# REFORGING THE LINK

FORWARD

While the FIA is perhaps best known as a regulatory body for motorsports, in reality its reach is much wider: it represents the interests of motorists and road users worldwide. Our FIA Action for Road Safety campaign is the most public face of this: it is committed to aiding the United Nations in the effort to reduce road deaths, with the ultimate target of preventing five million fatalities in this decade.

In equal measure it is both tragedy and cause for optimism that many fatalities can be prevented through simple steps. The FIA's Golden Rules promotes measures such as wearing a seatbelt and obeying the speed limit: straightforward perhaps, but nevertheless perfectly capable of dramatically improving safety.

While the biggest improvements in road safety will come about through adherence to a mundane set of good driving practices, there is always room for technological advancement. This is where we hope to see motorsports and the automotive industry working hand-in-hand. Motorsport has always developed technologies with a natural affinity for the road. There have been periods where this was overt, via technologies such as anti-lock braking systems or direct injection gasoline engines. The link is just as strong today, though perhaps less obvious to the casual observer.

With elite motorsport becoming increasingly specialised, responsibility falls onto the FIA to shepherd development. Our aim is to ensure racing remains relevant to the road while providing entertainment, but also fulfilling its historic role as an automotive test bench. Introducing hybrid technology to F1, and migrating to small-capacity turbos in both WRC and WTCC are good examples. These, of course, are environmentally driven – but as this article demonstrates, safety technology is rarely far from the thoughts of motorsports engineers.

*– Jean Todt, FIA President.*

The technology link between motorsport and the automotive industry has always been with us. Racing is the ultimate test bench: it provides a harsher environment and greater demands than the road; it operates with a much shorter development cycle and produces instant, tangible results at the fall of a chequered flag. For well over a century, racing has been a catalyst for automotive development.

There exists a long list of technologies created for motorsport – or more often appropriated by motorsport and swiftly enhanced – and then redeveloped for use in road cars. Many of these are in the field of safety or have a safety element to them: disc brakes and then anti-lock braking systems, for example, or intelligent all-wheel drive technology, or paddle-shifting gearboxes which allow drivers to keep both hands on the wheel. These are all regularly quoted as examples of how motorsports makes its contribution to road safety. They are all excellent examples, all have saved lives – but problematically all are rather long in the tooth.

Over the last two decades, elite-level motorsport has drifted away from the car industry. The quest for ever-improving performance has taken it away from road-going roots into more specialised fields; closer perhaps to aerospace than the automotive mainstream. As a consequence, the flow from the track to the showroom of big-ticket safety devices has dried up. The common perception is that the transfer of technology has itself dried up. This really is not the case: motorsport still contributes enormously to road-going safety technology – though it perhaps does so in less obvious ways than it once did.

AUDI

Doctor Wolfgang Ullrich, Head of Audi Motorsport, frequently states that the development of road-relevant technology is not a bi-product of his company's forays into motorsport, it's the reason Audi go racing in the first place. Audi aren't shy about trumpeting their racing heritage: the Quattro system that powered their iconic rally cars of the early 1980s still badges their all-wheel drives; the revolutionary FSI direct injection engines that took them to Le Mans victories at the turn of the century is now the core technology in every VW Group petrol engine – but there are more subtle ways in which motorsport contributes to the science of road safety.

The barrel roll performed by DTM driver Alexandre Prémat at the Adria Raceway in 2010 amply demonstrated the huge forces at work on touring cars and the terrible consequences when those forces get out of harness. Prémat's first lap accident is a YouTube favourite (700,000 views and climbing), though its fascination is as much for the fact that the Frenchman climbs out



unscathed as for the awesome destructive ballet his A4 DTM car performs beforehand. For engineers however, the data gathered as the car annihilates itself is a valuable asset for enhancing driver safety both on and off the track.

In the event of accidents of this magnitude Audi Sport works closely with the company's production car accident research department because a high-energy crash is as relevant to production as it is to the racing team. "Particularly with regard to the absorption of forces through carbon structures or hybrid constructions and the control of decelerations," says Dr Martin Mühlmeier, head of technology at Audi Sport. "Conclusions can be drawn about the forces and accelerations affecting the driver during the accident,"

Audi's line of reasoning is that, regardless of whether an accident takes place on a high speed oval or a country road, the effects on the driver or passengers – subject to the level of restraint – are the same. Testing has demonstrated that people can withstand high accelerations in frontal and rearward impacts: 150*g* (acceleration in relation to

**Top:** The Audi R18 of World Endurance Champions Marcel Fässler, André Lotterer and Benoît Tréluyer, fitted with AMOLED technology that is a 'forerunner' of a road car system.

