

The  
Economist

How to build  
a Babel fish

Towards the  
cyborg soldier

Prius-hackers and  
the 100mpg car

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## Can robots be trusted?

The challenge of making sure robots do no harm





## Plugging into the future

**Electric cars: A grassroots movement is building hybrid petrol-electric cars that can be recharged from the mains. Why?**

WITH a licence plate that reads "100 MPG", Greg Hanssen is used to his car attracting attention. Even so, he seemed especially pleased by the crowd that gathered around his modified Toyota Prius at a hotel parking lot in San Diego, during a recent conference held there by the Society of Automotive Engineers. They poked at various parts of the car with vigour, and positively gushed when he opened the back to reveal what any punter would have described as an ordinary-looking electrical plug.

Such enthusiasm is surprising, since automotive engineers are a hard bunch to impress. The technologies involved in cars have been refined countless times since the first internal-combustion engine appeared over a century ago. It would take a pretty big breakthrough to take their breath away today. And yet that is what happened in San Diego, at a conference devoted to hybrid cars.

Hybrid technology, pioneered by Toyota with its Prius, combines the usual petrol engine with an electric motor and battery that never need to be plugged in. The resulting gain in fuel economy is impressive: the Prius achieves over 40 miles per gallon, perhaps 20% more than it

would without hybridisation. But the gathered petrol-heads, almost all of them men, yawned through presentations on various aspects of hybrids until the final topic: "plug-ins". As experts described efforts to connect hybrids to the electrical grid, those in the audience scribbled furiously and asked eager questions. And when Mr Hanssen, a plug-in pioneer, was pointed out in the audience, the room gave him an ovation. Why all the hoopla, when his big idea—plugging the car into the mains for recharging—seems to some people to be a big step backward?

### Electric sceptics

For one thing, say the sceptics, plugging in will be expensive and will stress the already overloaded power grid. Actually, that is unlikely. Because drivers will mostly plug in their cars overnight, they will benefit from cheaper off-peak power rates. In America, using cheap electricity to power cars can reduce the cost per mile by 75% compared with petrol (or even more, given current high petrol prices). The savings are even greater in Europe, which has high petrol taxes. True, if many drivers plugged in during the day it would raise peak demand, but software in the cars could prevent daytime charging.

Sceptics also argue that electric cars are misleadingly clean: they are "pollute somewhere else" machines, they scoff. While running on battery power they produce no tailpipe emissions but, critics note, the coal-intensive grid electricity they use surely produces more green-

house gases than a petrol engine does. Again, that turns out to be wrong: studies by California's Air Resources Board confirm that generating the electricity to power cars in pure-electric mode produces only about half of the greenhouse gases of typical petrol vehicles. This assumes the power grid is half coal-fired, as America's is today. As the grid "decarbonises" over time, such emissions will fall.

Fine, but surely few people want a car you have to keep plugging in—what happens when the battery runs out? According to Bill Reinert of Toyota, one of the great advantages of the Prius electrical system—in which the battery is charged by the petrol engine and using energy recaptured during braking—is the fact that you never need to plug it in and that it never runs out of juice. That is far more convenient for drivers, insists Toyota, which has opposed the idea of plug-ins.

But Mr Hanssen notes that even if the battery pack in his modified Prius goes flat, it simply switches over to the petrol engine, just as a normal Prius does. The difference is that his car can go much further on battery power alone. That is because he has replaced the original nickel-metal hydride (NiMH) battery with a higher-capacity lithium-ion battery, and has hacked the control software to prevent the petrol engine kicking in until the car is moving at high speed. As a result, his modified Prius can travel over 30 miles in all-electric mode, compared with a mile or so for a standard Prius.

Toyota did not provide the software source code, but Mr Hanssen and his colleagues at EnergyCS, a firm outside Los Angeles, managed to trick the Prius's computer into thinking that his giant battery is really a factory-installed battery that mysteriously happens to be full of charge much of the time. Even when the petrol engine kicks in (as the master computer requires on all Prius cars at higher speeds), electric power is still blended in to improve fuel economy and provides up to 75% of the total power at 55mph.

