speed guns and roadside cameras, drivers have taken to radar detectors and maps showing camera locations. But a new system being developed in the United Arab Emirates (UAE) could hand ultimate victory to the traffic police. The UAE is investing $125m in a system that will make it possible to determine the speed of any of the Gulf state's 2m vehicles, no matter where they are. New devices, now being developed by the UAE's Centre of Excellence for Applied Research and Training (CERT) in conjunction with IBM, should be ready for installation in cars within four years.

Once fitted, these devices will use global positioning system (GPS) satellites to determine the car's location to within a few metres, says Farid Metwaly of IBM. By combining several position and time measurements, it is a simple matter to determine the car's speed. This can then be compared with a database of speed limits for all roads in the country. If the vehicle is breaking the local speed limit, the system will issue an audible alert, warning the driver to slow down. "It gives you ten seconds to slow down, and if no action is taken it will issue another warning," says Mr Metwaly. "If you still don't slow down, it will record the event."

What happens next remains to be seen. The system will be able to inform a central government server of such "events" via the mobile-phone network. But whether that information will be used to issue speeding fines, or simply retained for statistical purposes, is unclear. "It is for the country to decide what to do with this information," says Mr Metwaly. There is no doubt about the motivation behind the new system, however. The UAE has one of the worst road-safety records in the world: compared with most European countries or America, there are more than six times as many deaths per passenger mile on its roads.

The prospect of having a policeman on the dashboard might seem a little Big Brotherish to some people. But the UAE project may merely offer a glimpse of what regulators in other countries are also planning. Switzerland and Germany have already introduced automatic road-

toll systems for freight vehicles. These are widely seen as a prelude to extending similar measures to cars. The British government has suggested replacing its current road-tax scheme with a satellite-based "pay as you drive" system for all vehicles. The UAE system will also be used for road-taxing and for car-insurance purposes, says Tayeb Kamali, the chief executive of CERT. But it has not yet been decided whether charges and insurance premiums will be based on distance, time of travel or route taken.

Nor is it clear how the system will be rolled out. "I don't think you can make it compulsory," says Dr Kamali. But who would volunteer to have such a technological tattle-tale installed? It is all a matter of incentives, says Mr Metwaly: cheaper tax and insurance, perhaps, and the ability to determine the vehicle's position in the event of an accident.

Another crucial issue is accuracy. If, as Dr Kamali says, the system is to be able to tell when a driver runs a red light, then the accuracy will have to be good enough to stand up in court. The UAE project will test not just new technology, but new business models and regulations too. ■

Hear no evil

Digital media: Can an "open source" approach be applied to the music business? Magnatune, an innovative record label, thinks it can

IF, AS many people hope, the internet means that the major record labels will gradually become obsolete, what exactly is going to displace them? Apple's iTunes is clearly a part of the future, but it is arguably just a new distribution channel for the major labels' 50-year-old system of big stars and massive marketing budgets. A more radical answer is Magnatune, an independent online record label founded in 2003 by John Buckman. It has all the ingredients that could help future artists bypass traditional labels, earn more money and enjoy greater artistic freedom.

From a listener's point of view, the firm's website, www.magnatune.com, is enticing. You can legally listen, free of charge and with high sound quality, to full albums by any of the 200 or so artists who have signed to the label. (Your correspondent was immediately hooked by a song called "Making Me Nervous" by a one-man electro-pop band from Ottawa called Brad Sucks.) Music streamed is free, but to download it to your computer or burn CDs, you have to pay. Just how much is a matter of choice—Magnatune allows you to decide what the music is worth, and to pay as little as $5 for an album or as much as $18. Once paid for, the music is not locked up using "digital-rights management" software, so you are not prevented from making copies. Instead, Magnatune relies on its customers' loyalty to its artists not to pirate their music indiscriminately.

Mr Buckman likens this community-based, free-wheeling approach to that of Linux, the open-source operating system, although the analogy is inexact: Magnatune's customers do pay for music, you cannot remix and redistribute it, and the company does make a profit. What is more Linux-like is Magnatune's desire to unseat the industry incumbents and change the rules of the game by giving the artists a fairer, less restrictive deal.

Magnatune's slogan, "We are not evil", owes a debt to Google's slogan ("Don't be evil") and is a sideswipe at the major labels. Its contract is non-exclusive, so musicians are allowed to carry on selling their music elsewhere. And the label gives artists half of the revenues from what they sell online. Major labels typically give 10% or less.

Most of the artists on the site are professional musicians, and many have been signed at some point to the "evil" kind of record label. Some, like Trevor Pinnock, a conductor and harpsichordist, are famous, but others are unknowns who sent in a demo. Magnatune has a dedicated "artists and repertoire" (A&R) man, and gets about 400 submissions from new artists each month, from which it signs five or ten. It restricts itself to seven main genres—classical, electronica, jazz and blues, metal and punk rock, new age, rock and pop and world. Some genres are dying out in the world of physical CDs, says Mr Buckman, and Magnatune will soon be one of the few places you can find them. He is also a devotee of early classical music, which has a strong presence on Magnatune. Around 10,000 people visit the site every day, and one in 42 visitors buys some music—a far better ratio than the average for e-commerce (where conversion rates are typically between 1 in 400 and 1 in 1,000), and not much worse than in bricks-and-mortar music stores, where it takes 20 customers to generate a sale.

Magnatune has exceeded Mr Buckman's expectations in music licensing, another side of the business that has played a big part in helping it reach profitability. For non-commercial use, such as a school project, the site allows music to be used under a "Creative Commons" licence, a concept devised by Lawrence Lessig, a law professor and crusader for internet freedom. For commercial use, Magnatune makes licences available quickly and cheaply online. This business is growing at 30%, as Magnatune has become popular with independent filmmakers looking for soundtracks.

Though plenty of commentators have seized upon Magnatune as the online music model of the future, Mr Buckman has relatively modest aims. "We're going to stick to second-tier genres and we're not going after the majors," he says. For now, that is probably realistic, since like other internet-music ventures, Magnatune's weakness is that it does not have the resources to propel its artists into the mainstream via radio and television. For that reason, says Mr Buckman, it tends not to get musicians in their 20s sending in music. "They have an unpleasant attitude and still think they'll get the limo and the drugs," he says.

So artists considering the 50/50 split should remember that Magnatune is, for now at least, a fairly passive label. In contrast, says Brad from Brad Sucks, "the majors front all that money and take a lot of risk and they do deserve to get some money back." Any artist on Magnatune who was offered a deal with a major would jump at the chance, says Costa Pilavachi, president of Decca Music Group, a classical label owned by Universal Music Group, the world's largest major label.

This month Magnatune is introducing a new marketing strategy: if you buy some music, you are allowed to give it to three friends—another nod in the direction of the "share and share alike" spirit of the open-source movement. And even if Magnatune itself turns out not to be the web-powered destroyer of the major labels that everyone is waiting for, other, different models will come later. Even Warner Music, one of the majors, is said to be planning to launch an internet-only "e-label" later this year. It will only take one rock star born on the internet, after all, for everyone to pronounce the old model completely dead. ■

Building a better battery

Energy: As portable devices become ever more elaborate and demand ever more power, will battery technology be able to keep up?

JUST as you can never be too rich or too thin, you can never have a battery that lasts too long. But as mobile devices accumulate new power-sapping features, battery technology has been struggling to keep up. This led Yrjö Neuvo, the chief technologist at Nokia, the world's largest handset-maker, to warn of an impending mobile-energy crisis last year. But now several new developments could be about to come to the rescue.

In February, Altair Nanotechnologies, a small firm based in Reno, Nevada, announced a new kind of lithium-ion battery, the technology that powers many portable devices. Its prototype has three times the capacity of existing batteries and can be fully charged in six minutes.

Lithium-ion batteries are so named because during charging and discharging, lithium ions migrate between the battery's positive electrode (anode) and negative electrode (cathode). Altair's trick was to coat the anode with lithium-titanate nanocrystals, says Roy Graham, the company's development director. This enlarges the surface area of the anode from around three square metres per gram to 100 square metres, increasing the capacity of the battery and boosting the rate at which ions are able to move to and from the anode, which is what determines how long it takes to charge. In June, Altair secured a $477,000 grant from America's National Science Foundation to further its design by using nanoparticles on both electrodes. This could further increase power density and reduce charging time, says Mr Graham.

Hard on the heels of Altair's announcement, Toshiba revealed that it too has developed a battery using nanotechnology that is capable of charging to 80% of full capacity in one minute. The company is still working on improving the stability and reliability of the design, but plans to start selling the new batteries next year. Hiroko Mochida of Toshiba says the initial uses will be in electric cars and power tools, where high capacity and rapid charging are particularly necessary. Toshiba will not go into detail about its new design, but, like Altair's, it seems to use nanoparticles to increase the surface area of the electrodes.

There have also been recent improvements to a completely different kind of battery design, known as "beta voltaic" technology. Such batteries use beta particles from a radioactive source to generate a current in semiconductor material, in much the same way that photons liberate electrons to generate a current in photovoltaic solar cells. Batteries of this type can run for years, and are used in devices such as space probes and pacemakers, where changing the battery is impractical. Beta voltaics are safe and reliable but are limited by very low energy yields, says Philippe Fauchet of the University of Rochester in New York.

Now his team has developed a way to increase the power output tenfold, by increasing the surface area of the exposed semiconductor. Instead of a flat surface, his design uses a type of porous silicon, the surface of which is riddled with tiny pits. The radioactive gas within the pits is then almost entirely surrounded by the semiconductor, increasing the chances of catching the beta particles. The technology is now being developed by BetaBatt of Houston, Texas, which co-developed the new design. There is a growing demand for long-life batteries in medical applications, he says.

It all sounds promising. But no matter how hard researchers work to cram more energy into batteries, they are vastly outnumbered by other researchers dreaming up new ways to consume it. ■

No jam tomorrow?

Transport: New techniques are being developed to spot existing traffic jams, predict future ones, and help drivers avoid both kinds

IS SITTING in traffic as inevitable as death and taxes? Perhaps not. Many countries now have dedicated traffic-monitoring centres linked to networks of cameras and sensors. Throw in traffic-spotting aircraft, accident reports and the known positions of buses fitted with satellite-positioning gear, and it is possible to see exactly what is happening on the roads. Drivers could switch from busy to quiet routes and avoid congestion—if only they had access to this information.

And now they do. Systems such as the Traffic Message Channel and the Vehicle Information and Communication System (VICS), in Europe and Japan respectively, pipe data from traffic centres into in-car navigation systems via FM radio signals. Drivers can see where the traffic

An all-too-familiar sight

is and try to avoid it. Honda, a Japanese carmaker, even combines VICS data with position data from 150,000 vehicles belonging to members of its Premium Club so that they can choose the fastest lane on a congested road, says David Schrier of ABI Research, a consultancy.

Meanwhile ITIS, a British company, is one of several firms experimenting with mobile-phone signals to monitor traffic on roads that lack sensors or cameras. Its software hooks into a mobile operator's network and uses a statistical approach to deduce traffic speeds as phones are "handed off" from one cell tower to another. The data must be cleaned up to exclude pedestrians and cyclists, but this idea has great potential, says Mr Schrier.

Another way to dodge traffic is to predict where and when it will form. In Redmond, Washington, at the headquarters of Microsoft, employees have been testing a traffic-prediction system called JamBayes. Users register their route preferences and then receive alerts, by e-mail or text message, warning them of impending gridlock. JamBayes uses a technique called Bayesian modelling to combine real-time traffic data with historical trends, weather information and a list of calendar events such as holidays. Eric Horvitz of Microsoft, who developed the system, says it is accurate 75% of the time, and 3,000 employees use it daily.

A system called Beat-the-Traffic, developed by Triangle Software of Campbell, California, with funding from the National Science Foundation, goes further. It not only warns drivers of impending traffic but also suggests an alternative route via e-mail or text message. Andre Gueziec, the firm's boss, thinks traffic forecasts will become as prevalent as weather forecasts. Indeed, in June, KXTV News 10, a TV station in Sacramento, California, began showing Triangle's traffic forecasts for the coming week. ■

Websites of mass description

Social software: New "tagging" websites make it easier to share content, find items of interest, and form online communities

THE images flicker across the screen, one every few seconds: a bed, its ruffled covers pulled back to reveal a lonely emptiness; two pairs of lips gently touching, on the verge of a kiss; a lamb playfully nuzzled beneath its mother's belly; two little girls whispering secrets to one another. The photographs come from a college student in Oklahoma, a middle-aged man from rural England, and a Dutch woman, none of whom has ever spoken with or met any of the others. Each photo takes its place among the rest simply because it has been "tagged" by its photographer with the word "intimacy".

