Drivers at Le Mans need to be able to digest large amounts of information rapidly; thus teams ensure that information is presented as clearly as possible (Image: Lawrence Butcher)

Safety in numbers

Anne Proffit looks at some of the systems and other in-car devices designed to make life safer for endurance race drivers

In recent years there has been a series of incidents in endurance racing where LMP cars have been involved in collisions with slower GT cars, due to one driver or another not seeing the other. Of particular note are Audi driver Alan McNish's collision with a Ferrari in 2011, and Toyota driver Anthony Davidson's accident with another Ferrari in 2012. Both incidents were caused by a lack of situational awareness. In McNish's case, he failed to see the car he hit as he turned into a corner; in Davidson's, the Ferrari driver underestimated the LMP's closing speed and turned in on it.

The consequences can of course be very serious, and it is a testament to the safety of the current generation of LMP racers that neither these two nor the GT drivers involved in these accidents was seriously injured. However, the accidents have prompted moves within endurance racing to provide drivers with an improved perception of their surroundings. On the one hand, this is being pushed by the regulators, with the 2014 regulations for LMP cars prescribing revised cockpit dimensions to improve driver visibility, while on the other, the teams have begun to develop driver aids to minimise the risks of drivers colliding with each other.

Situational awareness

In 2013 it was the Americans at Corvette Racing who came up with the most impressive system to aid their six GTE Pro class drivers. The team developed a radar-based collision avoidance system that lets drivers know when a car is coming up on them, how quickly it's arriving and whether it's about to pass on the left- or right-hand side. The system provides this information to the driver in the form of easy to identify colour-coded symbols.

The idea for the system came about when Corvette Racing returned from Le Mans in 2010, said Doug Louth, engineering director of Pratt & Miller's, who prepare the Corvettes. "We'd been hit by a Peugeot in the Porsche Curves and [driver] Emanuel Collard wrecked the car. We came home and said, 'Boy, I wish we had some kind of warning system.' If you look at all the car-to-car incidents over the past three or four years, it's pretty remarkable that nobody was hurt any more than they were."

At the time, Corvette Racing used rearview cameras, but the concept of having radar with the cameras seemed like an ideal solution to provide the drivers vital additional information. Pratt & Miller's

The greatest innovation of 2013 was the introduction of a collision avoidance radar in the GTE Corvettes. The red chevron indicates the closing speed of the car behind (Image: Corvette Racing)

"The system is developed so that the driver has a really good idea of how a car is approaching"

software controls and electronics controls group began work on the project in 2011, with the blessing of Chevrolet, who recognised the safety benefits it could bring.

The system is based on Bosch Motorsport's long-range radar sensor (LRR3), which is fitted to the rear of the Corvette. It's a product that was originally produced for roadcar applications, where automated collision avoidance is a growing area of development. It has an aperture angle of up to 30° and can detect objects at distances of up to 250 m away. It can also, according to Bosch, track up to 32 objects simultaneously, looking at their distance and speed relative to the host vehicle.

Information from the radar is then combined with video footage and presented to the driver using a cockpit display. The camera and video screen are all off-the-shelf components from Bosch, as are the radar sensors. "We just looked at what was available and made some changes," said Louth. "We changed the system a couple of times and in the end, the most important part for us – the real development – was the microcomputer onboard and the software that actually runs the unit." Happy with their component selection, Pratt & Miller proceeded to produce all the control systems in-house, the heart of which is an in-car PC, powered by an Intel Core i3 CPU and incorporating 240 Gbytes of solid-state storage.

Corvette Racing began testing the collision avoidance system towards the end of 2012 and put it into racing use at 2013's season-starting Sebring 12-hour race. "The radar system is something I've been using for the past few races," said Corvette driver Oliver Gavin. "It was very much in mind for this race [at Le Mans] in particular, because there are large parts of the circuit we can't see and can't have spotting for from the crew."

On shorter circuits, it is possible for the crew to provide the driver with information on approaching cars, acting in a similar way to NASCAR's rooftop spotters, but at Le Mans this is not feasible; this therefore makes the new radar an invaluable tool. "This system was developed so that the driver has a really good idea if a car is coming up from behind," said Gavin. "We know how fast it's coming up from behind and the system also tells us which side of the car that car's going to go, and then tells us which side it's actually on.

"Now you might think okay, you've got mirrors for that, but there is a particular blind spot with our car – every car has a blind spot – and we've used the radar for the particular point where you're just turning into a corner and you're wondering where that car that was behind you has gone."

