



Though not perhaps the most common, certainly the most difficult incident to protect against is a side-on impact, often involving a very solid natural object

Sideways in safety

In terms of driver safety, rallying offers arguably the most technically demanding arena for motorsport engineers. We look at the latest developments within the sport

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Dynamic challenge defines rallying: rally cars carry two people, battle singly against the clock over all earthly surfaces and every climatic condition. Special stages are often lined by trees, telegraph poles, corners of buildings, walls and bridge parapets, all sturdy and all offering single-point contact if hit.

Safety is paramount in all branches of the sport, yet the unmatched conditions of rallying introduce a unique element to occupant safety. Rally cars 'go off' most often sideways and, if hazards are in their path, the cars' sides will usually hit first. Frontal and rear impacts do happen of

course, but these are less significant. In a World Rally Car, for instance, there is something like 1.5m of equipment-packed space between a potential frontal impact point and the crew's feet, whereas there is just 200mm between occupants' shoulders and the outer door skin. Reducing serious occupant injury, or worse, than in all major impacts is about absorbing the impact energy *before* it reaches the crew.

Mark Lovell and co-driver Roger Freeman perished on a US rally in 2003, when their 1400kg Subaru Impreza hit a tree sideways at high speed. As a result, Prodrive implemented studies at Cranfield

University into reducing rally crew risk in side impacts. Until then, there had been no co-ordinated research. Four post-graduate Cranfield MA in Motor Sport groups produced their results in March 2005, the year Michael 'Beef' Park died from the same type of impact in a Peugeot 307 WRC on Wales Rally GB. In the same year, the FIA Institute's Closed Car Research Group began more work on the subject, presenting its initial findings as its 'Seven Steps to Safety' at Rally Finland in 2007.

Improved side impact protection is the primary FIA priority and, while some of these early FIA suggestions were at variance with Cranfield findings,



An alternative solution to side impact protection is this carbon fibre cover over a foam structure. Note the troublesome factory window winder still in situ

the initiative was welcomed by team managers, engineers and drivers. Indeed, the subject had already voluntarily become a fundamental consideration for manufacturer team chief engineers in the designs of rally car homologations. The manufacturers' engineers encouraged the FIA to discuss the concept of introducing energy-absorbing material into the doors. Discussions became protracted, however, over the issue of having to remove window-winding mechanisms, thereby making the side windows fixed. Finally, the engineers urged the FIA just to 'get on with it and do it. It's so many years since Beef died that we've been asking for this,' as one top engineer put it.

It did the trick and the FIA initiative derived from the Institute set its initial investigations into a 60km/h side impact into a tree. It's worth noting here that Prodrive's director of engineering, David Lapworth, concedes this speed is 'not very quick, but 60km/h is unbelievably difficult to manage. You can forget 100km/h [in a side impact], it's almost unsurvivable.'

The FIA's advanced side impact system' was developed through tests at DEKRA, TRRL and Advanced Car Technology Systems. Subaru, Mitsubishi, M-Sport, Peugeot, Citroën, Racetech, Sparco,

Schroth, Sabelt, Stand 21, NASCAR, 205Challenge, CAMS-VB and Rally America all supported this.

One thing every top team engineer is praiseworthy of is the liaison that the Closed Car Research Group's Andy Mellor applies to the project: 'He comes round and we show him some things that don't make sense or are impossible to fit and, provided it's sensible, he accepts that. So

was hardly damaged, which he attributed to having chosen a high elongation steel [T-46] for the rollcage tubes. He added that the new FIA safety seat had played a major role, together with the car's [voluntarily added] impact-absorbing sills.

Lapworth pointed out that multiple rolls are in fact the best way of coming to a stop, as speed is lost over more seconds than in an instant impact, though quite

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David Lapworth, Prodrive director of engineering

we get a good compromise between him and us,' explained the Ford team's chief engineer, Christian Loriaux.

This year Jari-Matti Latvala's Focus WRC flipped onto its side at 95km/h during Rally Portugal, impacting the Armco with its roof then barrel rolling no fewer than 17 times down a 100m cliff face before impacting a tree side-on. Incredibly, Latvala and co-driver Mikka Antilla walked away virtually unharmed, though the driver later admitted he'd expected to die. According to Loriaux, the passenger cell

how this stands up when a car is dropping out of the sky is debatable.

