Power games

Can motor racing go green? **Andreas Trabesinger** asked Max Mosley, head of Formula 1, how he wants the sport to develop energy-efficient technology that will also work in road cars.

When Robert Kubica moved to overtake a rival at the hairpin bend in the Canadian Grand Prix on 10 June, he lost control of his Formula 1 car and smashed head-on into a wall in a truly horrific-looking crash. His BMW-Sauber was travelling at 280 kilometres per hour as he tried to pass Jarno Trulli's Toyota, and after ricocheting off the barriers, the car somersaulted along the track before coming to rest with only one wheel still attached. Remarkably, Kubica emerged from the crushed shell of his car with mild concussion and a sprained ankle. His slight injuries are a testament to safety improvements in Formula 1 cars, and to the commitment made by the Fédération Internationale de l'Automobile (FIA), the sport's governing body, to safety standards. Kubica almost certainly would not have survived a similar crash 15 years ago.

The Montreal event, as with all 17 races held in this year's Formula 1 championship, is about the thrill of pushing automotive technology to the very edge of reason. Making sure that the speed seekers are reined in and the sport stays within sensible limits is a difficult task in a contest of such extremes.

This task is the responsibility of the FIA, which until recently worried mostly about drivers' safety while keeping the race exciting enough to satisfy the tens of thousands of spectators at the circuit and the tens of millions of television viewers. But this heady mix of reason and adrenaline can have unexpected results. Last year, the FIA set out a 'green agenda' for Formula 1, announcing its intention to turn a sport in which cars guzzle 60 or 70 litres of petrol every 100 kilometres into a catalyst for greener technology for road cars.

> **"Brilliantly clever, amazing engineering but utterly pointless, and irrelevant to the real world."**
> — Max Mosley

Max Mosley is the man behind the wheel of the green agenda. In a penthouse high above London's Trafalgar Square, he lays out goals for the FIA to reach by 2009 and beyond. Now in his sixties, Mosley graduated from the University of Oxford, UK, with a physics degree, before going on to study law. He admits that he is no expert when it comes to car technology, but he has been active in motor sports as a driver and team owner since the mid-1960s, and has been president of the FIA since the early 1990s. Mosley's vision of how Formula 1 will contribute to green technologies is simple: make the research done in Formula 1 relevant to road cars, in particular reducing their emissions of carbon dioxide.

So how does Formula 1 plan to get there? The FIA has a powerful advantage in that it can rewrite the technical rules for the championship every year. In the past, the FIA restricted the power a car's engine was allowed to produce for safety reasons, typically by limiting the engine size. For the race engineers, the task was to extract the maximum possible power from a given size of engine (see 'Racing through the decades', overleaf), thereby ensuring that Formula 1 remains the fastest form of racing on a twisted circuit. But by the start of the 2011 season, Formula 1 teams will have to crack

SCHLEGELMILCH/CORBIS

a new technological nut: making the most of a given amount of energy. From then, the amount of fuel the cars can use in each race will also be restricted.

For Mosley the link with road cars is obvious: "This is precisely the problem that the car industry is trying to solve and indeed the world is trying to solve." He adds, "As soon as you look at it like that, you say 'why didn't we do this years ago?'" The reason, he says, is the same as why the road-car industry hasn't done it and that the public hasn't demanded it, because energy is still very cheap.

The links between Formula 1 and road cars have strengthened over the past decade. Of the 11 teams racing today, six are sponsored directly by major road-car manufacturers, only two of which — McLaren-Mercedes and Ferrari — were running their own teams in 1997, although many manufacturers were involved in the sport as suppliers of engines and other parts. The change came as the road-car industry embraced Formula 1 as a marketing platform, and its involvement has in turn benefited the sport as the costs of racing started to outstrip the available resources. Owning a Formula 1 team is a luxury few can afford, with running costs of up to hundreds of millions of dollars a year. Thirty years ago, the change of a single gearbox could require extra fundraising, but today the sport is flush with money from big-name sponsors and advertising.