Where the system really comes into its own is when running at night or in the poor weather conditions that are commonplace at Le Mans. "It's particularly good at night because, as cars come up on you with their lights, the rearview camera in the car completely whites out so you can't pick out closing speeds or which car it is. The radar system gives you those figures, even though it doesn't actually give you the ▶

The Audi R18 e-tron quattro features three LED screens providing the driver with both front and rear views (Image: Audi)

class," Gavin explained.

The radar system displays different colours and shapes to delineate following or approaching cars, using chevrons that change from green to yellow to red, with arrows pointing red or green from side to side. A red chevron represents a high closing speed and thus will generally be an LMP, while green ones will be other GT cars.

According to Corvette Racing driver Tommy Milner, "It's made life for us a lot easier. Now we don't have to focus so much on the screen [which was the case with the camera]; instead we notice the shapes and colours that show up. Certainly, with a rear camera you lose some depth perception, but the radar system gives you some of that back. Even when the radar picks up objects that are not racing cars, the intuitiveness of the display software allows us to rapidly filter them out.

"It's been pretty much bullet-proof since we first used it. Sometimes it will pick up false positives, like things on the side of the race track, but when it does, the objects show up as things that are going away. We know, based on the shape and colour that it is nothing too important," Milner said.

Ultimately, Corvette is more than happy with the system. "It does solve a lot of the problems that everyone here at Le Mans has been struggling with, and finding solutions for those problems that all of us have is so important," said Louth. While the collision system does add some weight and cost to the car, he said, "It's a pretty lightweight item and doesn't really add that much weight [2 lb for the sensor and 3 lb for display and PC]. It adds telemetry and cost to the car, but there are the potential savings from not wrecking the car so it makes it all worthwhile."

As has been mentioned at the beginning of this article, 2013 winner Audi has suffered its share of DNFs due to collisions with slower cars so, unsurprisingly, preventing such occurrences is a priority for the German team. For 2013, one development in this area was the introduction of a 'periscope' forward-looking camera system, in conjunction with an improved rearview camera.

The front-looking cameras were introduced in response to driver visibility being obscured by the LM P1's extensive front wheel arches. This was a contributing factor in driver McNish's 2011 crash, obscuring his view of the car he had just passed. To counter the problem, the R18 e-tron quattro now has a pair of cameras mounted high on the roof, giving a wide angle view of the front corners of the car. This view is then projected onto a pair of screens mounted on the A-pillars of the car.

In McNish's opinion these cameras, combined with the rearview camera, are exceptionally valuable. Speaking at the 2013 Le Mans 24 Hours he said, "It's made the mirrors just regulations requirements. With the camera we've got a very wide angle; I've got a monitor where the rearview mirror would be in the roadcar, but it's bigger than that. It gives me the spread of everything that's behind right where I would look, as opposed to looking in the side mirrors. I get a better, more stable view and a clearer picture. It is especially beneficial when the conditions are wet because then the outside mirrors can get a bit dirty, whereas the camera always stays pretty clean."

Resolution on the cameras and screens fitted to the Audis is exceptional. For comparison, the image on the display has a 50% ▶

The complex radio wiring within a driver's helmet (Image: Anne Proffit/MRTC)

"At Le Mans you can have sunshine on one corner and rain at the next. You don't know what to expect."

greater resolution than Apple's iPad 2, at 196 dpi (dots per inch). The camera system is made in-house, according to LMP project director Chris Reinke. "We buy the components, including the screen, and build it ourselves. It's giving the driver more comfort. We worked very, very closely with the roadcar production guys on this system, and we looked at a lot of aspects of the system, for example the different angles of the lens and the effect this has on the driver's perception."

McNish's experience at the 2013 pre-Le Mans test weekend showed just how good the system could be for avoiding damaging accidents. "I had a guy coming up behind me as I was exiting the pit lane. As you come out of the pits, you keep to the right-hand side to keep out of the traffic, and the team radioed to say there were two cars behind me. The first car came past in the wet and the second I could see coming up quickly behind me. I was keeping out of the way and he locked up the brakes! He was sliding towards me and I could see him coming in my peripheral vision as I was looking at the camera.

"I could see how close he was getting and I was releasing the brake pressure to be sure I had enough distance between him and me. He was coming a bit hard and he hit the back of the car, but if I hadn't had the camera he would have hit me significantly harder and done a lot more damage, so that's a good example of its use. There was nothing I could do to stop the incident, but it minimised the consequences significantly, which can make the difference between retiring and finishing a race."