**Above:** Alexandre Prémat crashes an Audi A4 DTM at Adria Raceway in 2010.

free-fall) in the case of the body and up to 250*g* to 300*g* for the head. Significantly more critical are the changing rotary accelerations, for example, generated when a car somersaults simultaneously about its longitudinal and transverse axes. Then it gets dangerous for the human brain. Accidents like the one in Adria are studied in great detail. The analysis is made with the help of measured data recorded by the 'black box' electronics within the chassis as well as video recordings.

Audi Sport say that their findings following events like Prémat's crash are not so much shared with the company's road car division as they are developed jointly. "Obviously you don't want such crash tests during a race, but they supply valuable data," says Ullrich.

PRODRIVE

No strangers to high-energy incidents, the FIA World Rally Championship has long been a medium through which road-going technologies are ultimately developed. Nowhere is the link more obvious that at Prodrive. The race engineering organisation developed and prepared the Subaru World Rally Team cars for World Champions Colin McRae, Richard Burns and Petter Solberg, and latterly managed the return of MINI to rallying. It also set-up its own road car engineering consultancy in the mid-1990s.

"A fact of life in motorsports is that we often develop high-quality engineering that doesn't have anywhere to go – our consultancy arm sprung up as a way to better use that technology," explains Matthew Taylor, chief engineer, vehicle dynamics. "It was a shop window: even if the technology is not immediately applicable to road cars – frequently because of the expense – it still opens up the opportunity for further discussions.

"We do produce a great deal of technology that finds its way onto the road, and much of that is safety related but often the time lag between a race technology and automotive take-up is such that the link becomes distorted. It's not immediately apparent to the outside world that a particularly technology came from a motorsport endeavour."

Prodrive have no shortage of heritage on track but Taylor argues that rally is much more likely to produce safety technologies than circuit racing. "Advances in engine technology and fuel are coming from the track at the moment but the reality is the rally car environment is so much more applicable to dangerous situations for road cars. The track environment is well controlled, from the point of view of knowing what the surface is, knowing what the bends are, knowing how the vehicle will perform on them – it takes much of the unknown out of the equation. In rally, of course, the stage changes every day with every car and with all the vagaries of weather. The rally car is constantly in an environment where the driver doesn't know what's coming next: he may have done a recce run in the morning but there might be a tree in the middle of the road by the afternoon. That aspect of pushing the car hard into the unknown translates directly to having a normal driver simply come across the unknown. Not through pushing the car but simply encountering the unexpected. How that road car deals with the unknown

## Audi looking backwards

*An ultra-modern example of Audi's use of motorsport as a technology accelerator can be found on the 24 Heure du Mans winning R18. In May at the Spa round of the FIA World Endurance Championship, Audi debuted a new, digital rear-view camera, enhancing the driver's rearward field of vision, and thus improving safety. Audi have not been shy in describing the technology as the 'forerunner' of a system for production cars.*

*Wing mirrors in motorsport have a bad reputation. Frequently miniscule in an effort to minimise drag, the vibrations common to a stiff racing chassis have a tendency to make them next to useless. Add in the effect of headlight glare when racing at night and drivers claim they are worse even than that. Audi therefore decided to rethink the whole concept.*

*A tiny rearward camera mounted in the roof of the R18 transmits its signals to a dashboard-mounted screen. Instead of the typical LCD (liquid crystal display) display with LED (light-emitting diode) backlighting, Audi use one of the newer active matrix organic LED display (AMOLED). The organic materials in this type of display are self-luminous and consequently, AMOLEDs are much thinner and lighter than conventional displays. In addition, they exhibit extremely high contrast, very good colour and switching times of just a few milliseconds, irrespective of temperatures. It gives Audi a fluid image flow in real-time transmission – even at 330 km/h down Le Mans' Mulsanne Straight.*

*Audi designed the system to be weather-neutral, functional during the day and at night, and to compensate for glaring highbeam headlights. "Our drivers came to highly value the digital rear-view mirror right on its debut at Spa," says Dr Ullrich. "With respect to the screen and the programming we greatly benefited from the work of our colleagues [at Audi's road car Technical Development department]. I'm sure that we'll be able to return valuable findings to them, from packaging the system into a very small space and the aerodynamic effects of the camera through to energy consumption. The intensity of the demands in motorsport, such as at the Le Mans 24 Hours, will cause a system like this to mature at an accelerated pace."*


## The Connected Future

*In recent years passive safety systems have matured and giant leaps in performance have been replaced with tiny, incremental gains. In their place active safety – the systems designed to prevent a crash rather than mitigate its effects – have come to the fore. Electronic control of the vehicle is where the big gains are currently being made but just over the horizon is the tantalising prospect of the third-generation of road safety technology: the connected highway.*