Later, Loriaux said the dramatic Latvala crash was 'not really a big deal at all'. In concert with Lapworth, he agrees there have been more severe shunts, and both engineers cite Petter Solberg's massive off in his Impreza WRC at Rally Deutschland 2004 as the most severe deceleration they have seen. 'A small number of really big impacts,' as Lapworth explained, and he should know.

One of the Cranfield studies produced >>

figures relating average deceleration rates and the distance between outer shoulder and outer door skin to injury severity or death. Taking this data into account and having just completed the engineering design of Ford's new Fiesta Super 2000 car, Loriaux states that Super 2000 cars cannot be as safe as current World Rally Cars. Everybody, to be competitive [in Super 2000], goes to a 'B' [segment] car, and a B car being smaller and narrower you can't do anything with it. You're closer to the accident. Some cars are so small you can't achieve the 200mm distance between the door and crew. With the Fiesta we can just about do it, but the trouble is it depends on which seat, because with the new FIA seat, the seat is so big we can't do it. Because the seat is bigger, and it catches the tunnel, you are then forced to move it outside, so it's a bit of a Catch 22.

COCKPIT AND SEAT INTEGRATION

Currently, the Closed Car Group is focussing on cockpit and seat integration. Mellor explains this work is indicating that the task appears to be relatively straightforward for circuit cars (WTCC and GT), while for the WRC the Institute

when deceleration rates reach certain levels, and become more hazardous if an occupant's head pivots on his spinal cord.

IN THE HANS OF THE GODS

Head And Neck Support systems, designed to prevent neck injuries, have been compulsory for WRC drivers and co-drivers since 2005. Multiple World Rally Champion Sébastien Loeb admits the device initially was uncomfortable and difficult to wear, but he's now used to it and considers HANS the most important safety improvement, adding, 'Nowadays, I don't think about wearing it, but if I drive without it I feel strange – I feel loose.'

Quite evidently, deformation of a car's side during an impact could be slowed by maximising the amount of space between the occupants' shoulders and the outer side skins of the car and, as can be seen, efforts are under way to achieve this in situations when co-driver and driver sit conventionally, side-by-side. Yet, if the concept is re-thought and each crew member's seat is installed as close as possible to a car's longitudinal centreline it would at a stroke maximise side space. One Cranfield study group looked at a concept that placed the co-driver behind

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Christian Loriaux, Ford team chief engineer

is looking at the feasibility of nets that do not inhibit emergency egress. A draft FIA specification should be ready during 2010. It will also be forbidden to carry tools in the front area of the passenger compartment next year.

Netting between driver and co-driver was installed in Suzuki and Subaru WRCs in early 2008, proving a slight hindrance in some crews' opinions. While acknowledged as useful in protecting limbs from flailing in certain circuit racing cars, such nets are not yet mandatory for rally cars. Institute work in this area continues but, in side impact protection terms, Lapworth feels this is a secondary area of research: 'It maybe gives some support to the seat, because obviously the seat on the impact side is going to be supported by the energy absorbing foam and eventually by the tree, or whatever it is, whereas the other seat is only supported by its brackets until it comes into contact with the other seat. Maybe the nets can provide some support for the other seat. Certainly, in the case of a rear impact, the nets can provide some support to the seat as well.'

Impact forces become dangerous only

the driver. Comment has been made about not having the co-driver directly behind the driver to avoid possibilities of his helmeted head hitting the driver's seat but, in general, the top rally engineers rate it as a valid concept. Both Ford and Citroën World Rally Cars already have the co-driver much further back and lower in the car than the driver, but Ford's Loriaux explained that he and his team are investigating one option that shows further possibilities. Citroën Racing chief engineer, Xavier Mestelan-Pinoin, agrees that there might be something in pursuing this sort of study, but points out that the way current cars are packaged would make this very difficult to achieve. Interestingly, he also mentioned that if rally engineers could have the freedom of 'prototype' regulations – similar to the TI Modified Cross Country Car rules – achieving such improvements would be both cheaper and better. But the FIA prefers teams to be working with 'standard' cars.