Driver communication

While electronic pit boards are still in use at Le Mans, the primary means of communication between drivers and the pits and garage is through the radios in the cars. Each driver has a microphone built into their helmet and the wiring has to be precisely built to European standards. That meant many of the US teams competing in the 2013 race had to remake the interiors of the helmets to accept European-spec wiring.

The communications companies who provide such equipment were also busy on the other electronics and communications devices which are so vital in modern endurance racing, such as the intercom systems used in the pits and garages, the headsets for the team mechanics and the pit crew, preparing pit-to-car digital radios and making custom ear moulds for everyone from drivers to crew to management.

"We do custom-fit ear moulds, taking impressions during the test and having them made in time for the race," said one communications company technician. "We are supplying 43 cars at Le Mans, and while we're not directly supplying the Toyota team, we do have a strong relationship with Oreca, and supply Toyota through that." The bigger teams – including Audi – have intercoms, and all the engineers who sit on the pit wall have radios that plug into the intercom so they can talk to the drivers, the crew and other engineers.

Driver Neel Jani of the Rebellion Toyota LM P1 team explained why these communication systems are so important. "At Le Mans, if you have sunshine at one corner and rain at another corner and you don't know what to expect from one to another, then the team can give you all that information. It's very helpful to know where it's really wet, where it's wet or dry and what's going on. Around Le Mans this is super-important," he said.

With a course that is so long and which has a good deal of concrete from one end to the other, communication without relays would be impossible. Atop the one communications supplier's trailer in the paddock – which moved from a spot closer to the top of the hill down towards the garage area to improve reception – were three poles that served as relay posts. The truck was fitted with two 15 m poles and a 12 m pole with a total of 12 antennas embedded into the three poles. With these relays, 43 teams could be provided with clear communications at any point on the circuit.

Another development that has improved pit-to-car communication is the advent of digital radios. At least two teams at Le Mans 2013 were using fully digital radio systems for their communications. As well as providing a clearer sound, digital radio gives a greater usable range and is less affected by car-generated interference, which normally reduces the range.

"The traditional solution to the problem of range when using analogue radio is to use a base station repeater," explained one engineer at a communications company. "This boosts the signal power to the car, overcoming range issues. This solution is expensive, however, and often only in the budget of bigger teams, but digital radio has given much better range performance to teams that can't justify the expense of a repeater."

Information systems

For works teams, whose budgets can accommodate such luxuries, pit-to-car communication can go beyond simple radio traffic. As Toyota Motorsport's John Litjens, project leader of the Toyota team, explained, "We have the steering wheel, which already provides the driver with some basic information through the inbuilt display, this is then backed up by a dash display. The steering wheel on the two Toyota LM P1 cars is sourced from TMG, and is the same as that in the Formula One cars TMG used to build, technology which transferred easily to sportscar racing.

"Because we still had a lot of components left over [from the Formula One programme) it was a good starting point. In the end, if you look at the functions between both type of cars, they are quite similar, so it didn't require much adaptation," he said.

The Formula One-based steering wheel worked well for Lapierre, driver of the # 7 Toyota in 2013. "I have all the usual information on the steering wheel, like rpm and traction control settings, but more important are all the hybrid settings like the state of the charge of the capacitor, tyre pressure, tyre temperature, brake disc temperatures, caliper temperatures and that's about it.

"I check the steering wheel very often – every bit of straight line I take a look – and if I really need to look at it, there's an alarm with flashing lights on the steering wheel that prompts me to look at the dash to find out if the brakes are getting hot, for example, if a tyre has exploded or if there's a puncture or leak, if the hybrid system isn't working any more… things like that.

"We had some problems with the hybrid system at Spa last year, as it stuck. The system broke down, and all the braking was made by the traditional caliper and disc, not the electric motor that's braking the car. We knew it had overheated because of the alarm on the steering wheel," he said.

The secondary dash display in the TS030 consists of an AMOLED (active matrix organic light emitting diode) colour display that allows the driver to see the state of the hybrid system, state of charge, as well as the sectors for which they're permitted to get a certain amount of energy release through the KERS system. The display system is fully visible in direct sunlight, fully configurable and its screen layout has been designed to match the needs of the TS030 exactly.

