THE WORLD'S FIRST *AFFORDABLE* COMPETITION HYBRID SYSTEM

Chris Pickering quizzes the experts tasked with delivering the British Touring Car Championship's ground-breaking new TOCA Hybrid system

All photos: Jakob Ebrey/JEP/BTCC

HYBRID powertrains are coming to touring car racing.

With almost every road car manufacturer now offering some degree of hybridisation somewhere within its range, it only seems right that touring cars should follow. But unlike the big budget worlds of Formula 1 or sports prototypes, the organisers of the British Touring Car Championship (BTCC) knew that they couldn't ask the teams to start writing blank cheques. It would have to be the world's first affordable competition hybrid system.

As far back as early 2018, the BTCC's organising body TOCA started looking at the possibility of introducing a hybrid system into its Next Generation Touring Car (NGTC) formula. A meeting with the teams and the major NGTC parts suppliers followed in July of that year at the Snetterton race meeting. There, three fundamental constraints were laid down: the system would have to provide equal performance for front-wheel drive and rear-wheel drive cars; it would have to involve minimal changes to the spec NGTC components; and it would have to be leased for no more than £20,000 per car per year.

"It was very important that it would fit the existing cars," comments TOCA technical director Peter Riches. "We didn't have a clean sheet of paper and we didn't want to spend large sums of money altering the suspension and things like that."

The year for the introduction of the new system was pencilled in as 2022. This was largely chosen because the NGTC formula is run in five-year chunks and the 2022 season would correspond with the start of the next period, so the contracts would be up for renewal and the cars may be evolving somewhat anyway.

The NGTC's use of standardised chassis and driveline components, plus the popularity of the TOCA crate engine (used by well over half the teams on the grid), would theoretically limit the number of different installation options that the engineers would have to face. However, there are still differences from one car to another. The most obvious challenge would be achieving parity between front-wheel drive and rear-wheel drive installations, both in terms of performance benefits and packaging convenience. But there ▶

> ***"We wanted the system to allow the driver to gain 15 metres in one single deployment per lap"***

LEFT One of the benefits of the new Cosworth-developed TOCA hybrid system will be to enable electric-only running in the pitlane

was also the question of ensuring compatibility with all homologated engines. These days the BTCC is only open to inline four-cylinder turbocharged machines, but there are still differences in architecture and characteristics.

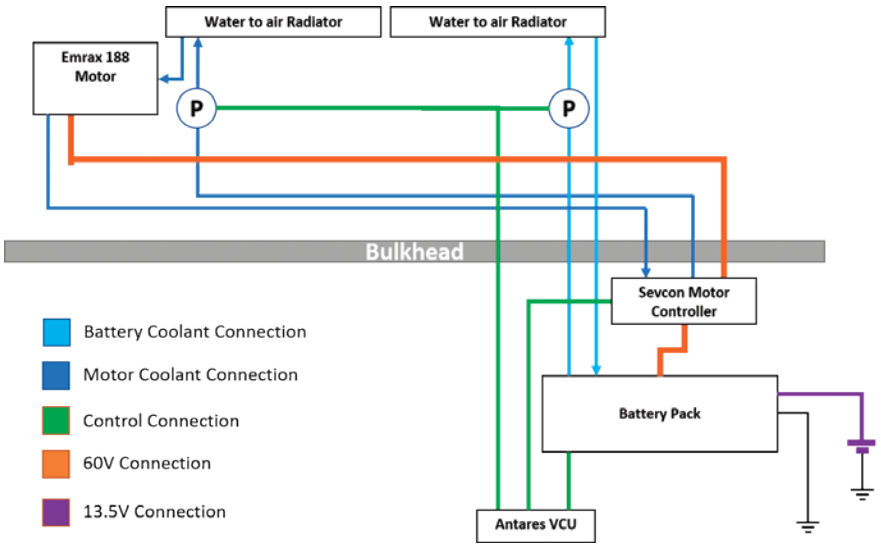
A series of meetings took place over the next nine months to define the system requirements, before the project was put out for tender. The two key technical requirements were that it had to offer a push-to-pass or defend functionality and that it would enable electric-only running in the pitlane for the start of each session. ("It wasn't feasible to mandate electric pitlane exit the whole time as we can't shut the engine down when the turbocharger is above a certain temperature," notes Riches.)