The photographs form part of a slideshow on Flickr.com, a website that allows its users to store, manipulate and share their digital photos. While such sites have been around for years, Flickr stands out because it makes it easy for users to categorise, search and share photos through "tags"—one-word descriptions that capture the essence of a photograph. A tag can be a name or a place, an adjective or a verb, concrete or abstract.

More importantly, though, tags allow Flickr and other sites that rely on them to harness the social power of the web. Give users the option to make their content public, and the ability to search everyone else's content for a given tag, and a world of possibilities opens up. As thousands of users tag photographs and web pages, information begins to percolate in new ways. Users themselves build a database of what is useful and important for others to draw upon. For example, a search for the tag "love" on Flickr brings up almost 20,000 photos that encapsulate people's idea of love.

What Flickr does for photographs, del.icio.us (pronounced "delicious") does for bookmarks, by providing management of bookmarked web pages. Hundreds of thousands of registered users have so far linked to over 10m web pages. Traditionally, bookmarks are stored within a web browser on a computer, and can only be accessed from that particular computer. With del.icio.us, users add bookmarks to their personal del.icio.us web page simply by entering the address of a web page and typing in a few words to tag it. The bookmarks can then be accessed from any computer. A user can surf cooking sites and tag "recipes" at the office, for example, and then easily access them from home.

For each bookmark, users can also see how many other users have bookmarked it and who they are. If another user's interests seem similar, their bookmarks can be called up to find new, unexplored sites. All of the bookmarks collected by all users can also be searched by tag, and the most popular links at a given time give a glimpse of the web in motion. With Yahoo! or Google, a mindless software "spider" is sent out to traverse the web looking for new pages. With del.icio.us, an army of people sitting in their homes and offices does the same, tagging web pages as they go along.

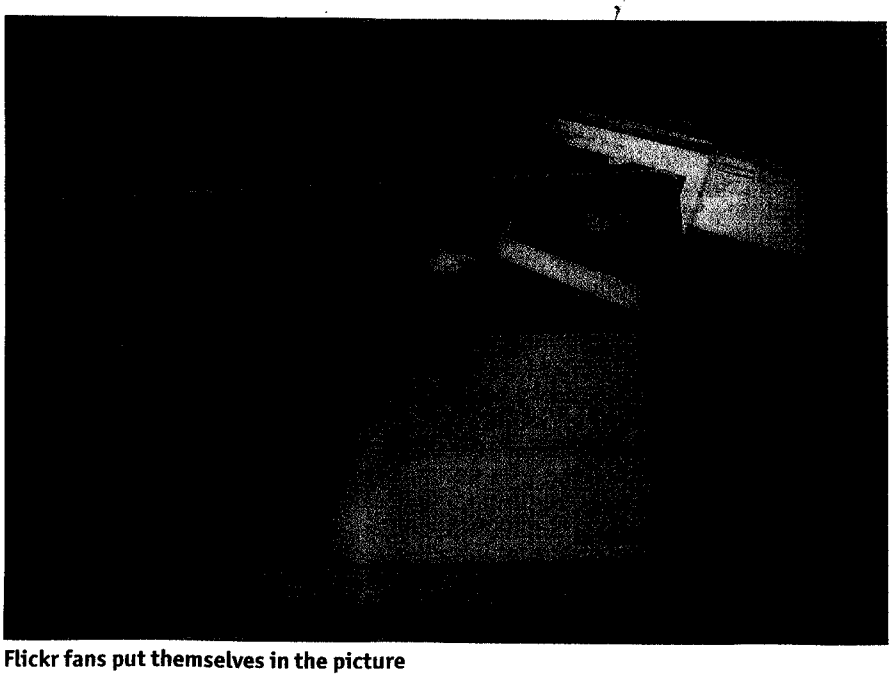
Because tags make it easy to share content, users of Flickr have also begun to interact with their photos in new and interesting ways, as communities have formed around particular tags. These communities of convenience are not based on real world connections or networking, but rather on bits of content. Consider the tag "memorymaps", for example. Memory maps are digital scrapbooks that make use of another feature of Flickr—the ability to annotate photographs with boxes which display pop-up captions when the mouse pointer rolls over them. Starting with a satellite image of a city or town, users attach captions to places of particular significance: their old school-friends' houses, for example. The memory map can then be shared with friends or added to by others who live in that city. Users of another tagging site, Tagzania.com, sprinkle maps with restaurants, bars and other places of interest.

After the London terrorist bombings in July, a Flickr group quickly formed to share photos of the aftermath. Since users can upload photos directly to the site from mobile phones and add comments to photos, an image of a tube ticket bought at King's Cross station on July 7th became a forum for people to share their thoughts and offer their condolences.

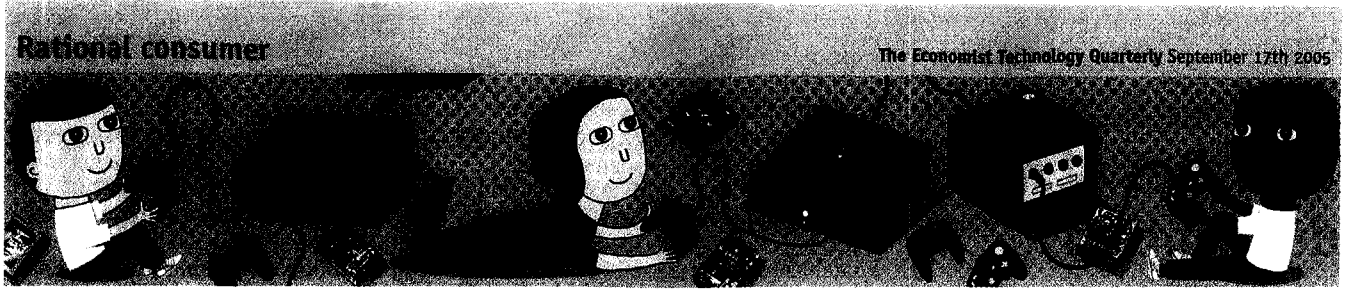
Other users simply want to have fun. The "infiniteflickr" tag invites people to contribute photos of themselves looking at Flickr photos of people looking at Flickr photos—*ad infinitum*. The Flicky Awards group votes for its favourite photos in different categories (self-portraits, underwater photography, and so on). A group calling itself "It's the Crew" uses Flickr to make bizarre online comic books. Photos are doctored using Photoshop, have captions added, and tell a story when viewed as a slideshow.

MAKE, a magazine geared toward hobbyists who like to play with and modify technology, has embraced both Flickr and del.icio.us as new ways to interact with readers. Writers contribute useful links and photos of projects as they research and write their stories; readers view and add to them as they work on projects of their own.

Is it all just another internet fad? In March, Flickr was acquired by Yahoo!, and in July Yahoo! launched MyWeb 2.0, a del.icio.us-like bookmarking site. Other tagging sites have sprung up that let users catalogue book recommendations or restaurant reviews. Technorati.com, which has been tracking blog entries using tags since 2002, now lets users search through Flickr photos and del.icio.us links as well. Having brought together social software, blogging and search, the idea of social searching (and tagging) looks as though it is here to stay. ■



Flickr fans put themselves in the picture



Gaming's next level

Consumer electronics: How will the next-generation games consoles differ, and how can they attract new gamers?

ARE you a PlayStation person, an Xbox aficionado or a Nintendo nut? You may not play video games at all, of course. But if you do, you will be aware that each of the three main games consoles has strengths and weaknesses that make it appeal to a particular audience.

Of the current console line-up, Sony's PlayStation 2 is the most popular machine, with the broadest choice of games. Its success is the result of several factors, including Sony's decision to launch the PlayStation 2 earlier than its two rivals, which gave it an insurmountable head start; its support for older games written for the original PlayStation console; its ability to function as a DVD player; and Sony's close partnerships with games publishers, which ensured a stream of popular titles. All of this enabled Sony to garner a 70% global market share.

But the two other current consoles have devoted fans as well. Nintendo's GameCube has a far narrower range of games than Sony's console, but what it lacks in quantity it makes up for in quality, at least for the family-oriented audience that Nintendo targets. Most of the best GameCube games, such as the Mario and Zelda franchises, are published by Nintendo itself, since third-party publishers have not really embraced the GameCube. But because Nintendo has very high production standards, the games that are available are impressive. And because most of the money in the games industry is made from software, not hardware, Nintendo makes the most profit among gaming firms, even though it has only a 15% market share, notes Paul Jackson of Forrester, a consultancy.

Microsoft, in contrast, has yet to turn a profit from its expensive foray into gaming. As the last of the three consoles to reach the market, the Xbox is easily the most powerful, so it appeals to hard-core gamers. After a slow start it now has an impressive line-up of games, including the "Halo" series of sci-fi shoot-'em-ups, which are not available on any other console. The Xbox also has by far the best online-gaming service, Xbox Live, which is run by Microsoft itself. All of this has helped the Xbox to do well in America, though it is still far behind the PlayStation 2, and its sales in Japan were dismal.

In short, then, the PlayStation 2 has the broadest appeal; the GameCube is aimed at younger gamers and families; and the powerful Xbox has been embraced by hard-core gamers. (Things are not quite this simple, of course, since many popular games are available on two or three of the consoles, and many dedicated gamers own more than one console.) The big question now, as the three firms prepare to launch their next-generation consoles, is how they will position them to maximise their appeal.

Changing the game

This time Microsoft is going first, with a November launch for its new console, the Xbox 360. Its aim is to establish an early lead, just as Sony did with the PlayStation 2 last time around. Microsoft has also made an enormous effort to bring Japanese games-publishers on board, to counter the home-field advantage enjoyed by its two Japanese rivals; the Xbox 360 will have 45 Japanese titles by the end of the year. Microsoft has also made some innovative marketing moves. It unveiled the console on MTV, rather than at a big industry trade show, in an attempt to reach out to consumers directly and steal "mindshare" from its rivals.

In addition, Microsoft has used a trendy technique called "alternate reality gaming" to leak details of its new machine and create buzz on gaming websites. And it has struck a deal with Samsung, so that the consoles will be placed next to high-definition televisions in big stores, where they will be seen by non-gamers. (The next-generation consoles are expected to prompt a flurry of interest in high-definition televisions, for which other content is currently lacking.) Overall, so radical is Microsoft's change of positioning compared with the original Xbox, which was aimed at hard-core gamers, that the new machine really ought to be called the Xbox 180, jokes Ross Rubin of NPD Group, a market-research firm.

For its part, Sony is emphasising the raw power of its new console, the PlayStation 3, which is based around a new chip, called Cell, and a high-capacity Blu-ray optical drive. This will give it substantially greater processing power and storage capacity than the Xbox 360, but both technologies are new and unproven, and it is not clear that consumers other than hard-core gamers really care about such things. And if technological teething problems delay the PlayStation 3 beyond its planned introduction next spring, Sony could lose a lot of ground to Microsoft.

Nintendo has not been so forthcoming about its new console, the Revolution, which is also due next year, except to say that it will have an unusual new kind of controller and—in addition to new titles—will be able to play Nintendo's entire back-catalogue of games, accessible via the internet. The idea is that these older games will draw in casual gamers who are put off by the complexity of modern titles, says Mr Rubin, though using today's powerful consoles to play classic games "doesn't seem to be an efficient use of resources". Even so, the success of Nintendo's touch-screen handheld console, the DS, suggests that innovative technology plus relatively simple games is indeed a winning formula.

The next round, then, will pit Microsoft's marketing might against Sony's technological prowess and Nintendo's quirkiness and innovation. What will ultimately determine the outcome, however, is the games. "It comes down to the software titles," says Mr Rubin. People buy consoles to play particular titles, not because they are impressed by their technical specifications. Most observers expect Microsoft to reduce but not eliminate Sony's lead, so that Sony captures 45% of the market next time around, with Microsoft on 40% and Nintendo on 15%. "It's really Sony's game to lose," says Mr Jackson. But whatever happens, at least gamers should have fun. ■

And now, the war forecast

Software: Can software really predict the outcome of an armed conflict, just as it can predict the course of the weather?

IN DECEMBER 1990, 35 days before the outbreak of the Gulf war, an unassuming retired colonel appeared before the Armed Services Committee of America's House of Representatives and made a startling prediction. The Pentagon's casualty projections—that 20,000 to 30,000 coalition soldiers would be killed in the first two weeks of combat against the Iraqi army—were, he declared, completely wrong. Casualties would, he said, still be less than 6,000 after a month of hostilities. Military officials had also projected that the war would take at least six months, including several months of fighting on the ground. That estimate was also wide of the mark, said the former colonel. The conflict would last less than two months, with the ground war taking just 10 to 14 days.