Over-engineering

What has that money achieved? According to Mosley, until the FIA froze engine development at the end of last year's season, an average of 4 milliseconds of lap time were gained for every million dollars spent on engine development, and 20 milliseconds for every million dollars spent on optimizing the aerodynamics. Mosley is clear in his verdict: "Brilliantly clever, amazing engineering but utterly pointless, and irrelevant to the real world, because the engines were inherently inefficient." He points out that the teams have massive wind tunnels, supercomputers and model shops and they work 24 hours a day just to refine known technology. "This I want to stop," he says. "Let's get the really clever people working on the problem the whole world is trying to solve — which is just as good for Formula 1."

There are two areas in which Mosley thinks Formula 1 can make a lasting contribution to road-car technology, and that in turn will ensure the lasting success of the sport. These will be to recover energy lost through waste heat and braking. About two-thirds of the fuel energy in a car is lost as heat into the atmosphere — through exhaust gases and coolants. The other third propels the car forwards, but some of that kinetic energy is also lost, ultimately turned to heat, when the driver brakes. From 2009, new regulations for Formula 1 will allow, and thus force, the teams to recover a restricted amount of energy lost in braking, and use it to propel the car. The harder task of recovering the two-thirds of heat lost to the atmosphere is deferred until new regulations are introduced for 2011.

RACING THROUGH THE DECADES

Formula 1 in the 1950s
Fatalities: 8
Engine sizes: 1.5–4.5 litres
Power: 270 horsepower in 1958

FOX PHOTOS/GETTY IMAGES

Formula 1 in the 1970s
Fatalities: 10
Engine sizes: 1.5–3.0 litres
Power: 485 horsepower in 1974

ALLSPORT UK/GETTY IMAGES

Formula 1 in the 1990s
Fatalities: 2
Engine sizes: 3.0–3.5 litres
Power: 755 horsepower in 1997

M. BRANDT/BONGARTS/GETTY IMAGES

At present, the teams are not allowed to recover braking energy because of concerns about how the technology would perform under the extreme forces experienced by a Formula 1 car. The technology that does this is called a kinetic energy recovery system (KERS), better known to drivers of hybrid vehicles as 'regenerative braking'. In a modern hybrid car — which has both a petrol engine and an electric motor — the motor's batteries can be charged by either the petrol engine or regenerative braking. The energy can be stored in different forms, but the most viable options for Formula 1 seem to be electrical storage in batteries or capacitors or the use of a flywheel.

Although the 2009 regulations will not limit the cars' consumption of fuel directly — and refuelling will still be allowed during the race — the ability to regain kinetic energy means extra power for racing. In short, the car gains energy without having to carry extra fuel, and therefore weight. Another advantage of KERS is that the stored energy can be used to improve performance, especially during acceleration out of corners or overtaking of other drivers, giving racing fans a more exciting spectacle. Together, these factors make KERS extremely attractive to Formula 1 engineers.

Electric dreams

Burkhard Göschel, chairman of the FIA Manufacturers' Advisory Commission and former board member of BMW, is the 'technical brain' behind FIA's green agenda. He expects that most teams will go for electrical storage systems, either in the form of so-called supercapacitors (which have very high energy density and can store and release energy quickly) or new battery technology based on lithium-ion batteries.

Long term, both Mosley and Göschel are betting that the car industry will move towards using more electric power. "The electrification of the automobile can be anticipated, there is no way back. We are exactly on the right track with Formula 1, and road cars will follow this track," says Göschel. He is convinced that Formula 1 will make electrical energy-storage systems more efficient, smaller and lighter, and that the technologies

One formula for zero emissions

Can racing become emission free? A small Dutch company based in Amsterdam wants to create a race series, called Formula Zero, that will be based on cars powered by hydrogen fuel cells. Unlike conventional engines, fuel cells produce energy by reacting hydrogen fuel stored in a pressurized tank with oxygen taken from the air, so water is the only exhaust product.

It is still early days for Formula Zero. Founded in 2003 by Eelco Rietveld, an industrial design engineer, and Godert van Hardenbroek, an environmental consultant, the company is planning a race series for hydrogen-powered go-karts, which it hopes will kick off in 2008 or 2009. So far it has persuaded several university teams to build fuel-cell go-karts, and it has earned an FIA-endorsed speed record for a fuel-cell vehicle that weighs less than 500 kilograms. Last year, its go-kart, pictured here, reached an average speed of 61 kilometres per hour over 200 metres from a standing start.