When it comes to other displays, such as rearview cameras, Toyota has not followed Audi's course. Litjens said, "for sure it can help the driver in certain circumstances, but in the end you have to have the best package, you want the best safety possible – but within the regulations – and you must be within the weight targets you are given. With the weight reduction for 2014 in particular it will be even more difficult to incorporate this kind of technology."

On a course as long as Le Mans, where a GT lap takes more than four minutes, tyre pressures are one of the most important areas of information a driver needs to be aware of. If a driver picks up a slow puncture, it is vital that they react as quickly as possible, as any delay before an engineer relays the information could be catastrophic. Tyre pressures are monitored through in-wheel sensors, with the information fed to both the driver through the dash and the engineers in the pits.

One such system used by teams operates at a 10 Hz data level, which is customarily reserved for Formula One. The sensors are linked to an alarm in the cockpit to alert the driver if pressures are not within their prescribed parameters. If the alarm sounds, the pit lane telemetry engineer will see the pressure readings and the alarm, so that the team can be prepared as the driver continues to the pits with caution.

Presenting such information to the driver in a clear and concise ▶

The masts used to ensure communication is possible at all points on the Le Mans track

The steering wheel of Strakka Racing's ARX03c provides the driver with a plethora of engine and transmission settings (Image: Anne Proffit)

the position of their hands.

The type of car naturally dictates the functionality required in the cockpit. Ben Levite of the SRT Viper team explained the layout of the GT car's driver controls. "The pair of Vipers have controls for the primary and back-up starter on their dashboard, together with ignition, master and override," he said. "The driver can select from high or low wipers and make sure the rain light is working. It also has switches for the main and reserve fuel pumps, as we've got two fuel pumps in the car at different levels in the tank.

"We have air condition control for the drivers on the dash, and we run two radios in the car, a primary and a back-up. The primary is powered by the car and the back-up has its own battery," he said.

The back-up radio can be very useful, and not just in case the primary system fails. If the car suffers a failure on track, or crashes, then the use of a separate battery allows the driver to maintain communications with the pits. In addition to a camera-based mirror system, another neat feature of the Viper is a built-in LED floodlight system. This can provide illumination of the electronics systems in the dark of the pit lane or, in a worst-case scenario, when a driver is attempting trackside repairs.

The entire rear of the SRT Viper is blocked so the drivers need to use the rearview cameras or side mirrors. There is a specific module for the electronic rear camera, placed in the rear bumper, and it's always on. "Whenever we replace the rear end it's got a new camera in it," said Levite. "Every bumper is fitted with one and we have five in total – two on the cars, two spares and one for worst-case scenarios."

Overall, engineers are constantly striving to provide the most ergonomic environment possible for the driver, without compromising any aspects of a car's performance. Sometimes this compromise may not come out as the most obvious choice. For example, the few grammes saved by leaving out a high-tech camera system may be completely negated when a driver collects a GT car that vanished into a blind spot. It is also interesting to note that, unlike drivetrain and chassis advancements, many of the systems have their roots in roadcar technology. However, their application as motorsport systems has, by all accounts, accelerated their advancement in order to account for the unique conditions found in endurance racing.

fashion is of course very important, and is best achieved using a combination of verbal and visual systems, with different teams adopting varying approaches. Danny Watts, a driver on the LM P1 Strakka Racing team, said he needs to know "specific information – such as my pace, my position and the gap with the car in front – and it's always nice to know how many laps left you've got of your stint. We use radio communications with the guys on the pit wall. I've got my race engineer and the team manager, and back in the garage are the HPD [engine and chassis] guys, who can assist me with maybe adjusting the engine mapping, maybe the traction control settings and what our circuit position is like, for example."

The HPD steering wheel has a variety of multifunction switches to allow the driver to control a plethora of systems, one of the most important of which is the pit lane speed limiter, set just under the mandated 60 mph maximum. Another more mundane but no less important function available in the wheel is the drinks button – important for keeping the driver hydrated under the gruelling race conditions.

Nothing is perfect, however, and Watts no longer uses the drinks button after having some bad experiences with it. "The thing was spraying me in corners or on the inside of my visor, which is a nightmare when you're trying to look through it, so I just don't use it," he said.

There are also the customary traction control and engine management settings, including an 'overtake' button that switches to a high-power map for brief periods. The layout of the buttons is also of considerable importance, with functions such as the start button well out of the way to prevent it being caught accidentally, while the most important functions can be reached without the driver having to adjust

Acknowledgements

The author would like to thank; MRTC, Stack, Strakka Racing, Corvette and Pratt and Miller for their assistance. ■