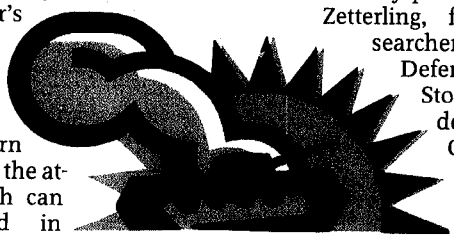
Operation Desert Storm began on January 17th with an aerial bombardment. President George Bush senior declared victory 43 days later. Fewer than 1,400 coalition troops had been killed or wounded, and the ground-war phase had lasted five days. The forecaster, a military historian called Trevor Dupuy, had been strikingly accurate. How had he managed to outperform the Pentagon itself in predicting the outcome of the conflict?

His secret weapon was a piece of software called the Tactical Numerical Deterministic Model, or TNDM, designed by the Dupuy Institute, an unusual military think-tank based near Washington, DC. It was the result of collaboration between computer programmers, mathematicians, weapons experts, military historians, retired generals and combat veterans. But was the result a fluke, or was the TNDM always so accurate?

Bosnia was its next big test. In November 1995, General Wesley Clark asked the Dupuy Institute to project casualty scenarios for NATO's impending peacekeeping mission, Operation Joint Endeavour. The resulting "Bosnia Casualty Estimate Study", prepared using results from the TNDM, stated that there was a 50% chance that no more than 17 peacekeepers would be killed in the first year. A year later, six had died—and the Dupuy Institute's reputation had been established.

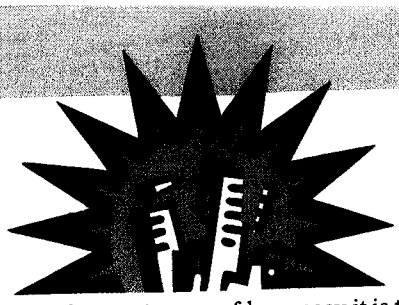
The TNDM's predictive power is due in large part to the mountain of data on which it draws, thought to be the largest historical combat database in the world. The Dupuy Institute's researchers comb military archives worldwide, painstakingly assembling statistics which reveal cause-and-effect relationships, such as the influence of rainfall on the rate of rifle breakdowns during the Battle of the Ardennes, or the percentage of Iraqi soldiers killed in a unit before the survivors in that unit surrendered during the Gulf war.

Analysts then take a real battle or campaign and write equations linking causes (say, appropriateness of uniform camouflage) to effects (sniper kill ratios). These equations are then tested against the historical figures in the database, making it possible to identify relationships between the circumstances of an engagement and its outcome, says Chris Lawrence, the Dupuy Institute's director since its founder's death in 1995.



All of this is akin to working out the physical laws that govern the behaviour of the atmosphere, which can then be used in weather forecasting. But understanding the general behaviour of weather systems is not enough: weather forecasting also depends on detailed meteorological measurements that describe the initial conditions. The same is true of the TNDM. To model a specific conflict, analysts enter a vast number of combat factors, including data on such disparate variables as foliage, muzzle velocities, dimensions of fordable and unfordable rivers, armour resistance, length and vulnerabilities of supply lines, tank positions, reliability of weapons and density of targets. These initial conditions are then fed into the mathematical model, and the result is a three-page report containing predictions of personnel and equipment losses, prisoner-of-war capture rates, and gains and losses of terrain.

What is perhaps even more surprising than the TNDM's predictive accuracy is the fact that it is for sale. The $93,000 purchase price includes instruction classes, a year of technical support and a subscription to the TNDM newsletter, although subsequent updates to the software cost extra. Organisations that have acknowledged buying the software include the defence ministries of Sweden, South Africa, Finland, Switzerland and South Korea, along with the aerospace giant Boeing. Such customers rarely divulge the uses to which they put the software. But Niklas Zetterling, formerly a senior researcher at the Swedish National Defence Research Institute in Stockholm and now an academic at the Swedish War College, says his country uses the software to improve its arsenal. Mr Zetterling toyed with the ▸▸



software's technical variables "to create hypothetical weapons" that could then be proposed to engineers.

Rather than simply buying the TNDM, most clients contract the Dupuy Institute to produce studies that combine the software's predictions with human analysis. American clients have included the Joint Chiefs of Staff, the Army Medical Department, the Department of Defence, the Vietnam Veterans of America Foundation and the Sandia National Laboratories (a government-owned weapons-research centre run by Lockheed Martin). The institute is currently preparing a secret forecast of the duration and intensity of the Iraqi insurgency for the Centre for Army Analysis, a Pentagon agency.

Leader of the pack

The TNDM is not the only war-forecasting system. Many other systems have been developed, primarily by armed forces, government agencies and defence contractors in America, Australia, Britain, France and Germany. Some are glorified spreadsheets, but many are far more complex, including the American Navy's GCAM software, the OneSAF model used by the Army and Marine Corps, the Air Force's BRAWLER system and the Australian Department of Defence's JICM. With all these systems, younger officers tend to have more faith in the technology than their older counterparts. (According to a joke among technophiles, old-school military planners refuse to upgrade from BOGSAT, or "Bunch of Guys Sitting Around a Table".)

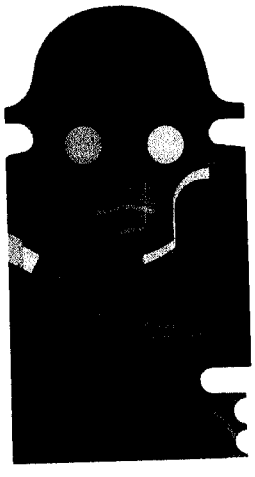
A survey of American war-forecasting systems by the Dupuy Institute found that very few are for sale or hire, and officials in charge of government models are often unwilling to share them with rival agencies. The simple availability of the TNDM has favoured its growth, although technology-transfer laws not surprisingly restrict its sale to certain countries.

Another attraction of the TNDM over rival models is the Dupuy Institute's independence: it has no weapons to sell, is not involved in internecine competition for budgetary funding, and has no political stake in military outcomes. Software developed primarily for, or by, a contractor or a branch of the armed forces often favours certain hardware or strategies, says Manfred Braitinger, head of forecasting software at IABG, a Munich-based firm that is Germany's leading developer of war-forecasting systems. The Air Force and Army models differ widely, for example, in their estimates of how easy it is to shoot down planes. "If you run both models you will see a remarkable difference in attrition rates simulating the same scenario," Mr Braitinger says. Systems with a wide customer base, like the TNDM, are regarded as more credible, since they do not have such biases.

The TNDM's reliance on real combat data, rather than results from war games or exercises, also gives it an edge. Another forecasting system, TACWAR, was used by America's Joint Chiefs of Staff to plan the overthrow of Saddam Hussein. Like many models, it was largely developed with data from war games. As a result, says Richard Anderson, a tank specialist at the Dupuy Institute, TACWAR and other programs based on "laser tag" exercises tend to "run hot", or overestimate casualties. Real-bullet data is more reliable, because fear of death makes soldiers more conservative in actual combat than they are in exercises, resulting in fewer losses. The discipline is only just beginning to recognise the "tremendous value of real-world verification", says Andreas Tolk, an eminent modelling scientist at Virginia's Old Dominion University.

Yet another factor that distinguishes the TNDM from other war-forecasting systems is its unusual ability to take intangible factors into account. During NATO's air campaign above Serbia and Kosovo in 1999, for example, the Serbs built decoy tanks out of wood and tarpaulins and painted *trompe l'œil* bomb-holes on to bridges. Microwave ovens, modified to operate with their doors open and emit radiation, were used as decoys to attract HARM missiles that home in on the radar emissions of anti-aircraft batteries.

Such cunning is one of the many intangible variables that are taken into account by the TNDM's number-crunching equations. Mr Lawrence says incorporating human factors into equations is controversial: most models favour "harder" numbers such as weapons data. But Robert Alexander, an expert on war simulations at SAIC, an American defence contractor, says these are "almost secondary" to human factors.

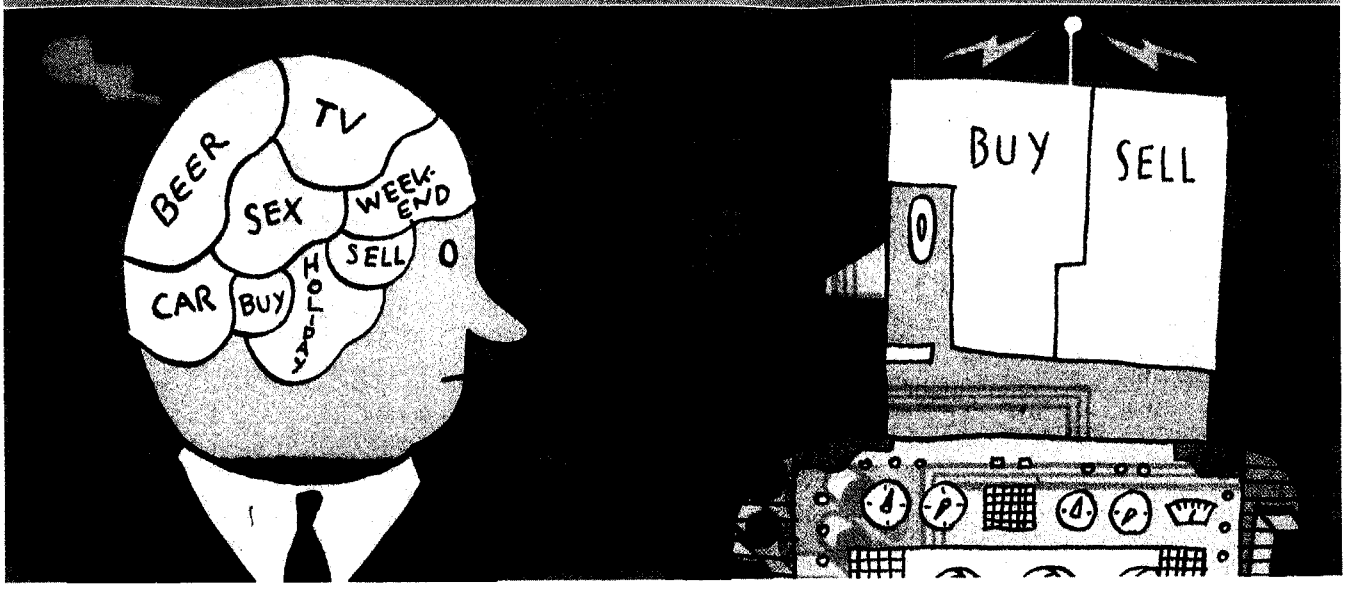


The Concepts Evaluation Model (CEM) developed at the Pentagon's Centre for Army Analysis, provides an instructive example. While testing the model, programmers entered historical data from the Battle of the Bulge, the German offensive in 1944 against American forces in Belgium. The CEM predicted heavy German losses in the initial attack, yet German casualties were in fact light. The probable error? The model overlooked the shock value of launching a surprise attack. Analysts duly recalibrated the CEM—using an early version of the TNDM.

The Dupuy Institute is renowned for its ability to take into account such non-material factors: the effect of air support on morale, fear engendered by attack with unexpected weaponry, courage boosted by adequate field hospitals. The mother of all intangibles, within the TNDM model, is initiative, or the ability of lower-ranking soldiers to improvise on the battlefield. Armies from democratic countries—where people are empowered to make decisions—benefit by giving their soldiers some scope to change tactics in the midst of a firefight. Soldiers fighting for authoritarian regimes may not have the reflexes, or the permission, to seize opportunities when they arise in battle.

Maintaining the accuracy of the TNDM means feeding it with a constant stream of new information. The Dupuy Institute's analysts visit past battlefields to augment their statistical data, follow the arms industry closely and cultivate contacts with government defence procurers. In countries where access to military archives is limited, the Institute surreptitiously pays a handful of clerks to provide photocopies.

The next challenge will be to expand the TNDM's ability to forecast the outcomes of "asymmetric" conflicts, such as the Iraqi insurgency. To this end, the Dupuy Institute is hoping to get its hands on the Vietcong archives, as Vietnam opens up. Insurgencies rarely leave much of a paper trail, but the Vietnamese kept detailed records of their struggle against the French and Americans. The resulting papers provide the world's most extensive documentation of guerrilla fighting. "That's where warfare seems to be heading," says retired Major General Nicholas Krawciw, who is the president of the Dupuy Institute. And wherever warfare leads, war-forecasting systems must follow. ■



The march of the robo-traders

Software: Programs that buy and sell shares are becoming ever more sophisticated. Might they replace human traders?

IMAGINE the software equivalent of a golden goose: a program that continually produces money as its output. It sounds fanciful, but such software exists. Indeed, if you have a pension or endowment policy, or have money invested in share-based funds, the chances are that such a program—variously known as an "autonomous trading agent", "algorithmic trading" system or simply as a "robo-trader"—has already been used to help your investments grow.