The agreed price point of £20,000 effectively defined the battery capacity for the system. Meanwhile work carried out with Motorsport UK and other stakeholders determined that the nominal voltage should be no higher than 50 volts. This greatly simplifies the health and safety implications compared to a high voltage system (F1, for instance, is now close to 1,000 volts).

Likewise, the decision was taken to mount the battery in the space currently used for the ballast box. This avoids having to create new packaging space, and it was enabled by the decision to abandon the current system of success ballast from 2022. Instead, the performance balancing between the drivers will be carried out by adjusting their hybrid system allocation.

The performance requirements were quickly fleshed out with some basic calculations. Although it's what would commonly be referred to as a push-to-pass system, the TOCA technical team concluded that what they wanted was a system that would allow the driver to get alongside another car, without simply gifting them the position.

"We decided that we wanted the system to allow the



ABOVE An electric motor is integrated into the transmission, driving directly onto the input shaft, in what's known as a P2.5 layout

BELOW It was hailed as an "extraordinary effort" to pull together the hybrid programme, on schedule, in such challenging times

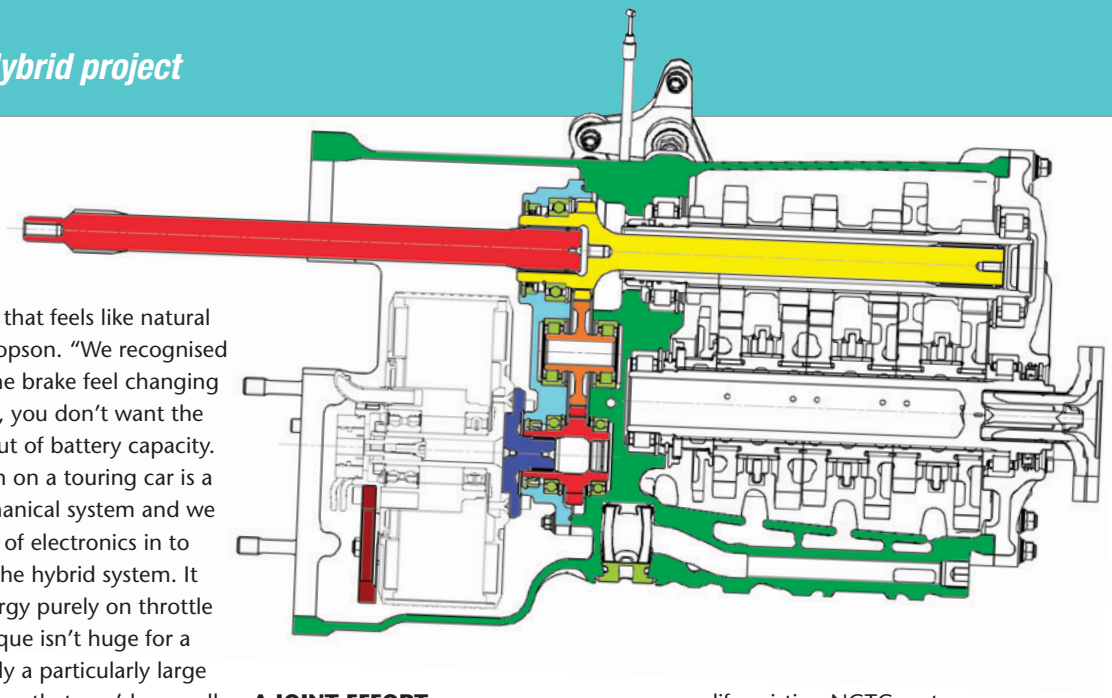
BELOW LEFT & RIGHT
The battery, seen here on a CAD image of the floorpan (right) and in the car itself, is accommodated in the passenger footwell

driver to gain 15 metres in one single deployment per lap," explains Clive Dopson, chair of TOCA's engine technical review panel. "If you analyse the data from the various circuits that the series visits you can look at the maximum time on wide open throttle. Looking at the worst-case circuits, that would require a 30 kW (40 bhp) boost for 15 seconds. This led us to a minimum requirement of 1.5 kWh for the battery capacity."

Another key point was that the electric motor would be integrated into the transmission, driving directly onto the input shaft, in what's known as a P2.5 layout. "A P1 layout – mounted on the front of the engine – was considered, but that would have been difficult, because there are options to homologate different types of engine," notes Dopson.