However, Loriaux takes a more pragmatic attitude: 'If you wanted to really look at safety, you would make the car a prototype and effectively try to place >>

Cries for help

Many rallies pass without incident, but not all, and the sport's very nature highlights hazards. These came to a head at the Tour de Corse in 1986 when FISA boss Jean-Marie Balestre banned the Group B 'supercar' category, and its Group S successor from 1987, after Henri Toivonen and Sergio Cresto perished in a flaming Lancia Delta on a Corsican stage.

To add perspective to today's encouraging efforts to improve occupant safety in rallying Roccar Engineering sought out a key rally engineering insider with insight from that period to today's World Rally Car years.

Father' of the 205T16 Group B car, Peugeot and Citroën's Rally Raid racers and Citroën Sport's works rally cars from the Xsara Kit Car to the current C4 WRC, Jean-Claude Vaucard is a renowned rally engineer. He also engineered and ran the chassis of Peugeot's 905 Sports Prototype for three seasons. If anybody knows his stuff, it is he.

Of any Group B engineer Vaucard was the most concerned about occupant safety. Then, and now, he gives his honest opinion and today admits safety was always in his mind, but car efficiency / stopwatch figures were also very important. It was a compromise. We cannot say it was absolutely for the safety, but there were some modifications where we said 'no, you cannot do that because it's too dangerous... – to have the tank on the side, for example.'

The 205T16's plastic fuel tank was under the seats but was not foam filled as safety tanks were not required by FISA [as the FIA was then]. Reconsidering this T16 design decision Vaucard admits, 'I think it was a mistake for us – we shouldn't have done that. On the ZX Rally Raid we still had the tank on the floor, but used aeronautic safety techniques. I think it was a lot better, but it took time to come to that.'

When he returned to the WRC, initially with Citroën's Xsara Kit Car, the FIA had developed a little more concern for rally car safety, but 'there was minimum modification and I can tell you I was always campaigning for [safety improvements] for the impact on the side. I said this is the weak point of the



Load-spreading door bars, inspired by those used in NASCAR, were developed by the FIA Institute in 2005



Among many other projects, Jean-Claude Vaucard was responsible for the Peugeot T16 Group B car

safety of the car... we improved safety for the front, for the roof, but had nothing on the side. We were like people without clothes!

'And I asked many times to have the mechanical window winders removed from the rules. The FIA said, "No, you have that in the standard car, you have to fit them." I said you can save some space to put in some foam or something like that, cancel the [winders], put in a plastic window and, after that, you can put that [foam] in the door. We make maybe 10 per cent or 20 per cent of the safety, but maybe it is enough to save a life.'

Around the beginning of this century the FIA removed the need for standard interior door trims in Group A-based rally cars. These could be replaced by a carbon fibre sheet. Vaucard vehemently attempted to get this changed claiming, correctly, that the carbon

was too rigid and that the modification was 'all in the mind' and actually did nothing, if not made things worse. His attempt was in vain.

During his working time in the WRC Vaucard constantly requested side air bags to be evaluated, though completely agrees with the FIA's claim that some air bags could trigger easily under the magnitude of forces in a rally car. The problem of an air bag on a rally car is that you have a lot of *g*, but the weak point is vertical or longitudinal. Have an air bag in the steering wheel and you can have an air bag come from it and that is dangerous, but on lateral it is never hard, you slide only.

'For me, we can have three air bags and we have to look at it if it is possible. If it works well, why don't they do that? Because they have no room. Maybe this will be the next way to look, though, as you can have 10 air bags if

you want – it is like that now on a high-level [road] car.'

He fully understands the issues involved and advocates the voluntary measures being taken by top teams using more rigid side sills. 'I think it is not bad to have some kind of rigid structure on the side. To hit a tree is a bad thing, but it is very rare that you hit it at 90 degrees – you [usually] arrive at an angle and, if you have some tube or something, you can avoid [an intrusion]. I think Michael Park's accident was identical... but it was so soft this car... if he had a tube at the bottom and one half-way up... But maybe the structure of the car can help, too.'

'I lost an uncle in an accident like that a long time ago in a [Citroën] Traction [Avant] – he hit something and hit the steering wheel. He had no seat belt and he died a few days later. [At the time] nobody thought this was possible because everything was very rigid.'

Today, drivers are far from the steering wheel in a World Rally Car. It is good and very safe to be far from the engine and now you have one metre [between occupants and engine], so in longitude it is also very good.'