Simple software-based traders have been around for many years, but they are now becoming far more sophisticated, and make trades worth tens of billions of dollars, euros and pounds every day. They are proving so successful that in the equity markets, where they are used to buy and sell shares, they already appear to be outperforming their human counterparts, and it now seems likely that their success will be repeated in foreign-exchange markets too. Proponents of robo-traders claim that, as well as making more money, they can also help to make markets more stable. And, of course, being made of software, they do not demand lunch breaks, holidays or bonuses.

This has prompted an arms race as companies compete to develop the best sets of rules, or algorithms, to govern the behaviour of their robo-traders. "We live and die by how well they perform," says Richard Balarkas, global head of advanced execution services at Credit Suisse First Boston, an investment bank. The better the technology, the more money it makes for the client, he says.

At the moment, big strategic decisions, such as deciding which shares to buy and sell, are still made by experienced human traders, says David Cliff, who is the director of Deutsche Bank's Complex Risk Group in London and a veteran of the field. Robo-traders are then given the power to decide how to buy or sell shares, always with the aim of hiding their client's intentions. If you are a pension-fund manager and have decided to sell a million shares in some company, merely revealing your intention to sell will result in the market moving against you, even with very actively traded shares, notes Dr Cliff. So the aim of the game is to try to unload the shares in such a way that no one notices what you are doing.

Buy! Sell! Exterminate!

The simplest algorithmic-trading systems might try to drip-feed the market by slicing up a big trade into a hundred smaller orders. By introducing these trades slowly into the market over some predetermined period of time—a few minutes, or hours, or days—the idea is that the smaller orders are less noticeable, and so have a less dramatic effect on the market price. But such "salami slicers" would not win any prizes these days, says Dr Cliff. Today's more advanced robo-trading programs can cover their tracks more adeptly, for example, by varying the amount they sell, and sometimes even buying back the very stock they are trying to get rid of, he says.

Some firms, such as FlexTrade of Great Neck, New York, now offer complete algorithmic-trading platforms. These allow clients, be they investment banks or hedge funds, to straddle different markets seamlessly and use built-in but customisable trading rules to do their buying and selling. The advantage is that the clients get to use algorithmic trading without all the hassles that come with it, such as having to connect to particular exchanges, check data feeds are live or deal with the sending out of orders that have been placed; the platform does all of those things automatically. But while these kinds of platforms are likely to increase the prevalence of algorithmic trading, those in the business regard them as rather primitive when compared with more sophisticated, proprietary systems.

Robo-traders' main advantage is speed, says Marcus Hooper, a specialist in global electronic-trading solutions for Bear Stearns International in London. In many electronic markets the time delay, or latency, associated with making a trade can be quite significant—in some cases several seconds. This is a major headache for traders. "By the time their fingers hit the keyboard, someone else could have beaten them to it," says Mr Hooper. So any algorithm that can respond faster than human traders has a definite edge, he says.

Another advantage stems from the basic limits that exist on how much information human traders can realistically absorb. Studies have shown that professionals make their trading decisions only after considering three or four variables, ▸▸

"Eventually, robo-traders may be capable of analysing news feeds, deciding which shares to buy and sell, and devising their own strategies."

says Mr Balarkas. Computers, on the other hand, can take in hundreds of variables simultaneously, and refer back to a wealth of historical data, in the blink of an eye. In 2001 Jeffrey Kephart, a researcher at IBM, compared the performance of human commodity traders with autonomous trading agents. He found that the software agents, which included one developed by Dr Cliff (who at the time was a researcher for Hewlett-Packard in Bristol), produced 7% higher returns than humans.

So is this the end of human traders? Far from it, says Mr Balarkas. Instead, man and machine work best together. "Algorithms are not the financial-market equivalent of an unmanned droid—they need a trader to operate them, just like a Formula 1 car needs a driver," he says. This requires judgment, something computers have yet to master. Algorithmic trading is emerging as an important new tool, but human traders will only use it when appropriate.

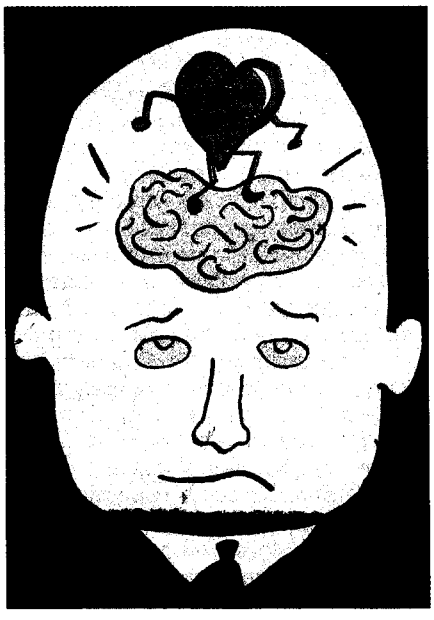
For instance, although the latest trading algorithms can be pretty sophisticated, a lot of them are based on what are called volume-weighted average-price models. These models set buying or selling prices based on what is calculated to be the average price for a given day—in other words, they use a low-risk, follow-the-herd approach. This has its uses: it can, for example, be useful to unload a large number of shares far more quickly than might be practical manually.

The human touch

But to make the real money, human traders rely upon riskier strategies that enable them to outdo their competitors. This requires more than just experience, market knowledge and the ability to keep up with the news. And such "alpha-seeking" strategy is extremely underdeveloped in algorithmic trading, says Mr Hooper—not because of any lack of demand for it, but because it is very hard to do. In this regard, human traders still have an edge over heartless robo-trading algorithms. But it is still early days. Algorithmic trading is still in its infancy: it has taken off only in the past four or five years, mainly due to the introduction of the Financial Information Exchange Protocol, which has done for trading what the internet's TCP/IP protocol did for data networking, by allowing different proprietary systems to plug into a common standard.

Some programs do exist that make decisions about which shares to buy and sell. These are used for statistical arbitrage—the practice of monitoring and comparing share prices to identify patterns that can be exploited to make a profit. In the past, software has been used to carry out this sort of analysis and identify, for example, that the best time to buy a particular company's shares is when the spread between its share price and that of a rival firm has reached a certain value. Historically, this information would then be passed on to a human trader to act on. But these days, statistical arbitrage systems are often plugged straight into the market, and can place their own trades.

Might that not be rather risky? Some blamed the 1987 stockmarket crash on computers instructed with simple decision-making rules. These essentially



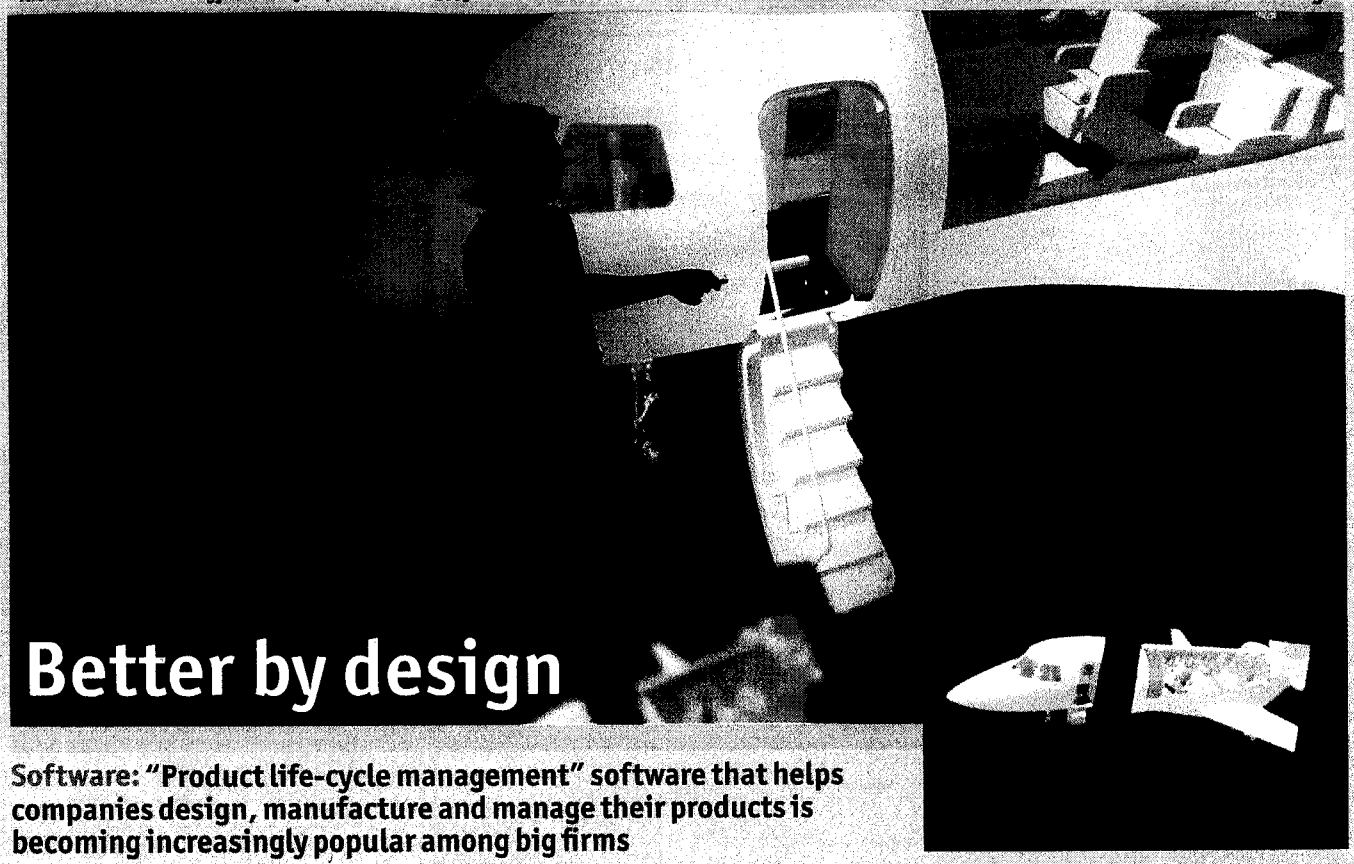
amounted to little more than "if-then" rules of thumb: if a share price drops below a certain threshold, then sell. When a market is falling, this can make a bad situation worse, as low prices prompt more traders to sell, which further depresses prices. Yet despite such worries, the industry has continued to embrace the technology. Indeed, part of the reason for computerising exchanges such as the London Stock Exchange and NASDAQ was to facilitate algorithmic trading, says David Birch, head of research and development at the London Stock Exchange.

Some exchanges now regulate the use of algorithmic trading, both to prevent their systems from being overloaded and to avoid a repeat of the 1987 scenario. On July 7th, for example, the London Stock Exchange asked for algorithmic trading to be suspended after the London bombings. Even though it is impossible for an exchange to tell whether a person or an algorithm is issuing trades, it is possible to monitor the rate of trading to tell whether algorithmic trading is going on, says Mr Birch; human traders cannot issue several trades per second. But a greater dependence on algorithmic trading could eventually make it impractical to order such trading to be suspended, he says.

Mr Balarkas believes the risks are minimal, and that it may not be necessary to switch off algorithmic trading. "By definition, execution algorithms are stealthy and designed to create as little volatility as possible," he says. And the very fact that they are designed to reduce the market impact of trades should, in fact, have a stabilising effect. No one wants a repeat of 1987, says Dr Cliff, and nobody would knowingly implement an algorithm that they thought might cause a crash. The trouble is, he says, that the secrecy that surrounds these algorithms means that there is no way to evaluate how various trading systems might interact with each other. It is an intractable problem. "But without hideous levels of regulation there is no way round it," says Dr Cliff.

Beyond worries over market stability, might an even greater danger be lying in wait? Mr Hooper proposes a doomsday scenario. Some day, advances in natural-language processing and statistical analysis might lead to robo-traders capable of analysing news feeds, deciding which shares to buy and sell, and devising their own strategies. Given that companies are very keen to patent their algorithms, it is quite possible that just one company could then emerge as the victor in this algorithmic arms race, says Mr Hooper. This outcome would create a particularly challenging problem for regulators. "It is a possibility that you could have an unfair advantage—and there would be nothing governments could do about it," he says.