Part of the decision behind the P2.5 configuration comes down to energy recuperation. Given the relatively low power levels involved and the difficulties of balancing front-wheel drive and rear-wheel drive, the decision was taken not to harvest any energy directly from the braking system; instead the spec AP Racing brake package would be kept separate and the energy would come purely from reverse ▶

ABOVE The hybrid control system is based around Cosworth's next-generation ECU, which will become mandatory from 2022



torque during engine overrun.

"The aim is to get something that feels like natural engine braking," comments Dopson. "We recognised early on that we didn't want the brake feel changing as you decelerate. For instance, you don't want the braking to change if you run out of battery capacity. As it stands, the braking system on a touring car is a relatively straightforward mechanical system and we didn't want to have to put lots of electronics in to allow it to communicate with the hybrid system. It was simpler to recover the energy purely on throttle pedal position. The reverse torque isn't huge for a 30 kW motor, so it's not actually a particularly large percentage of the engine braking that you'd normally get. It's only comparable to having a slightly larger combustion engine."

Once the P2.5 layout was confirmed it was agreed to extend Xtrac's supply contract until 2026, to ensure the same transmission supplier was used for the duration of the project. A request for quotes for the hybrid system went out in June 2019, by which time the specification was fairly firm. The various proposals that came back were put to the teams, who voted to go with the Cosworth Hybrid System and a 2022 start date. The countdown to the BTCC's hybrid era had begun.

A JOINT EFFORT

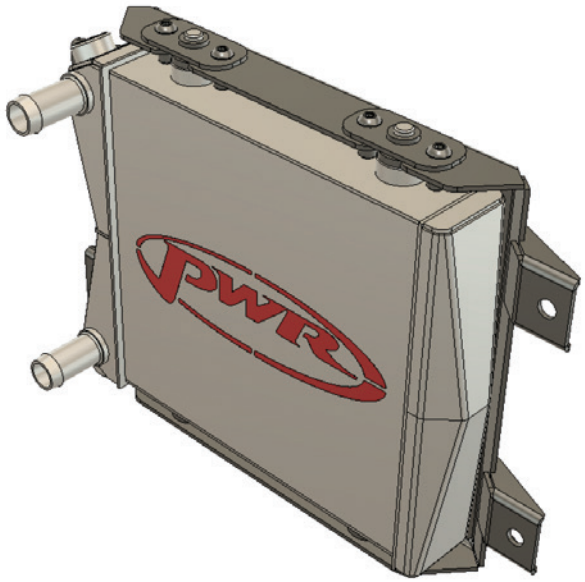
The project has been very much a joint effort. Cosworth led the integration of its own Hybrid system supported by a consortium that includes a number of existing NGTC suppliers, along with Delta Motorsport that Cosworth appointed as the battery provider.

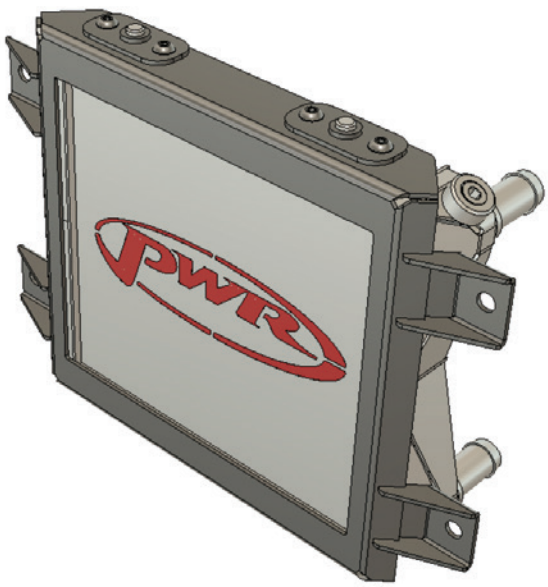
In order to keep costs down to a realistic level, the group planned to use off-the-shelf components or modify existing NGTC parts wherever possible. Xtrac, for instance, would eventually manage to design a conversion kit for the current gearbox that involves just 10 new parts to adapt it for hybrid use. But this comparatively simple approach brought its own complexity in terms of developing the hybrid package and ensuring that it was compatible with all the different car configurations.