Part of the Cranfield studies and a welcomed concept by all the top WRC engineers is to consider placing the co-driver much further back in the car than the driver, thereby enabling them to sit closer to a car's centreline and provide more lateral space for side impact protection. One privateer champion actually got there well before them.

'Why not allow the co-driver to be one metre behind the driver, so you can stagger them? On my Talbot Lotus when I was an amateur, they put the co-driver [Christian Geisdörfer, co-driving Walter Röhr] like that. And one winter, I worked at my house on the Talbot Lotus I put my co-driver one metre behind. But when I arrived at the first rally the year after, they said, "Oh, now last year is finished, didn't you read the new regulations? We changed everything – the rollcage, there's not a law for you... But it was very nice for safety." So on the first rally they allowed me to go. I wasn't far from victory, but I stopped with a clutch problem. I stopped in the stage and went very quickly out of the car by the right [it was a left-hand drive car] and there was nobody, nothing in the way!'

'It is a lot of work to put the tubes in, but everything is better – the co-driver is furthest from the dashboard. It is a good idea. But you would have to start from a new car. //

them [the driver and co-driver] centrally one behind the other. You could still get one behind the other safely, but it would make the car too expensive and, at the moment, we try not to make prototypes and try to keep it reasonably cheap.'

Evidently, to fully integrate such a concept would require modification to the cars' longitudinal centre tunnels, which is why the Closed Car Research Group is not currently working on this area.

The 2008 WRC season began with WRC cars mandated to a 200mm space between the outer door skin and seat edge (which some top teams had introduced previously), filled with standardised energy-absorbing material. The performance requirements were established through dynamic sled tests and quasi-static strength tests, enabling Andy Mellor's Institute team to define a foam specification. A foam volume of 60 litres, with no concessions, is mandatory, and the 2009 WRC technical regulations prescribe a 60g/litre closed cell foam, which is available from one of three suppliers as either Zotefoam HD60, BASF Neoplene RG60 or ARPRO RG60. Each is 'quite expensive', according to Loriaux.

SAFETY SEAT

The Institute's safety seat was introduced in many works cars at Rally Japan 2008. With seat bracket and belt positions optimised for best retention of the torso, pelvis, shoulders and head, protection is maximised by dispersing loads evenly through the body in side impact. This stronger, more supportive seat is also more effective during rear impacts. Further testing during Wales Rally GB helped establish a new FIA Standard, in place since the start of the 2009 season.

Driver and co-driver sit close together toward the centre of the car in both the Citroën C4 WRC and Ford Focus RS WRC and each car has strengthened side members. Ford's extra crash beams inside both sills, together with positioning, add an extra 7kg to each side. This extra weight is low in the car, however, and Loriaux is convinced the beams make a huge contribution to occupant safety. Indeed, he believes that without them François Duval's co-driver Patrick Pivato would have been killed in the crash on stage six of Rally Japan in 2008. In that instance, Pivato's fractured pelvis and leg were the result of a massive side impact, his injuries resulting from intrusion into the cockpit.

Institute efforts were rewarded in 2008 with the Professional Motorsport World award for its work on side impact protection in rallying. Rally car rollcage work continues and the Institute has now purchased seven Subaru Imprezas to establish best practice in rollcage design,

Now mandatory in world rallying, a 60g/litre closed cell foam door insert with a volume of 60 litres helps absorb the huge forces of a side-on impact and protects occupants within. Currently, three manufacturers offer a product that conforms to the regulations



SIDE IMPACT
PROTECTION

ARPRO RG60 door
skins meet 2009 WRC
regulations
baldspotsports.com

construction and fabrication. Testing was due to commence this October, comprising impact tests and monitoring load paths through the 'cage' and the vehicle, together with assessing six different types of steel.

David Lapworth considers crash testing 'actual' rally cars would be beneficial, yet says, 'it's quite difficult to model exactly how the car is going to behave... Where

you hit the pole relative to the c of g will completely change the way the car reacts – whether it spins off, wraps itself round the pole or just ricochets off.'

And this neatly highlights the biggest problem engineers working in this field have to face. As Ford rally boss, Malcolm Wilson, says: 'The trouble with rallying is you never get the same accident twice.' //