It is an interesting idea. But it seems unlikely, since there are so many possible trading strategies, and unlike simpler problems in computing (such as sorting a list) it is doubtful that there will turn out to be a single trading algorithm that outperforms all others. Yet perhaps such a suggestion should not come as a surprise. For whenever robots are being discussed—even if they are merely the software-based, share-trading variety—the idea that humans will lose their jobs and the robots will take over the world always seems to be lurking in the background. ■



Better by design

Software: "Product life-cycle management" software that helps companies design, manufacture and manage their products is becoming increasingly popular among big firms

ON DESKTOPS and tables in offices and homes around the world, and on the laps of latte-sippers from Miami to Mumbai, you will find computers made by Dell, the world's biggest PC manufacturer. For a company that shifts tens of millions of boxes each year it is a mammoth task to keep track of all the different components that go into each of its various models, and to ensure that 400 suppliers around the world are kept informed of changes in design or specifications—even as similarly global teams of designers are continuously updating its product line to stay ahead of the competition. Like many other large firms, Dell uses clever software to handle all of these tasks. It is called product life-cycle management (PLM) software, and it is becoming integral to the operation, growth and profitability of many big companies.

As its name suggests, PLM software can manage the entire "life-cycle" of a product, from concept and design to production, marketing and even recycling. Using PLM software, for example, when Dell's engineers design a new computer, they can reuse parts of previous designs, and so keep to a minimum the number of new parts and suppliers. The software also ensures that old and new components fit together perfectly. But according to PLM devotees, there are many other benefits: lower prototyping costs, reduced time-to-market for new products, less waste, improved product quality and faster turnaround of marketing materials.

PLM software, in short, provides the framework within which companies can take new ideas and implement them quickly in actual products. "PLM is becoming the enabling tool for innovation," says Navi Radjou, a PLM guru at Forrester, a consultancy. As a result, PLM is currently the fastest-growing segment of the business-software market, according to AMR Research, another consultancy. Last year the PLM market was worth $9.65 billion, and grew by 10%; AMR expects 8% growth this year (see chart on next page).

A brief history of PLM

PLM's sudden growth is largely the result of its spread beyond the niches where it first evolved—in the aerospace and automotive industries—into the broader markets of consumer electronics, clothing and packaged goods. In the past, says Walter Donaldson, IBM's general manager for PLM, he would find himself talking to the vice-president of engineering. But these days he is more likely to find himself talking to a company's chief operating officer about how to use PLM to become more competitive. The latest trend, says Mr Radjou, is that large retailers are starting to invest in PLM to manage their private-label goods and compete better with big consumer-goods firms such as Procter & Gamble and Unilever.

Vendors of PLM software, such as Cadence, UGS, PTC, SAP, Dassault and Agile, generally sell suites of software that do many things, and which have formed by accretion over many years. PLM's origins go back to computer-aided design (CAD) software, a range of computer-based design tools which engineers and architects began using in the 1980s.

In the 1990s, this evolved into product-data management (PDM) software, which features CAD design tools combined with a database of information about components. This makes it possible to work out quickly how much a design change or a new product might cost, among other things.

PDM systems also helpfully centralise product information into a single, authoritative database—sometimes called the "system of record"—thereby doing away with paper plans and reducing the scope for error or misunderstanding. And any changes to a product's plans are quickly visible to the team designing the production line on which it will be built. Nikon's camera division, for example, used to produce around 15,000 design drawings a year that had to be distributed and approved. Using PDM, it has reduced the amount of paperwork by 80%, and drawings can be retrieved five times faster.

Such systems have now been extended so that they are not just for designers and engineers, but also include tools for use by senior managers and marketing people. According to AMR, CAD still accounts for 53% of spending on PLM, but non-CAD spending is growing twice as fast, or 13% a year. The latest PLM systems may include "requirements manage-

"PLM software provides the framework within which companies can take new ideas and implement them quickly in actual products."

ment" and "portfolio management" tools, so that managers can, for example, look across the range of products in development to make sure they match the demands of the market in question. If they do not, then specifications can be tweaked or products killed off.

PLM systems also allow packaging to be mocked up quickly and then displayed to focus groups via the web, so that the most effective packaging can be identified. In theory, all of this means that the needs of the market can be anticipated and communicated back along the chain to the research and development department. PLM has, then, evolved from humble design tools into elaborate systems that help companies develop and manufacture products that their customers actually want to buy.

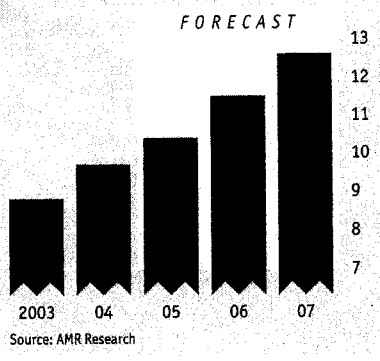
The desire for greater competitiveness and faster response are two reasons why PLM is growing so quickly. But its adoption is being driven by other factors, too. One is globalisation. When firms start to design, manufacture and sell products in many different countries, each with their own requirements and regulations, they face a huge increase in complexity. Heinz uses PLM software to keep track of the different ingredients that go into its ketchups and other products in various countries, to cater to local tastes. By centralising this information, it has been able to optimise its recipes and reduce costs.

For companies that rely on outsourcing or have multiple design and manufacturing centres around the world, PLM can simplify things by allowing people in different countries to communicate and collaborate within a single, secure environment. Rolls Royce, for example, used PLM to facilitate around-the-clock development by engineering teams in Britain, India and America of the Trent 900 engine for the Airbus A380.

Another factor driving PLM is that products themselves are becoming far more complex, which makes it harder to ensure that all the different parts will fit together and work properly. PLM can help to minimise such problems for even the most complex products, such as aircraft.

Dassault Aviation claims that its Falcon 7X corporate jet, launched this summer, is the first aircraft ever to be designed entirely in a virtual environment. PLM software was used to link Dassault with 27 subcontractors to create a digital model of the aircraft. Everything was meticulously modelled, including the robots that build the tools to fit the aircraft's parts together and the maintenance processes once the aircraft is in service. This eliminated assembly problems, so that the first plane to be constructed was perfect: there was no physical prototype. The parts were manufactured and put together, and the plane took to the air.

Purchasing like mad
PLM market revenues, $bn



Source: AMR Research

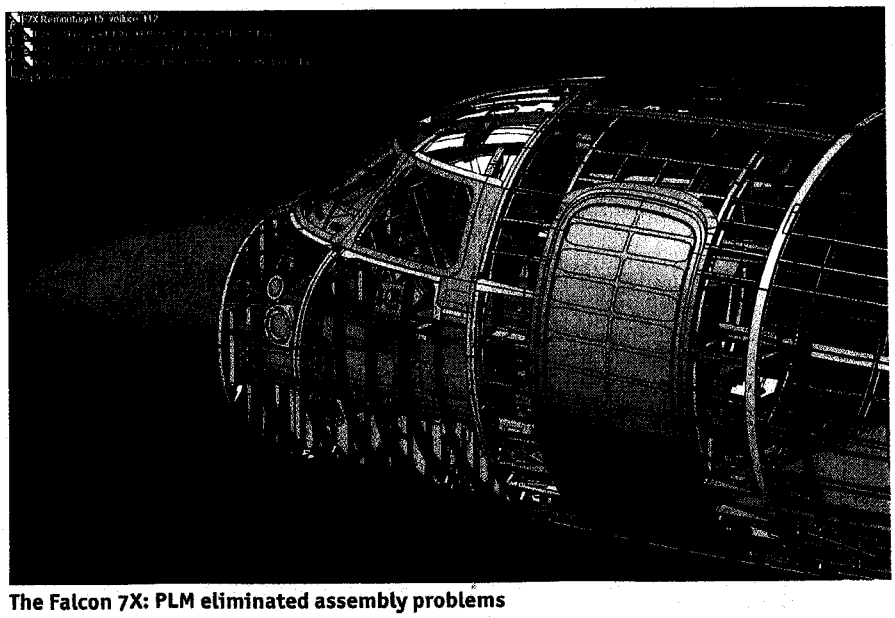
The need to comply with different regulations provides another reason to adopt PLM. New restrictions on the use of lead, cadmium, chromium and other materials in electronic equipment will come into force in Europe in 2006. So companies need to be able to track what is going into their products. PLM systems can produce a bill of materials for each product, making it easier for a firm to check that its products comply with local regulations.

Regulation has also prompted the adoption of PLM in package design. Pharmaceutical companies that frequently repackage their products, but must comply with strict regulations that vary from country to country, can use PLM to track design changes and make sure that each package conforms with the local regulations. Once the software is in place, people in the legal, medical and design departments can look at the design in parallel and approve it—rather than waiting for paper documents to circulate. Chris Farinacci of Agile says that 50-60% of pharmaceutical product-recalls are to do with packaging problems.

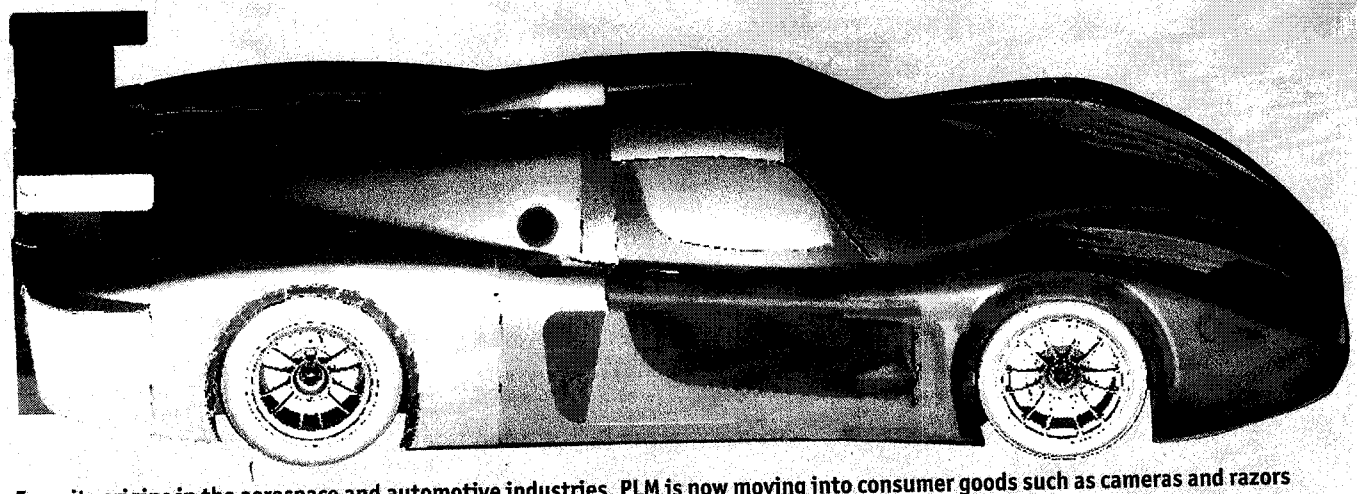
A poster child for PLM

Some firms, of course, face many of these challenges at the same time. A good example is General Motors. Speaking at a recent conference in London, Diane Jurgens, a PLM guru at GM, said the company regards PLM as crucial to its survival. Her job title is, rather improbably, "director of global product development process and systems integration and information systems and services". But her job is essentially to make the world's biggest carmaker more efficient.

GM employs 325,000 people, has 19 design centres around the globe, and builds cars in 32 countries. To add to the complexity, it has different brands in different regions, such as Holden in Australia and Opel in Germany. It must balance the desire to centralise where possible with the need to localise where necessary: American buyers expect a "new car



The Falcon 7X: PLM eliminated assembly problems



From its origins in the aerospace and automotive industries, PLM is now moving into consumer goods such as cameras and razors

smell", for example, but Asians do not.

In 1997, GM was taking an average of 48 months to develop each new vehicle, compared with 36 months at Toyota, one of its biggest competitors. GM was big and unwieldy, and had competing teams of designers, says Ms Jurgens. So in 2000 the company decided to sort out the mess, and bought a PLM system from UGS. Today, 10% of GM's employees use it. Parts and whole subsystems from one vehicle can now be easily reused in another. Changes to a vehicle's design can be immediately reflected in the design of the dies that stamp out the doors and body panels. And new models can be crash-tested thousands of times in virtual reality. GM also uses PLM to collaborate with its suppliers. This makes it possible for everyone to see what a part should look like and where it fits into the overall design, to ensure that it fits perfectly. But perhaps the best illustration of the success of GM's PLM initiative is that the development time for new vehicles is now just 12-18 months.