"We began working with Xtrac ▶

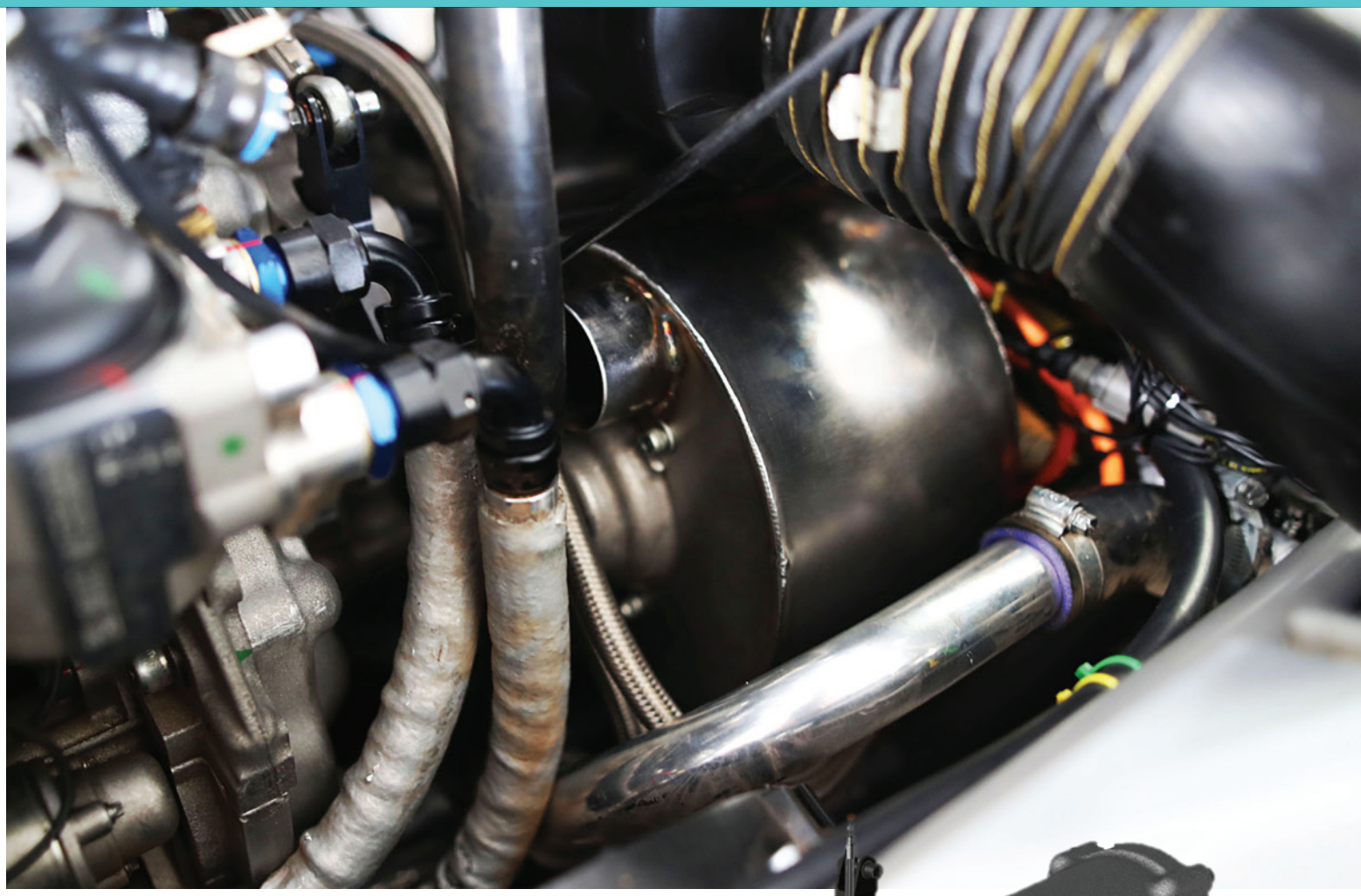
ABOVE The rear-wheel drive Xtrac gearbox seen in section. A number of options were explored to gear the drive from the motor to the layshaft

LEFT Two small coolers are positioned under the headlights. One serves the motor and its electronics, while the other is dedicated to the battery pack





LEFT Cosworth worked closely with PWR to satisfy the system's cooling requirements