Riding with Mr Hanssen from San Diego to Los Angeles in his hacked Prius, your correspondent saw the other reason he is a hero to the engineers. The detailed diagnostics screen on his dashboard verified that his licence plate does not lie: his car really does achieve 100mpg. Given that the average fuel economy of new American vehicles is less than 30mpg, that is quite an achievement.

EnergyCS has handled the conversion of around half a dozen Prius cars already. ▶▶



## "A motley crew of hackers, entrepreneurs and idealists has sprung up to boost the nascent technology of plug-in hybrids."

With the help of Clean Tech, a systems integration firm, it plans to offer plug-in retrofits to the general public this year for around \$12,000. The company hopes to plug in Europeans through Amberjac, its European partner. It may find a receptive audience: Priuses in Europe already have a button allowing drivers to go into all-electric mode for brief periods. (The button is not wired up in American Priuses, though it can be activated.)

### Blame it on the hydrogen

EnergyCS is at the forefront of a clean-car revolution, but it is not alone. A motley crew of hackers, entrepreneurs and idealists has sprung up to boost the nascent technology of plug-in hybrids. Most of these enthusiasts are in, or from, California—not surprising, given the state's greenery and its love of electric cars. Curiously, another common thread is a passionate hatred for hydrogen fuel cells.

As a forthcoming documentary film "Who Killed the Electric Car?" (released later this month) makes clear, this crowd does not blame the failure in the 1990s of battery cars—such as GM's EV1, the most aerodynamic production car ever made—on the limitations of battery technology or a lack of customer interest. Chelsea Sexton, a former marketer of EV1 cars and a star of the film, typifies the view of the plug-in crowd when she blames gullible regulators and cynical carmakers for abandoning electric cars for the distant dream of hydrogen. Inspired by the hacking of Priuses, various lobbying groups have sprung up hoping to entice manufacturers to produce plug-ins and to push politicians to support them. Ms Sexton, for example, now helps run Plug In America, a group that includes Jim Woolsey, a former head of the CIA.

Felix Kramer runs the California Cars Initiative (CalCars), a non-profit advocacy group that promotes plug-ins. With help from EnergyCS, his outfit created the first plug-in Prius—though it used cheap lead-acid batteries, which are much heavier and shorter-lived than lithium-ion ones. During Earth Day celebrations in April, Ron Gremban, CalCars' technology guru, led a group that converted a Prius into a plug-in in three days, while the public watched. In co-ordination with the Electric Auto Association, CalCars now plans to release a free "open source" version of its conversion instructions.

Plug-In Partners, which counts many electric utilities and green groups as members, is drumming up "pre-orders" for

fleets of plug-in vehicles to prove that demand for them really exists. That is important not only because carmakers are notoriously risk-averse (given the huge sunk costs of existing capital stock). Battery enthusiasts whisper darkly that the car companies never wanted battery cars to succeed, and so lied about a lack of consumer demand. Ms Sexton and other former insiders point to long waiting lists they say were ignored by the big car companies, who chose instead to shut down their electric programmes and to crush most of those electric cars.

All this talk of the obstinacy and ruthlessness of Detroit comes as no surprise to Andrew Frank, an engineering professor at the University of California at Davis. The oil shocks of the 1970s inspired him, he says, to pursue technologies to make a big car capable of 100mpg. For three decades, he has been advocating hybrid technology—and seemingly getting nowhere with the big car manufacturers.

And yet Dr Frank has persevered. Visitors to his lab today find a plug-in Ford Explorer sports-utility vehicle (SUV) equipped with a giant 16 kilowatt-hour (kwh) battery designed for long range—a conventional Prius battery has a capacity of 1.3kwh. He has replaced the original 3.5-litre internal-combustion engine with a frugal 1.9-litre version, thus boosting fuel economy, but the added kick from the electric motor means this SUV can still accelerate to 60mph faster than an ordinary Explorer. He has made similar modifications to a Mercury saloon, so it can travel 40 miles in all-electric mode and achieve an astounding 200mpg.