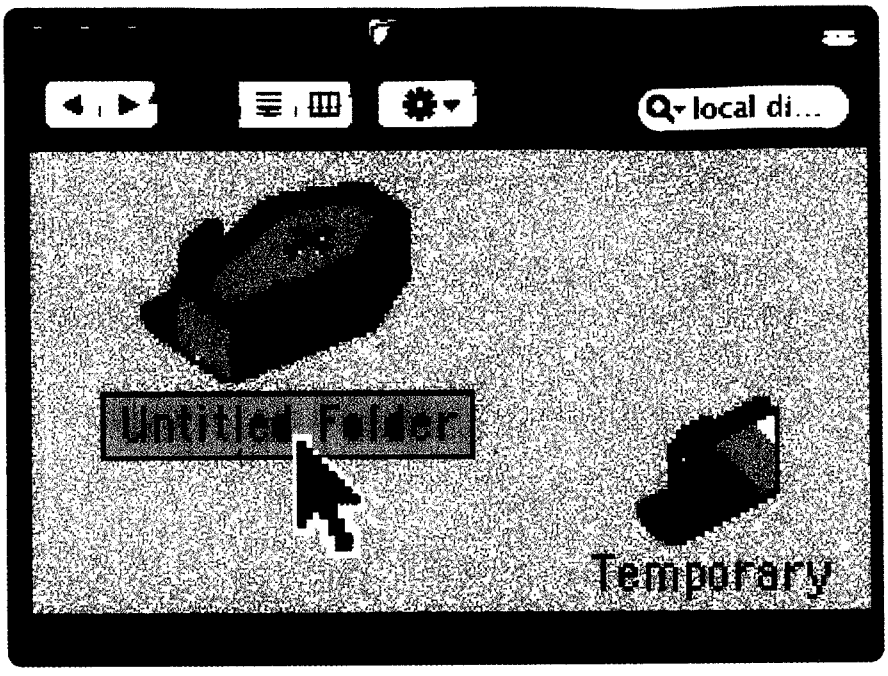
The trickle-down theory

GM's experience also highlights some of the challenges involved in adopting PLM. By its very nature, it changes the way that people work and interact. Industrial designers, for example, may find themselves having to work very closely with engineers—having previously been separated by incompatible file formats. The research & development department may not be accustomed to dealing with the marketing department. And old habits die hard. Many GM staff did not ordinarily share their files and data, says Ms Jurgens. And designers, in particular, were reluctant to switch to the new PLM-friendly design software.

Where next for PLM? The next step, says Mr Donaldson of IBM, will be to broaden access to the technology and bring medium-sized companies, not just engineering and consumer giants, into the world of PLM. It is shaking off its engineering origins and is moving, he says, into the mainstream parts of business. IBM is currently working to help business and engineering schools better understand the technology. Clearly, if lots of newly minted business graduates have been taught about PLM, they are more likely to want to use it when they get jobs.

Mr Radjou notes that the trend towards outsourcing is already forcing medium-sized companies to adopt PLM in order to service their larger customers. PLM is a collaborative tool, and the more that working practices such as design and manufacturing are broken down into modules, the more scope there is for even smaller companies to plug into bigger firms' PLM networks. "But the vendors are not really providing anything for them yet," says Mr Radjou, "which is why Microsoft is getting into the space." At the same time, other technology vendors such as IBM and SAP are also starting to incorporate PLM features into their other business software.

This is a testament to PLM's success, but paradoxically could cause it to disappear. "I'm not sure PLM will survive as a stand-alone category," says Mr Radjou. Instead, he says, PLM functions will be broken down and bundled into other applications, such as supply-chain management systems and even desktop productivity software. Oracle, the world's second-largest software company, will probably buy one of the PLM vendors and incorporate its software into its general business suite, Mr Radjou predicts. Microsoft is working to add collaboration and document-sharing features to its Office suite. So PLM could become almost as ubiquitous as PowerPoint presentations or Word documents—but by then it will almost certainly be called something other than "product life-cycle management". It is the hallmark of a successful technology that it becomes almost invisible. And so the final, triumphant stage in the gradual ascent of PLM could be that it disappears altogether. ■



Death to folders!

Computing: Cheap hard disks and fast search software could change the way we store and find documents on our computers

ANYONE who uses a personal computer will be familiar with the idea of a "graphical user interface", which was introduced in the 1980s and became ubiquitous in the 1990s. It did away with the need to type cryptic keyboard commands to manipulate files, making it possible to manipulate them directly instead, using a mouse: double-click on a file's icon to open it, drag it to the bin to delete it, and drop it on a folder to file it away.

All of this made computers far easier to use. But the once-revolutionary notion of files, folders, filing cabinets and other desktop icons is now showing its age. What started out as a helpful metaphor now seems rather limiting. Why hobble digital documents with the limitations of paper ones, such as the need to have a single fixed location? "A lawyer cares about things like dates and cases," says Thomas Rizzo, the head of Microsoft's next-generation file system project, known as WinFS. How can a lawyer file the same document by both client and by date? He cannot, notes Mr Rizzo, without using unwieldy multiple-location workarounds such as aliases and shortcuts.

Another problem, as personal computers start to fill up with thousands of photographs, music tracks, saved web pages and other documents, is that the file-and-folder metaphor requires users to decide upon a logical filing system, and then stick to it, if they want to be able to find things easily. The only thing worse than creating such a nested hierarchy of folders, or directories, is not creating it. Folders thus saddle computer users with the menial task of keeping the filing system neat and tidy, notes Philip Schiller, Apple's senior vice-president of marketing. "You're the janitor," he says. But most computer users could not care less about folders, a way of organising digital files that is a relic from computing history.

To further complicate matters, data on personal computers is being Balkanised as different pieces of software circumvent the creaking file-and-folder approach and establish their own structures for organising particular kinds of data. E-mail programs were early examples of this trend: most of them maintain what is, in effect, a database of e-mail, hidden away in its own folder and often inaccessible to other programs. Contact-management, calendar and photo-album programs now do the same. To find all the information relating to a personal contact, you may need to search within a contact-management program, a calendar, an e-mail program and the computer's file system—though filenames do not always contain enough information to connect them to a particular person or project.

Oddly, however, just as it is becoming harder to find things on your computer, it is becoming much easier to find things on the web. Search engines such as Google can search billions of pages in a fraction of a second: if you have a broadband connection, it is usually quicker to look up the phone number of a restaurant via Google than to boot up your address-book software. The desktop-computing metaphor, and the notion of folders in particular, has fallen behind. It is time to shed this relic of the past. It is time for folders to die with dignity—and to yield to a new, more web-like way of storing and finding things.

Never delete

This new approach to organising data is being brought into being by the convergence of two trends: the plunging cost of hard-disk storage and the growing reach of search software. Have you emptied the rubbish bin on your desktop lately? Probably not—unless you edit a lot of music or video, the chances are that you have far more disk space than you need. A typical hard disk on even a cheap computer today holds 40 to 80 gigabytes of information, which is enough for millions of e-mails, tens of thousands of photos, and hours of video. By 2009, a typical PC will have a 160-gigabyte hard disk, and the biggest disk drives will have a capacity of 1,000 gigabytes, or one terabyte, says Dave Reinsel, director of storage research at IDC, market-research firm. Today, he says, most users' hard disks are about 30% full. When storage space is so abundant, why throw anything away?

As storage capacity has grown, however, the ability to search such large piles of data has not kept pace. Until recently, most operating systems, including Microsoft Windows, Apple's Mac OS X and the various versions of Unix had the same search functions they had ten years ago. Only now are they being revamped. Even today, Windows and, until this year, Mac OS X performed the most primitive form of searching by matching a query against filenames one at a time. Searching in this way is akin to looking for a library book by examining every book on every shelf, one at a time. Libraries, of course, have catalogues to make it easier to find books. And now the same idea is being grafted on to computer file systems. The first implementation appeared in Mac OS X, but Microsoft and Google are close behind.

In theory, speeding up search is easy: ▸▸

"As the power of desktop-search software grows, the need to organise things in folders disappears."

all you have to do is build a database, akin to a library catalogue, that has an entry for each file, along with information about its content. But for this database to be useful, it must be constantly updated. Every time a file is altered, its corresponding entry in the database, and the various indexes that refer to it, must be updated too. This involves meddling with the computer's operating system at a fundamental level, and has historically been difficult to achieve without a dramatic reduction in the computer's performance.

Apple finally solved this problem this year when it released Mac OS X 10.4, known as Tiger. Every time a file is changed, it is added to a queue for re-indexing by Tiger's built-in search engine, called Spotlight. The re-indexing then occurs when the computer is relatively idle, which ensures that maintaining the file database does not overpower the system. The result is that documents scattered across the hard disk can be summoned with Google-like speed and simplicity.

Microsoft is doing something similar through its even more ambitious (but much delayed) WinFS project. The aim is to build an advanced database, using elements of Microsoft's SQL Server, into the Windows filing system to enable access to files with the speed and complexity of a database query. "We are fundamentally changing the way you store your data inside your file system," says Mr Rizzo. Project-management software could, for example, call up all files relating to a particular project, or a jukebox program could ask WinFS to retrieve all files of type "music". But although WinFS was originally intended to be part of Microsoft's forthcoming Windows Vista operating system, formerly known as Longhorn, it was dropped as an integral element when development fell behind schedule. Vista is expected in late 2006, but WinFS will not be released until 2007.

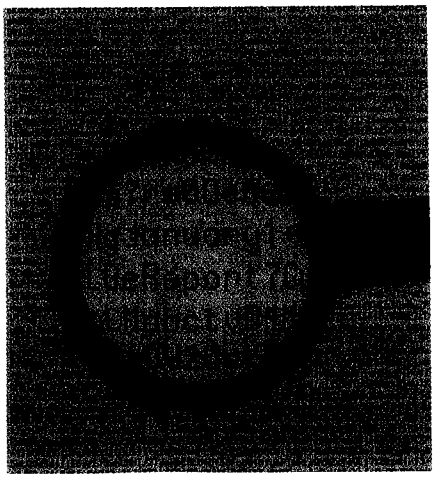
In the interim, both Microsoft and Google have launched Windows-based desktop-search products that lack the deep and elegant integration of Spotlight or WinFS, but do similar things. Windows Desktop Search (toolbar.msn.com) and Google Desktop (desktop.google.com) are separate, free software packages that must be installed on the desktop, though Microsoft's product will be incorporated into Windows Vista next year. Like Spotlight, both have a variety of plug-ins that let them index common file types, such as Microsoft Office documents and messages inside popular e-mail programs.

By doing away with the main drawback of traditional file-searching—that it cannot see inside the files, only their names—Apple, Google and Microsoft are hammering nails into the coffin of the old file-and-folder approach. As the reach and power of desktop-search software grows, the need to put things in organised folders disappears. With Spotlight, "I just search for everything now—I spend almost no time browsing through folders," says Steven Johnson, author of "Interface Culture", a book about computer interfaces.

Let's play tag

That said, search engines cannot reach inside every kind of file: they cannot yet distinguish photographs of one person from another, for example. Many kinds of file, however, incorporate helpful "tags" that describe their contents. Digital cameras attach tags to photographs to record information about the time, date and exposure details; MP3 audio files generally contain tags listing the track name, artist, and other information. "We believe that data is becoming more and more structured. That's good for being able to find things and relate things together," says Mr Rizzo. Increasingly, users will start to attach tags of their own to files, too.

When saving a document five years from now, rather than naming it and dropping it into a folder, you may well tag it with a few keywords and drop it into a database. "You can just tag it instead of filing it, and you can rely on the search system to quickly find all the things with the same tag," says Marti Hearst, a computer scientist at the University of California at Berkeley's School of Information Management & Systems. Her tag-based retrieval system, called Flamenco, can be seen online at bailando.sims.berkeley.edu/flamenco.html.