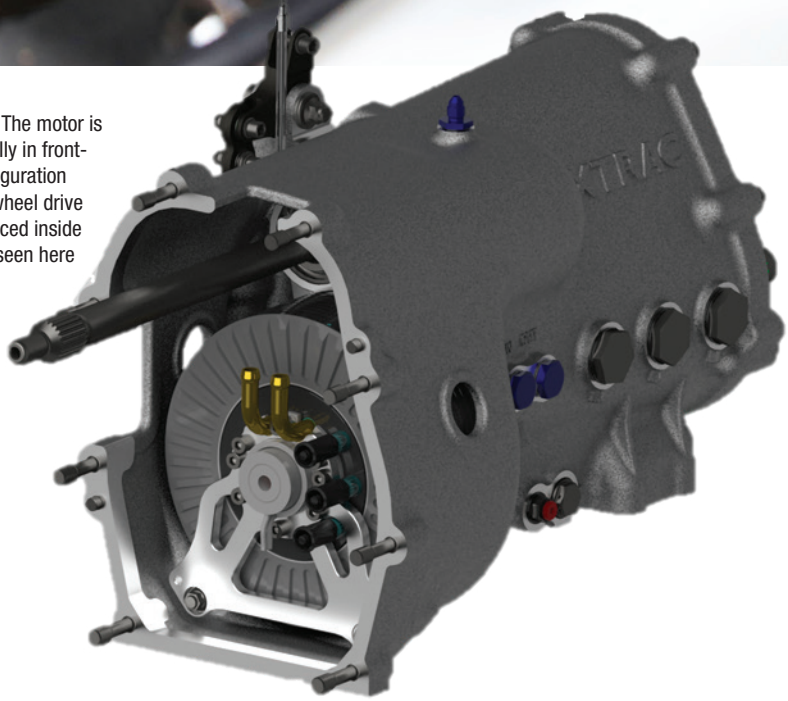


very early on to look at the installation requirements and working with Delta Motorsport helped us to define the project requirements," comments Rob Morrow, hybrid applications engineer at Cosworth. "Integrating with every single car on the grid introduced a few key challenges – one of them being cooling the battery and the motor, so we worked with PWR to ensure that the cooling system could be deployed successfully onto every single car."

The motor was selected by looking at the power-to-weight ratios on offer from commercially available permanent magnet designs. Perhaps somewhat counterintuitively, the engineers sought to achieve parity between the transverse and longitudinal installations by packaging them differently. The motor is mounted externally in front-wheel drive setup, while the rear-wheel drive configuration places it inside the bellhousing.

> *"The cooling portion of the hybrid system will be an identical package for all installations to prevent a 'cooling war'"*

Simply integrating both into the transmission casing wouldn't work, as the front-wheel drive bellhousing wasn't wide enough to accommodate the motor that the engineers had in mind. A thinner, larger diameter motor was considered, but this would place it too close to the suspension and subframe. Meanwhile, the option of using the external layout on both was ruled out as this would lead to packaging issues in the transmission tunnel and could impact whether the teams were able to run left-hand drive or ▶



ABOVE & RIGHT The motor is mounted externally in front-wheel drive configuration (above). In rear-wheel drive cars it will be placed inside the bellhousing, seen here in CAD (right)

right-hand drive. In the end, the decision was made to go with two different layouts.

"For us, it was a case of dropping the drive from the motor onto the layshaft," comments Tom Cooper, design engineer for the BTCC hybrid programme at Xtrac. "When we first considered it, we had a CAD model with the RML subframes and our gearbox options to look at how we could gear the drive from the motor to the layshaft. We entertained a few different ideas, including driving onto sixth gear, but the solution that we came up with was driving onto the reverse gear.

"From there, we were able to set the motor's position in the Y-axis [across the car]. Next came the X-axis [longitudinally]. We needed the motor far enough away from the gearbox that it would fit, but close enough that we could get the drive into the transmission with some sensible ratios. The ratio that we chose was 1:1, so the motor spins at the same speed as the engine, reaching peak power at about 7,000rpm. Positioning the Z-axis [vertically] was important. It's a 7.4 kg motor, so if it's too high the driver will feel that in the car."