*With very limited exceptions, road vehicles still operate in isolation: the idea of the connected highway has cars exchanging information with road infrastructure and with each other. The commercial opportunities are obvious: information about parking, congestion, even points of interest – but in the field of road safety, there are bigger issues at stake. The connected car would be able to deliver information regarding its state of repair and it would become more aware of its surroundings, informed about the condition of road ahead. It's an area in which McLaren, via its McLaren Electronic Systems business, believe they have a role to play.*

*"Clearly you can use information for better dynamic traffic management, you can start linking with fixed systems in cities and you can also start looking at the condition of the cars to help with things like predictive maintenance before something goes wrong," says Peter van Manen, managing director of McLaren Electronic Systems.*

*Implementing this technology on the road requires a dependable method of sending and receiving data and also an infrastructure capable of dealing with the exchange. While a relatively new concept for the road, it's something that's been used in Formula One since the mid-1980s.*

*"There are some technical issues and some elements of straight physics that need to be overcome but a lot of that we're able to deal with thanks to what we've learned and experienced in the Formula One environment," says van Manen. "Issues such as how to connect to a fast moving vehicle in a fast-changing environment and still get reasonable bandwidth coming off it.*

*"The difference between a racing track and the open road is that a racing track is a structured environment: the cars are going around a set path and so you are able to create an infrastructure that is well-suited to that. The challenge when you go on the open road is that there's a less well-controlled infrastructure you need to deal with.*

*"The infrastructure most likely to be used on the roads is the very widespread mobile phone networks that exist in many countries – whether it be GPRS, 3G or the new 4G networks. Again, you can learn a lot from what we do in motor racing. Cars will be moving from areas of good telephone coverage into areas of poor telephone coverage, you can save up data and then send it when the coverage improves. In the same way that our telemetry systems work at the track: if you go into an area of poor reception, things don't just stop; you basically wait until you're back in a reception area and then start sending the data again. The key is making the system robust and dependable. You can then start using the live location and context information to adapt and improve performance, efficiency and safety."*

is remarkably similar to how a rally driver has to deal with it: you suddenly have to do something that was unexpected. The better the car is at carrying out the commands, the more likely the accident is to be avoided. I think that's the direct association between the two, and why the technology link is a very strong one."

A case in point is Prodrive's Active Torque Dynamics (ATD) system. ATD appeared in WRC at the end of the 1990s. Prodrive built a road car demonstrator soon after but the vagaries of licensing, technology proving and the lengths of vehicle development programmes ensured it did not appear commercially for almost a decade after its rally debut. Today it's found a home with heavy off-road commercial vehicles, but also with various car manufacturers – though with traditional engineering consultancy discretion Prodrive are coy about saying which ones.

> ***ATD is designed to greatly extend the envelope of 'normal' car response.***

ATD enhances safety and performance with a bespoke algorithm to automatically manage the amount of torque delivered to each wheel attached to the driveline of a vehicle with lockable differentials. Traditionally, controlling traction in a vehicle with lockable differentials requires a high-level of driver skill. The purpose of ATD is to manage that process on behalf of the driver, leaving them to concentrate on speed and direction.

On a rally stage the purpose of ATD was to get around a corner as quickly as possible but on the road it fulfils a rather different function: many accidents on low-grip surfaces (snow, wet tarmac etc) are avoidable – but once the vehicle begins to slide and exhibit 'non-linear' behaviour – i.e. not responding with the expected linearity to steering or brake inputs – the inexperienced road car driver either continues to add in more steering or braking input or simply freezes, unable to process vehicle behaviour outside the normal parameters. Situations that could be recovered frequently result is crashes. ATD is designed to greatly extend the envelope of 'normal' car response: described in the most basic terms it manages torque to ensure the vehicle continues to go where the driver points it.

"So, rather than becoming unable to turn in as the car starts to run out of grip, we can say that it's going to be able to turn in until the point where it can't possibly generate any more grip at all," says Taylor. "ATD will maintain the ability to go around a corner, right up until the point where it's physically impossible to go around that corner. It just pushes out that envelope of linearity."

Much of Taylor's work relates to control and compliance, though rally cars have historically also been structurally closer to road cars than their racing cousins. Since the introduction of carbon fibre chassis, racing has been largely tangential to the development of structural safety in the road car industry. That may be changing.