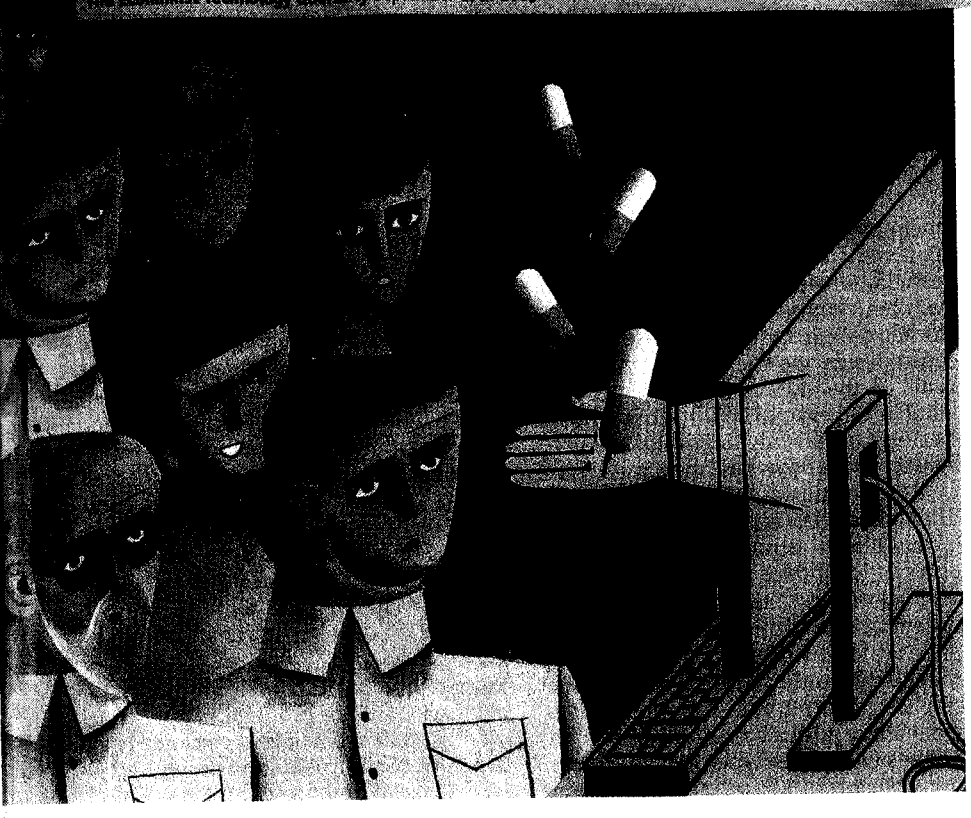


Ironically, the search-based metaphor also allows folders to be reincarnated in a new and more useful form. Spotlight has a "Smart Folder" feature that looks like a folder, but is in fact the result of a search. So you could, for example, create a Smart Folder that contains all files, e-mails and other documents mentioning "sausages" that were modified in the last month: the search software then populates the folder with anything that matches these search criteria, and keeps the contents constantly updated. (The name implies that if these are Smart Folders, then existing folders must be stupid ones.)

The idea of establishing relationships between pieces of information, to allow connections to be made and results to be retrieved, is not new. Vannevar Bush, in his famously prognostic and influential essay in the *Atlantic Monthly* in July 1945, described how adding structured code words to associated microfilm pages in his imaginary "Memex" information-retrieval system would help researchers. "It is exactly as though the physical items had been gathered together from widely separated sources and bound together to form a new book. It is more than this, for any item can be joined into numerous trails," Bush wrote.

Flamenco, WinFS and Smart Folders allow items that meet particular criteria to appear many times in the same hierarchy, and to move around as their contents or attributes change. Traditional folder hierarchies, in contrast, are rigid structures resistant to updates and multiple views.

Looking further ahead, the combination of databases, tagging and search will make it possible to navigate large numbers of documents in all kinds of radically new ways. David Gelernter, a computer scientist at Yale University, imagines searching using time and space axes: imagine picking New Haven, Connecticut, on a map and then zooming back to 1701 to see information about its founding. Ben Shneiderman of the University of Maryland has devised a new way to display search results in which data appear as concentrations of information in a "tree-map": the colour, position and size of thousands of results can then be taken in at a glance. As folders fade away and search software evolves, it seems that we may, at last, be able to find what we're looking for when we need it. With the death of the folder, perhaps we can finally get some work done. ■



Just what the patient ordered

Medicine: Patient-driven approaches to developing drugs for orphan diseases are turning pill-takers into pillmakers

IN THE face of mortal illness, patience is not necessarily a virtue. When Kathy Giusti was diagnosed with multiple myeloma, a form of cancer, doctors gave her just a few years to live. Like many patients, Ms Giusti took to the internet to learn as much as she could about her illness. But that meant precious little when it came to treatments for her disease. At the time of her diagnosis, in 1996, there were no exciting new drugs in development for multiple myeloma; in fact, there were no new drugs at all. "The medicines they recommended for me were the ones they used on my grandfather, years before," says Ms Giusti.

With only 50,000 sufferers in America, multiple myeloma is one of thousands of "orphan" diseases that are simply not common enough to interest most drugmakers: there are too few sufferers to justify the cost of developing a new treatment. Although special legislation exists in Europe and America to encourage drugmakers to tackle orphan conditions, the combination of tax breaks and market exclusivity on offer are simply not enough for many firms to attract them to the field. So Ms Giusti, a former pharmaceutical executive, set out to do something about it—and she has succeeded. In 1998, she and her twin sister founded the Multiple Myeloma Research Foundation (MMRF) with the aim of raising money and awareness to "jumpstart" researchers' bright ideas into treatments. Just a few years later, MMRF has garnered more than $50m for research, there are now roughly 110 drugs in various stages of development for the disease, and Ms Giusti has proven her doctors' prognosis wrong.

The idea of charities or patient advocacy and support groups funding drug development is nothing new. In the 1950s, for example, the National Foundation for Infantile Paralysis and its "March of Dimes" bankrolled the development of a polio vaccine. But today's patients' groups are more intimately involved in the nitty-gritty of drug creation, creating their own clinical-trials networks, establishing tissue banks and even setting up their own biotech companies.

So why are today's patients getting more involved in drug development? Frustration at the slow pace of research is one reason, according to Bob Beall, head of the Cystic Fibrosis Foundation (CFF). When the gene for cystic fibrosis was discovered, patients expected this knowledge to be converted relatively quickly into therapies. When commercial interest was slow to materialise, patients realised they would need to play a more active part, says Mr Beall. This patient power stems from a general medical trend, particularly noticeable in America, where "health-care consumers" are encouraged to take greater responsibility for their own well-being; seven years of direct-to-consumer advertising of prescription drugs, bombarding television screens across America with commercials for the latest, greatest pills, have also raised both awareness and demand.

At the same time, says May Liang, head of the Epilepsy Therapy Development Project, "venture philanthropists"—entrepreneurs who bring the same rigorous thinking and streamlined decision-making to not-for-profit foundations as they apply in their normal business lives—are transforming the field. Their business savvy allows patient groups to speak the same language as the companies with which they need to deal. Ms Liang's own foundation, for example, was created by three men with backgrounds in business and banking, whose young children developed epilepsy, and who came together to stimulate interest in drug development.

CFF is another prominent player. Since 2000, the group has spent almost $240m on research into this fatal inherited disease. As well as financing academic scientists, the foundation also provides venture capital to biotech firms that are willing to take on the tricky task of finding a drug to treat the underlying genetic defect of the disease, not just treat its symptoms. The group has venture deals, which feature all the regular commercial terms of milestones and royalties, with a number of biotech companies, including Vertex. The first drug emerging from that partnership could enter clinical trials within the next couple of years. This sort of money is particularly welcome to small biotech firms which are finding it hard to secure early-stage financing from increasingly wary investors. The idea, says Mr Beall, is to take much of the risk of drug discovery and development off the shoulders of companies, in the hope of enticing them into the area.

But such foundations are worth more ▸▸

"Patients are getting involved in drug research and trials, and are even setting up biotech firms."

than money alone. MMRF, for example, has managed to instigate and co-ordinate valuable research collaborations. Such initiatives start with information. The foundation has compiled a web-accessible database of 110,000 people with an interest in multiple myeloma, from researchers and clinicians to patients and even financial analysts covering the biotech industry. MMRF also keeps track of all clinical trials on multiple myeloma, so it has a clear view of exactly what is happening in the field.

The power of information

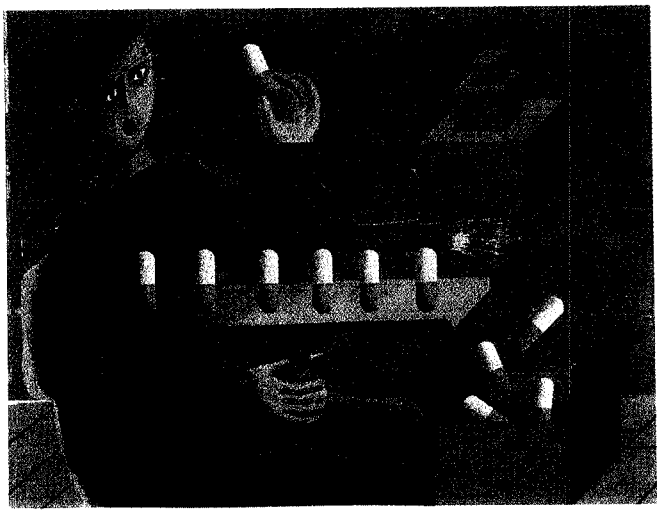
It then turns this information into action. MMRF has put together a consortium of medical centres in America and Canada which can undertake clinical trials, with common protocols for everything from patient recruitment to patent rights. The consortium is working with Chiron, a biotech firm, on an early-stage trial of a new anti-cancer drug, with several new centres and compounds expected to enter the network over the coming months. MMRF's power comes not just from its dollars but from its constituents. As a patient-based organisation, it can tap directly into one of the scarcest commodities in drug development—access to the right patients for clinical trials.

This connection to patients and research centres is vital for small biotech firms, says Julian Adams, chief scientific officer of Infinity Pharmaceuticals, a cancer company. "We are not like big pharma. We are not the 800lb gorilla who can just put money on the table and buy our way into the clinic." The medical consortium is intimately involved with the companies that tap into its networks, tracking their progress in monthly conference calls and offering tiny firms help with paperwork and other practical points that might otherwise hinder their efforts.

MMRF also brings together representatives from America's drug regulator, the Food and Drug Administration, with experts from academia and industry to tackle bottlenecks in drug development. Dr Adams is impressed by the group's convening power. When he was working at Millennium Pharmaceuticals and leading the development of Velcade, a breakthrough drug for myeloma, he attended a meeting held by MMRF which assembled the leading researchers and clinicians in the field. After presenting some early clinical data, "instead of the usual rubber-chicken dinner, I asked Kathy Giusti if we could design the trial," says Dr Adams. With all the experts in one room, they worked out exactly how the trial should be run; it began only three months later—lightning speed for the industry.

Other groups are also pitching into drug discovery and development. Genetic Alliance, a network of more than 600 support groups representing patients with inherited disorders, is trying to set up a database of information about the diseases in question for researchers to consult. Not only does this provide one-stop shopping for scientists, but also provides them with information they might not easily find elsewhere, such as negative trial results. Like MMRF, the alliance has also established a biobank so that its constituent groups can deposit tissue samples and clinical data, using standardised consent forms, material transfer agreements and other paperwork—a potential treasure trove for researchers interested in testing drugs for these conditions.

The ALS Therapy Development Foundation (ALSTDF) has gone even further, hiring scientists and setting up its own laboratory to look at hundreds of existing compounds for their potential to treat amyotrophic lateral sclerosis, a fatal neurodegenerative disease. The benchmark for success is straightforward, says James Heywood, its director, whose brother Stephen was diagnosed with ALS seven years ago: "What piece of information would convince me to put Stephen on the drug?"



So far, progress has been slow. On a budget of $4m a year, the group has funded clinical trials at the University of California, San Francisco of two drugs, currently used to treat sickle cell anaemia and HIV, which showed modest activity against ALS. (In a strange twist of fate, the neurologist who designed the trial, Rick Olney, has developed ALS and is now participating as one of its patients.) ALSTDF has also spun off a biotech company, called Alsgen, to develop some of the ideas emerging from its earlier work.

"I've learned a couple of things that are a little disappointing," admits Mr Heywood. "I thought initially that there were all these good ideas that just needed a push; it turned out that there weren't a lot of great ideas." The problem, says Mr Heywood, is that much of the pre-clinical evidence on which people were willing to take drugs to trial turned out, on further investigation, to be wrong. The foundation now hopes to strengthen these scientific foundations by trying to establish a valid biomarker—a biochemical or biological feature that correlates with disease and can therefore be used as a surrogate measure of drug efficacy or safety—for developers to use in their efforts on ALS.

For many other patient groups, however, the trouble is not too few drugs on the horizon, but rather too many. As Ms Giusti points out, only 25% of the drugs in development for multiple myeloma are probably worth pursuing: the key is to choose the most promising candidates, and focus precious money and manpower—especially scarce patients for clinical trials—on them.

Another challenge lies in co-ordinating the patient groups themselves, so that those working on, say, myeloma or ALS, are not duplicating, or worse, competing with, each other's efforts. Above all, there is the tricky business of explaining to patients, whose donations largely fund the efforts of groups such as CFF and MMRF, that most drugmaking will end in failure. That, after all, is why the big drug companies are unwilling to invest: the reward does not justify the financial risk. Patients' groups, of course, quantify risks and rewards using an entirely different yardstick. "The biggest risk", says Mr Beall, "is if we hadn't made this investment at all." ■

Medicine without frontiers

Leroy Hood, one of medicine's boldest visionaries, has spent his career marrying biology with technology

TEN years from now, you will not have to spend hours in a doctor's office to complete a comprehensive health check-up. Instead, with just a single pin-prick, a nanotechnology device will quickly measure and analyse 1,000 proteins in a droplet of your blood. Based on this "molecular fingerprint", your doctor will prescribe drug regimens tailored to your personal state of health that will not only be able to reverse many diseases, but will also prevent their manifestation in the first place.