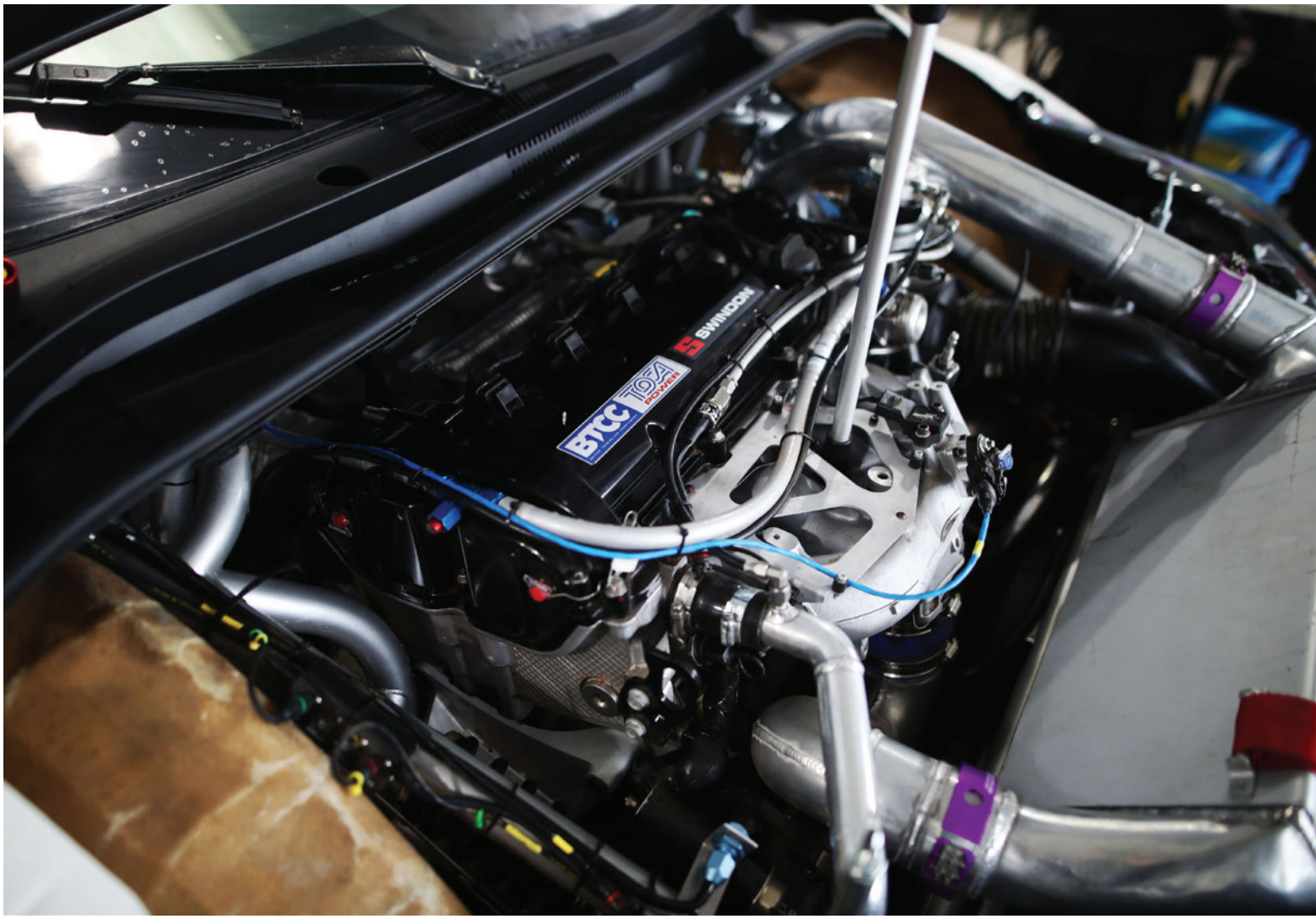
In terms of the all-important centre of gravity, the positioning of the electric motor is still slightly higher and slightly further forward in the front-wheel drive installation. TOCA has a plan to address this without affecting the architecture of the drive system.

> *"Teams can construct their own control strategy for the hybrid system using an open-source platform"*

Another important point was serviceability. The Xtrac engineers were keen to ensure that jobs like changing gearbox ratios or replacing a faulty motor would take around the same time in either installation. Likewise, they wanted to make sure that it would be possible to remove the motor with the engine and gearbox still in the chassis.

KEEPING COOL

The next big packaging challenge relates to the cooling system. This proved particularly tricky, because cooling for the internal combustion engine is an area where the NGTC teams have a degree of freedom to optimise their own designs. As such, there are a variety of different



BELOW The cooling system represented a big packaging challenge

packaging solutions and varying levels of success with the existing cooling options.

The combustion engine operates at a far higher temperature, so piggybacking the hybrid cooling system onto the radiator or the charge cooler was not an option. Initially, the possibility of placing a third radiator across the middle of the car was considered. The conclusion was that there wouldn't be enough air flow down the centreline of the car, so instead it was decided to place two small coolers under the headlights. One serves the motor and its electronics, while the other is dedicated to the battery pack. Both are supplied by their own individual pumps.