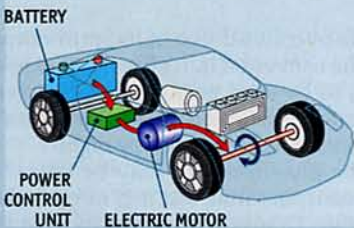
Dr Frank draws inspiration from "The Great Race", a film from 1965 in which the offbeat Professor Fate takes on a conventional challenger in an automobile race. Team Fate, as Dr Frank's researchers are called, has won a number of contests with its hybrid vehicles—as the black victory banners depicting skulls and crossbones (Professor Fate's insignia) on the lab's walls attest. "In the movie the professor is really wacky," jokes one of his students, "and that's right on the money."

Dr Frank seems comfortable with his image as the absent-minded professor. "I've been Professor Fate a long time," he says with a smile. Even when he got somewhere with the big car firms, he thinks he got cheated. He showed off his technology years ago to visitors from Toyota. At the time they expressed no interest, he says, but he was struck by the similarity of the Prius technology later unveiled.

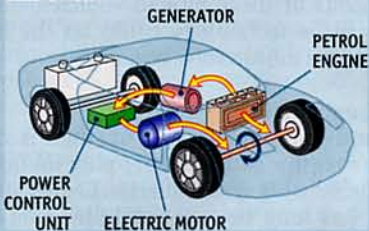
### Plugging away

How plug-in hybrid cars work

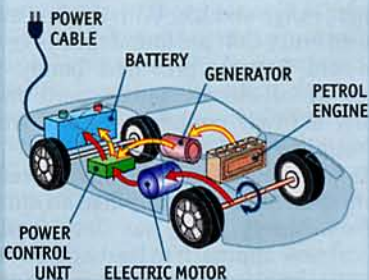
1. When running in all-electric mode, the vehicle relies on battery power to drive an electric motor, which in turn drives the wheels.



2. The petrol engine comes into play only when the vehicle is running at high speed (for example, on a motorway) or if the battery is exhausted. Power from the petrol engine drives the wheels directly, and also turns the generator, which drives the electric motor.



3. The battery is recharged in three ways. When braking, the electric motor acts as a generator, converting the vehicle's kinetic energy into electrical energy and storing it in the battery. The engine can also recharge the battery directly when necessary. And, of course, the battery can be recharged from the mains by plugging the car in.



Source: Toyota, The Economist

Hymotion, a Canadian firm, has also converted a Prius into a plug-in. Rather than retrofitting cars on-site, this firm has developed a modular kit that is intended to be installed (in just two hours, supposedly) by authorised garages around North America. Ricardo Bazzarella, Hymotion's president, hopes his kit will fall in price from \$12,000 today to \$6,500 by 2008. He plans to develop similar kits for the hybrid versions of the popular Ford Escape SUV and the bestselling Toyota Camry saloon. "Every new hybrid that comes out, we're looking to make into a plug-in," he says.

Entrepreneurs and academics are not the only ones plugging in. The Electric Power Research Institute (EPRI), the research arm of America's power utilities, has joined up with DaimlerChrysler for a ▶▶



► trial in over two dozen of its Sprinter vans will be converted into plug-ins. It expects them to be used primarily as fleet vehicles, such as delivery trucks, that return to a depot for recharging every night.

The plug-in crowd may be paranoid and conspiratorial, but it is nevertheless effective. Thanks to its efforts, the number of vehicles converted to plug-in status seems likely to soar from a handful today to hundreds within a year. And if, as plug-in advocates hope, some of the big carmakers develop official, commercial versions of these plug-in vehicles, then this niche technology could hit the big time over the next few years.

### Enough juice?

Grand ambitions are fine, but there is still one snag that could yet keep plug-ins from hitting the big time: batteries. Energy storage has long been the Achilles heel of electric cars. Have batteries really become cheap, reliable and compact enough? The answer is a definite maybe. Earlier versions of electric cars (such as the ill-fated EV1) used lead-acid batteries. This old technology is cheap and safe, but cannot compete with newer technologies on weight, range and life. With the first-ever hacked Prius, CalCars found that its 135kg lead-acid battery provided barely 10 miles of all-electric range, performed poorly at lower temperatures and wore out within a year.