At the start of the 21st Century the automotive industry is waging a battle against emissions. More efficient engines – electric, hybrid and conventional internal combustion – are the obvious route but diminishing returns from the latter and technology barriers for the former are roadblocks in the path of legislation-friendly emissions performance. The alternative is to make the vehicle lighter, thus requiring the engines to do less work. In many respects this goes against form – road cars are increasingly content driven: more features, more luxury, more weight. To compensate for that, advanced materials are increasingly attractive to car makers. The 'traditional' approach is to use thinner grades of higher-strength steel but the use of 'exotics' such as carbon fibre is also on the rise. Obviously the industry is not prepared to sacrifice strength in its push to lose weight, which presents a problem: it understands the properties of steel and aluminium very well, but the car industry has no experience with how to safely build with composite materials: the research and experience that had led to the creation of exceptionally safe, exceptionally strong conventional cars becomes worthless when faced with new materials. This is where motorsport becomes useful.

MCLAREN

McLaren has been a pioneer of carbon fibre technology for over 30 years. In 1981 it raced F1's first carbon fibre monocoque, following in 1989 by the carbon fibre McLaren F1 road car. It used resin transfer moulding technology to construct the carbon fibre tub of the Mercedes-Benz SLR McLaren when that car launched in 2003, and currently has the 12C, and recently launched 12C Spider, in production, which features a carbon fibre chassis. While strong, lightweight, and extremely crashworthy, supercars are perhaps not the most relevant example of technology transfer but frequently it is the case that automotive technologies are proven in low-volume sectors before making the transition to the mainstream.

"I think that scenario is very likely," says Dick Glover, director of research in the vehicle development department of McLaren Automotive. "There is a lot of activity around it: the world at the moment is looking for the best way to make composite cars in high volume. The raw material itself, although it's more expensive than steel, isn't the big problem. The big problem is the requirement for very high levels of automation."

The advantage of using carbon fibre has always been the strength it offers for very low weight; the downside is that traditionally it's a very labour-intensive material to work with. In motorsports that was acceptable but for mainstream

**Right:** McLaren technicians build an MP4-12C sports car around a carbon fibre tub, derived from F1 technology.

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automotive production, it's a deal-breaker. McLaren has made great strides in automating the process: The McLaren F1 road car chassis took approximately 1000 man-hours to construct; for the SLR that was driven down to 300 man-hours. The carbon fibre tub of the 12C takes around 100 hours. It will soon overtake the SLR as the highest-volume carbon fibre road car ever produced.

"We're continuing to push in the direction of cost-down and trying to be more efficient in how we use carbon fibre," says Glover. "That will allow us to make more of the car out of carbon fibre – or introduce cars made out of carbon fibre at a lower price-point. It's largely a matter of automation. Ideally we would like a 12C tub to take a lot less than 100 hours to construct: there's a fantastic opportunity here to continue improving the composite manufacturing process."

McLaren's affinity with composites stems directly from motorsports and the transfer of technology is based partly on experience (Glover spent a decade with McLaren Racing and there are similar stories throughout McLaren Automotive), partly on materials, and partly on tools.

"It is a very real transfer of technology from F1 but it's quite interesting to understand that it's not just taking carbon fibre technology from McLaren Racing's autoclave. Rather it's using that as a seed to generate a whole new stream of development," says Glover. "There are a number of tools we use that are common to F1. For instance our tubs undergo a load and acoustic inspection to ensure they have been manufactured completely defect-free. It's exactly the same inspection that's used by the F1 team. It's also nice in areas such as finite element analysis and computational fluid dynamics to use the same tools, share the same people, use the same computers; make sure we go up the learning curve together. Very often F1 is leading us because they need to be much more deeply into things like that but actually in areas like crash analysis, I'd say we're probably leading these days because we've got more crash tests to pass.

"Our crash and repairability strategy is different from a metal-bodied car. The tub should not be damaged in an impact – the car is repaired by replacing crash tubes and body panels. In our crash testing work we've subjected a single tub to three very high-energy impacts. After each impact the car seems to be completely destroyed – but it's very easily rebuilt and then hit again. I think in that particular case the windscreen didn't break at all: it's really impressive that the structure is strong enough to withstand that sort of energy."

Motorsport has a reputation for arrogance but none of those interviewed here suggest that the work they have done would be beyond the capabilities or resources of the automotive industry. Rather, the positioning and demands of motorsport serendipitously placed them in a better position to do it first and do it faster. But does the automotive industry need motorsport to fulfil that role? Possibly it does not, though it could be argued that motorsport itself needs to be useful.

Racing and rallying have evolved. Competing for the joy of it all is a concept less applicable in an age where sport is big business. And like any big business there exists in the background a nagging moral obligation. There will be a small but vociferous minority who treat motorsport as a pariah. They point to the nuisance noise, the huge carbon footprint, the danger to life and property. They point to the huge expense. Technology transfer insulates motorsport from that criticism. As a proving ground for new technologies, especially environmental and safety technologies, it has a compelling argument to justify its existence.

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