But its long-term goal is more ambitious: a race series for car makers to showcase zero-emission technologies in full-sized race cars. Van Hardenbroek says they fully support the FIA's drive towards fuel economy: "Max Mosley made a very wise move; the world will move towards hybrid cars, and Formula 1 should reflect that." But he recognizes that the technology has a long way to go to compete with petrol engines: "For Formula 1 it would be very hard to make a transition towards fuel cells, this is not an incremental step." **A.T.**

developed on the way will be directly relevant to road cars. For example, the batteries used by hybrid fuel–electric vehicles are still too heavy, and the amount of energy that can be put in and taken out of a storage device is limited — problems that Formula 1 research, with its short design cycle and high-performance goals, seems ideally suited to fix. Mosley is confident that the race engineers will deliver: "You can't say you'll have it ready in two years, because the teams say they need it next week. The people in the next garage will have it next week."

So is Formula 1 heading in the same direction as the road-car industry? Paul Eisenstein, publisher of *TheCarConnection.com* in Pleasant Ridge, Michigan, and observer of the automotive industry since 1979, has no doubt that the car business is under enormous pressure to improve fuel economy; at the same time however, consumers are not willing to compromise on car size or performance. For these reasons, says Eisenstein, hybrids are not doing as well in practice as on paper: "The cost is high, and the performance of many models mediocre, in particular in terms of fuel economy. Most existing hybrids don't deliver what they promise; that's not good."

The next breakthrough for hybrid vehicles will have to come from making the interplay between the electric motor and the petrol engine more efficient, says Eisenstein. What will race engineers contribute to hybrid technology? "I see no reason why race-car technology shouldn't make it into road cars," says Eisenstein, "but such technology will have to meet tough criteria: What is it going to cost? How long is it going to last? Nowadays, such components are expected to deliver at least 100,000 miles." Whether the technologies developed for Formula 1 will deliver both performance and durability, at reasonable cost, remains to be seen.

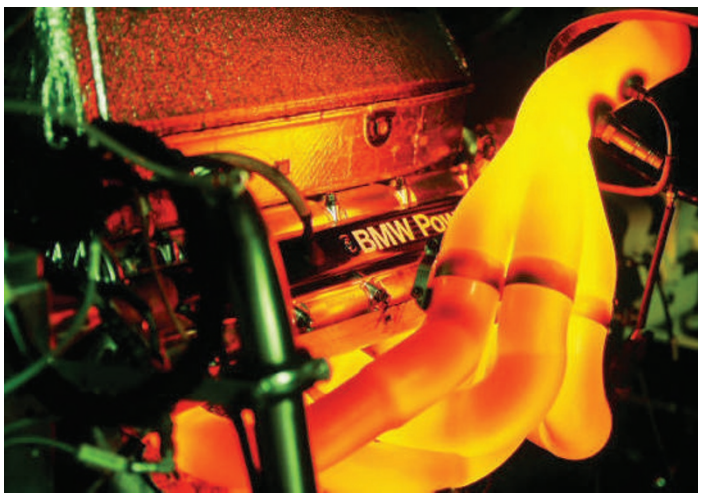
Heat treatment

Hybrid vehicles would benefit from improved regenerative braking, but the recovery of kinetic energy is still playing with only a third of the energy contained in the fuel that the car burns. There is still the two-thirds lost as heat to think about. Getting that energy back is attractive, says Göschel, but not as simple to address. Formula 1 cars have previously harnessed 'turbocharging' technology to improve the engine efficiency. In a turbocharger, exhaust gases drive a turbine that compresses the air flowing into the combustion chambers, and thus, eventually, allows fuel to be burned more efficiently.

Turbochargers were used by the teams during the 1980s, before being banned in 1989 because they gave engines dangerously too much power. The changes to the FIA regulations for 2011 onwards could provide a chance to bring the turbochargers back, but they have yet to be framed. What Formula 1 will bring to turbocharger technology for road cars — widely used in vehicles from turbodiesels to high-performance sports cars — is far from clear.