Hope springs eternal, however. Firefly, a firm spun off from Caterpillar, an industrial-machinery giant, has developed a radical new approach to lead-acid batteries. The firm replaces the conventional lead plates with graphite foam, which carries a slurry of chemically active materials. The foam increases the area of contact between the electrodes and the active chemicals, and greatly reduces the problem of corrosion. The firm claims that this new approach reduces weight and matches the performance of NiMH at one-fifth of the cost. It hopes to apply this technology to hybrid-car batteries.

It sounds promising, but has yet to be proven in the field. In contrast, NiMH batteries are battle-tested and safe (unlike some lithium-battery technologies, which have an unpleasant tendency to explode). Toyota's conventional Prius has a NiMH pack that weighs 35kg or so and costs around \$1,600. Putting NiMH batteries into a plug-in Prius, as CalCars has done with the help of Electro Energy, a battery-maker, means carrying a lot more weight around. Such a battery costs



The Prius hackers get to work

around \$5,000 and weighs 180kg—though CalCars hopes to reduce that weight by half with its next prototype. Stan Ovshinsky, who pioneered the NiMH battery, says he has now come up with a radical improvement on that technology that would be perfect for plug-in cars—if only his firm ECD Ovonics (partly controlled by Chevron, an oil giant) would let him go ahead.

Yet the future may belong to lithium technology after all. One reason, says Menahem Anderman of Advanced Automotive Batteries, a consultancy, is that recent increases in the price of nickel and cobalt have limited the opportunity for further cost reduction of NiMH and made lithium batteries, which have traditionally been far more expensive, more competitive. Alan Mumby of Johnson Controls, a big car-parts supplier, agrees. His firm has recently entered into a joint venture with Saft, a French battery giant, to produce lithium-ion batteries for hybrid cars. Mr Mumby maintains that “the lithium-ion battery both delivers and accepts power very readily, making it ideal for hybrids with regenerative braking. Lithium-ion technology is the wave of the future.” Lithium also has the crucial advantages of low size and weight. Hymotion's production-ready battery kits, due later this year, will feature lithium-ion batteries weighing just 70kg but delivering an all-electric range of 25-30 miles.

### Dead end or stepping-stone?

Even if the battery woes that have long bedevilled electric cars can be solved, however, such progress may yet prove a stepping-stone to hydrogen—the *bête noire* of the electric-car crowd. “Long term, plug-ins with fuel cells may be the ideal vehicles,” says Mr Graham of the EPRI. Dr Frank agrees, noting that the hybridisation would mean cars would need less hydrogen on board, and smaller (and thus cheaper) fuel cells. Dr Ovshinsky

even stood up after the New York premiere of “Who Killed the Electric Car?” to lecture the film's director and audience that batteries and hydrogen can work smoothly together.

Everyone is agreed on the need for better batteries, however. And A123 Systems, a spin-off from the Massachusetts Institute of Technology, is now promoting a new lithium battery technology which combines a novel lithium-ion phosphate chemistry with nanoscale materials that increase the surface area of the electrodes. Although it is still unproven in hybrid cars, even the sceptical Dr Anderman thinks this chemical cocktail is “considerably less volatile” than conventional lithium approaches; furthermore, it has potential for lower cost and long life. A123's batteries can already be found in some Black & Decker power tools, where they deliver two to three times the run-time and peak power as rival batteries. A123 plans to supply Hymotion with batteries for plug-ins, and says it has the manufacturing capacity to make 10,000 such batteries a year.

Given that there are only a handful of plug-in cars on the road today, that figure sounds rather ambitious. Even so, the lesson offered by Professor Fate is that thinking big can eventually pay off. “The automobile business is a gigantic battleship, and after 30 years I may have moved it an inch,” reflects Dr Frank. That inch may yet grow to a mile. If the EPRI trial of plug-in Sprinter vans ends successfully, says Mr Graham, DaimlerChrysler is likely to produce a commercial version. Having long been dismissive of plug-ins, Toyota has confirmed that it is now seriously working on a plug-in Prius. Even Ford's boss, Bill Ford, has made encouraging noises about plug-in hybrids. Rising fuel prices and improving battery technology only strengthen the case for them. “This is here-and-now technology,” says Dr Frank with some satisfaction. ■