That, at least, is how Leroy Hood, the president and co-founder of the Institute for Systems Biology, a non-profit organisation based in Seattle, lays out the future of medicine. "The Human Genome Project has given us a parts list," he explains. The next step is to capture the information from all the elements in a biological system: DNA, proteins, cells and organs, and then create new mathematical models that will represent the relationships between them. The ensuing digitisation of biology, he reckons, will revolutionise the entire health-care system and usher in a new era of predictive, preventive and personalised medicine.

Today, it sounds far-fetched. But as many of his colleagues and friends attest, Dr Hood, an avid outdoorsman, has never been shy of climbing a mountain or going out on a limb. Throughout his career, the 66-year-old has made it a habit to champion ideas that were initially unpopular but later proved correct. For one thing, he was one of the early proponents of the project to sequence the human genome, at a time when many of his contemporaries had doubts about its viability. Moreover, the very instrument that turned the endeavour into a success, the automated DNA sequencer, originated in his laboratory.

Yet the machine for which he is best known is only one of many inventions Dr Hood has successfully commercialised. To date, he has co-founded more than ten companies, including Applied Biosystems, which went on to become the biggest life-science instrument company in the world, and Amgen, the largest biotechnology firm in the world. He also holds 14 patents, has won numerous awards, and has co-written four textbooks—with a fifth, about systems biology, now in the works. But, most important, he has become one of medicine's boldest visionaries.

Even at a young age, Leroy Hood showed an independent streak. Growing up with his family in rural Montana, he developed an early affinity for the outdoors and started hiking in the nearby mountains as a young boy. While he excelled in the sciences, he was never a nerd. He learned to play the piano, among other instruments, joined a successful debating club and, during high school, was quarterback in an American football team that was undefeated for more than three years.

He finally set his sights on biology when his high-school chemistry teacher asked him to help teach a class on the subject for younger students. He agreed on the condition that he could base his lectures on articles from *Scientific American*, a popular science magazine. One article from 1956, about the structure of DNA, made a lasting impression on him. The same chemistry teacher also pushed the young Hood to apply to the California Institute of Technology, where he would spend much of his student and professional life.

Immune response

As a PhD student at Caltech in the mid-1960s, Dr Hood got his first taste of scientific controversy, when he became involved in an argument over how the human immune system produces such a wide diversity of antibodies to fend off disease. Up until then, the explanation for antibody diversity had been based on the theory that one gene provides the recipe for one protein, or polypeptide chain. (An antibody consists of four such chains, in two identical pairs.) But when it became apparent that the human genome contained at most 100,000 genes, while the body could create hundreds of millions and possibly billions of antibodies, that explanation was thrown into question.

Together with his mentor, William Dreyer, Dr Hood proposed a radical new hypothesis. They suggested that antibodies were encoded by a relatively small number of genes that can rearrange themselves to make up new sequences, akin to creating new sentences by breaking up and reshuffling a string of words.

The suggestion that some genes might not have a permanent structure, but ▸▸

"Critics suggest that systems biology may simply be too complex for mathematics. Dr Hood is unfazed."

could splice and rearrange themselves, seemed outrageous at the time, and it catapulted Dr Hood into the midst of a cutting-edge discussion in immunology. As a result of all the hoopla, and despite being only a graduate student, he was invited to travel and give lectures at prominent universities and national meetings (though he also spent hours in the laboratory sequencing proteins by hand). In the end, it took another ten years until all the tools became available to prove the theory right, which led to a 1987 Lasker prize for Dr Hood, Philip Leder and Susumu Tonegawa (who also received the Nobel prize later that same year).

Frustrated by the limitations of manual laboratory work, Dr Hood concluded that it was essential to invent new tools that could drive biological discovery. So when Caltech hired him in 1970 as an assistant professor, he decided to divide his time between technology and biology. By the end of the decade, his efforts had born fruit—his laboratory created a new protein sequencer that was much more sensitive than previous instruments. And when a friend suggested mass-producing the device, Dr Hood went knocking on doors.

Finding a sponsor was easier said than done. After 19 rejections, Dr Hood was somewhat discouraged. Fortunately, a venture capitalist heard about the prototype and offered him $2m to start a company. Dr Hood was elated, but his difficulties were still not over. Today, eager universities help professors to file patents and commercialise ideas. But back then it was uncommon for academic institutions to be so co-operative. Caltech's president at the time, Marvin Goldberger, was reluctant to make commercial deals, although he finally relented and gave the go-ahead for the creation of Applied Biosystems.

The company's success was based on four machines, all of which originated in Dr Hood's laboratory during the 1980s. (As a result, Caltech still receives patent royalties of approximately $10m a year.) Together, they opened up new fields in biology. The protein sequencer, for example, made possible the analysis of small amounts of protein that had previously been inaccessible. Next, the protein synthesiser assembled long chains of amino acids, making it possible to produce large quantities of proteins. The third machine, the DNA synthesiser, could churn out pieces of genes to aid in DNA mapping and cloning. But the most sophisticated instrument was the automated DNA sequencer. It replaced confusing radioactive labels with laser-activated fluorescent dyes, making sequencing faster and much more precise.

Back in 1985, however, when Dr Hood participated in the first meeting to discuss the possibility of sequencing the human genome, biology was still very much a manual science. People worked with Petri dishes and cultures of goo, explains Michael Hunkapiller, a former research fellow in Dr Hood's lab who went on to become president of Applied Biosystems, and is now a venture capitalist. "The molecules that affected biology were viewed at that time as too complex to analyse easily," he says.

As a result, many biologists were wary of the project. They worried that the technology was not up to the job, that it would take too much time and cost a fortune, thus drawing away valuable resources from other research. Others were repelled by the idea of "big science", fearing that the sociology of the field might change to one that would be dominated by expensive, large-scale enterprises.

Biology without borders

In the end, the project—which finished in 2003, ahead of schedule and under budget—fundamentally changed how biology is practised. According to David Baltimore, the current president of Caltech, it highlighted the need to involve scientists from fields outside biology, leading many universities to adopt cross-disciplinary approaches to the subject. This approach is, of course, vintage Leroy Hood, observes Roger Perlmutter, executive vice-president of research and development at Amgen, and who also heads the board of the Institute for Systems Biology. "Since he joined Caltech as a faculty member, he has been trying to marry engineering and the physical sciences with biology in order to produce tools that could revolutionise biomedical research," he says.

Over the years, as the ambition of Dr Hood's plans grew, so did his staff. When he first arrived at Caltech in 1970 he had fewer than ten people associated with his lab. By 1990, there were more than 100. Dr Hood then became interested in creating an entirely new department, explicitly dedicated to cross-disciplinary efforts and comprised of biologists, chemists and engineers. But such a grand vision for the relatively small school did not sit well with the rest of the faculty. In the end, the majority of biologists reacted negatively to the idea.

In 1992, Dr Hood was invited to chair the new cross-disciplinary Department of Molecular Biotechnology at the University of Washington in Seattle. With $12m in start-up funds from Bill Gates, he accepted. "But the seeds of tragedy were sown for the next thing," says Dr Hood, even though he achieved a lot over the following years. Among other activities, his department operated two of the 16 centres for sequencing the human genome, and one of its members helped create the field of proteomics, the cataloguing of the proteins for which the genome provides the recipes. But in the end he was unable to convince the dean of the medical school to allocate more space for his once-again growing department.

Experiences like this convinced Dr Hood that it is virtually impossible to develop revolutionary new ideas within existing structures. So in 2000, at the age of 61, he decided to leave academia behind. Together with two former colleagues, he formed the Institute for Systems Biology—without a penny of endowment.

Already, the institute has more than 170 staff members and an annual operating budget of $28m, mostly from government contracts and grants. Moreover, Dr Hood has been able to attract an amazing calibre of collaborators, including Michael Phelps, the inventor of positron-emission tomography, who chairs UCLA's Department of Molecular and Medical Pharmacology, and James Heath, a physical chemist at Caltech who belonged to Richard Smalley's group that discovered "buckyballs" (soccer-ball shaped carbon molecules). Together they have founded the NanoSystems Biology Alliance, with the aim of developing a nanosensor device capable of making five measurements from a blood sample by the end of this year, and 1,000 or more within ten years. "These nanotechnology tools will be mass-produced and used by every scientific investigator, even in small labs," predicts Dr Hood.

Despite his track record, his new ideas have proved as controversial as ever. Critics point out that systems biology may simply be too complex for mathematics; others say the timetable for creating the proposed nanotech instruments is too ambitious. But Dr Hood, who has heard similar arguments before, is unfazed by the scepticism. "It doesn't bother me in the slightest," he says. "In the end what counts is what you do." ■

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The Economist

SEPTEMBER 17TH-23RD 2005 www.economist.com

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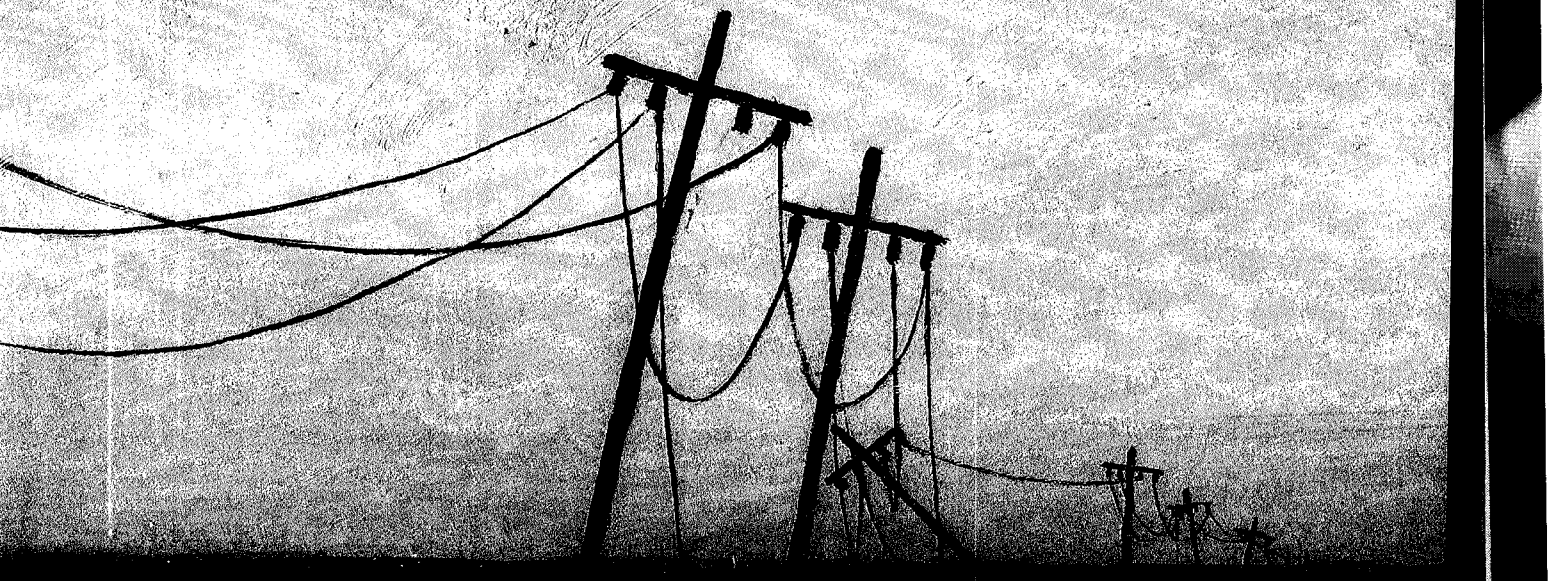

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Albania	L600	Czech Rep	KC130	France	€4.90	Ireland	€4.90	Latvia	LVL2.60	Nigeria	Naira 400	Saudi Arabia	Rials32	Sweden	SEK42
Austria	€4.90	Cyprus	CE2.85	Germany	€4.90	Israel	NIS25.00	Lebanon	LE8,000	Norway	NKr43	Slovakia	SKK160	Switzerland	Sfr8.00
Bahrain	Dinar3.00	Denmark	DKr43	Greece	€4.70	Italy	€4.90	Luxembourg	€4.90	Poland	PLN17.50	Slovenia	SIT820	Turkey	TL4,300,000
Belgium	€4.90	Estonia	EEK60	Hungary	Ft900	Kenya	KShs400	Malta	Lm2.00	Portugal cont.	€4.70	South Africa	R29.00	Turkey	YTL4.30
Bulgaria	BGN7.00	Finland	€4.90	Iceland	IKr400	Kuwait	Dinar2.50	Netherlands	€4.90	Qatar	Rials31	Spain	€4.90	UAE	Dirhams 30