Charging up

More speculative are new ways to transform waste heat directly into electrical energy by use of physicochemical processes, but Göschel notes that such devices have very low



BMW

The heat is on: from 2011, Formula 1 teams will be able to reuse waste heat from the car's engine to boost performance.

efficiency. Further developed is a steam turbine that BMW introduced under the name of 'turbosteamer' — who would have thought that one of those could ever be discussed in the context of a Formula 1 car? — which is powered by the heat created by the petrol engine, so mechanical energy is recovered from heat. In a similar device, known as a 'turbo-compound', the exhaust gases drive not only the turbine of a turbocharger, but also a turbine in the stream of exhaust gases whose extra power can be used either directly or stored electrically. Unlike turbochargers, none of these devices is yet in production for road cars.

How have the Formula 1 engineers reacted to these rule changes? "The teams don't like it, because we ask them to stop doing things they understand, and do things they don't understand," says Mosley. Göschel has noticed a more positive trend: "In the very beginning, our engineers had some concerns, but now there is a lot of excitement in working on new technology." Nick Fry, head of the Honda Racing F1 Team, hopes that the rule changes will challenge young engineers, in particular, to come up with new solutions: "It's an investment in people, in learning and in intellectual property. By pushing this type of technology where we have to perform publicly every two weeks, we must advance very quickly."

H. NELEMAN/GETTY IMAGES

Many hands make light work: short design cycles put Formula 1 engineers under pressure to deliver.

Alternate take

But why stop with efficient energy recovery? Formula 1 could switch to using biofuels, maybe starting in 2011, says Mosley: "We would like to use a biofuel. The question is, which one. There are so many competing biofuel systems." What Formula 1 might end up doing is taking whatever fuel becomes adopted more widely, rather than picking a fuel in advance. Fuel cells relying on hydrogen are not yet being considered for Formula 1, although a small Dutch company is trying to launch a fuel-cell race series (see 'One formula for zero emissions'). In addition, the FIA has an Alternative Energies Commission that organizes an annual cup race with vehicles that use alternative energies.

"We are exactly on the right track with Formula 1, and road cars will follow."
— Burkhard Göschel

Mosley is planning to step down as FIA president at the end of his fourth consecutive term in October 2009, so is this green agenda all about his legacy? He admits that it plays a part, but he compares today's environmental concerns (See 'Carbon credentials') with the safety concerns that dominated Formula 1 when he first became president of the FIA. "It's a little bit like the safety debate, in that you work on safety because you don't want to kill anybody, you don't want anybody to get hurt, but also, society won't permit you to kill people like we did in the 1960s." During that period a driver died every year in Formula 1. "So, you've got two reasons: you want to do it yourself, but also you have to have regard to what society allows you to do."

Will Formula 1 be perceived as a 'green sport' in the future? "I don't know whether the fans will like it," says Mosley but he doesn't think that reason and adrenaline are incompatible. As people become increasingly conscious about carbon emissions and fuel economy, he hopes they will still be fascinated by a very fast, very powerful — but fuel efficient — Formula 1. In general, Mosley is pragmatic about the effect of the rule changes: "If it's technically interesting, that's fun, and if it makes a contribution to society, that's good," but ultimately he thinks Formula 1 needs public support in order to survive. "The number one thing is to make it so attractive and interesting that the public continues to pay for it." ■

Andreas Trabesinger is an associate editor for *Nature Physics*.

Carbon credentials

Since 1997, the Fédération Internationale de l'Automobile (FIA), motor racing's governing body, has supported a research project aimed at offsetting the carbon-dioxide emissions caused by Formula 1 teams (from the race cars themselves and from transporting teams to events) during a Grand Prix season. Through the FIA Foundation, a UK-registered charity, the FIA offsets annual emissions of the 11 teams racing — estimated in 1997 to be around 20,000 tonnes of CO_2 — by supporting the 'Scolel Té' project, which helps communities in southern Mexico to develop sustainable land management and better livelihoods.

As of December 2005, 888 farmers from 43 communities across the states of Chiapas and Oaxaca were included in the project, says Richard Tipper, president of the Edinburgh Centre for Carbon Management, UK, which consults on the project.

Unlike other sporting events, such as the 2006 World Cup in Germany, the FIA does not offset emissions caused by fans who travel to the events, so it can't claim to be carbon neutral. David Ward, director general of the FIA Foundation, says that the project's effectiveness will be reviewed this year, and the foundation will review the carbon footprint for the Formula 1 teams to see whether it has changed since 1997. As yet, The FIA Foundation has no plans to go carbon neutral. **A.T.**