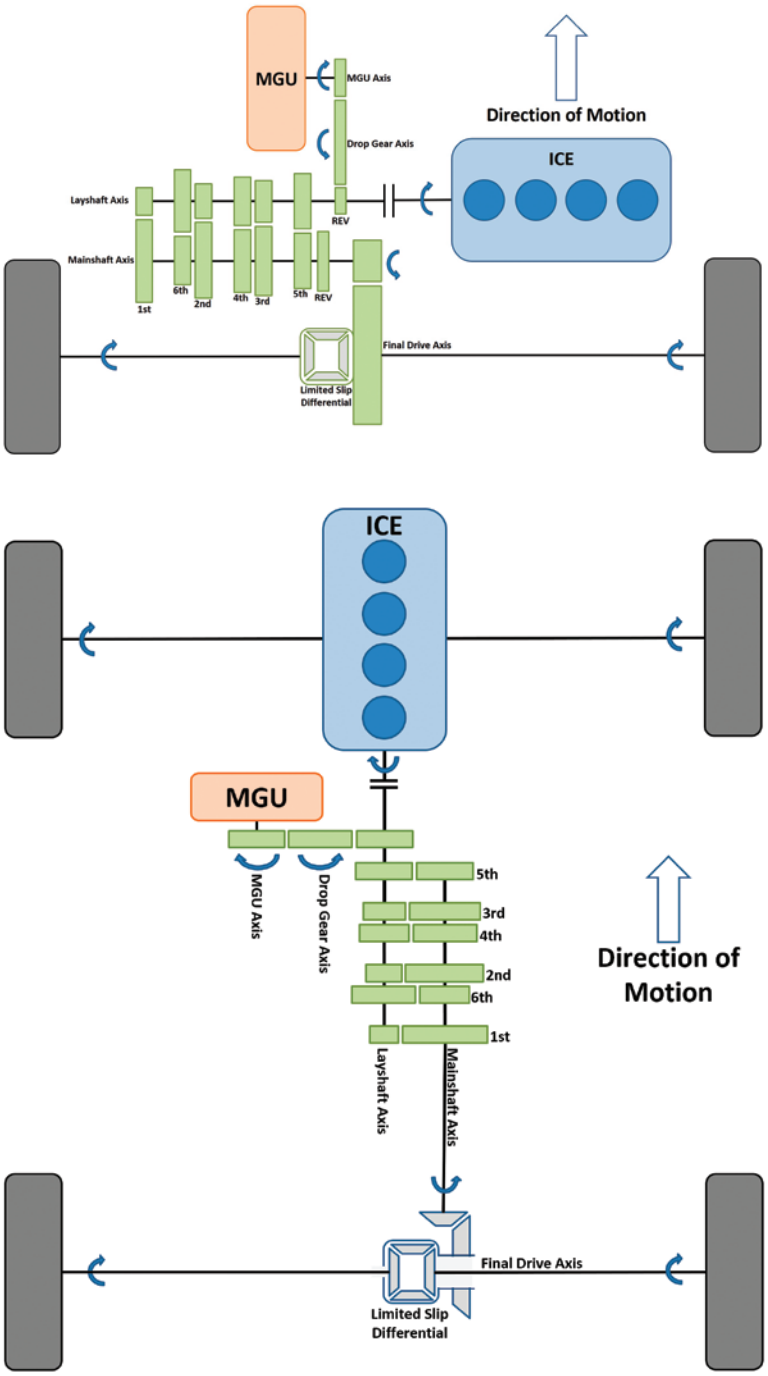
"For us, the difficulty comes with the location of the coolers," comments Andrew Parker, operations and customer support engineer at PWR. "There's always a trade-off there between packaging space and the cost of the technology that you choose; because of the vulnerable location right at the front of the car we didn't want to use anything that would be particularly costly to replace, but that in turn increased the packaging volume that we'd need."

The stakes are quite high here, he points out, because the electric motor also acts as an alternator supplying the car's 12-volt system through a DC-DC converter that's driven from the high-voltage battery. Given the BTCC drivers' sometimes robust driving styles, it was critical that the motor could continue to function as an alternator even if the cooling system was damaged and the hybrid side was disabled.

"The cooling system is quite critical on something like this where you're regularly charging and discharging," comments Simon Dowson, managing director of Delta Motorsport. "We adopted a cooling system that we'd worked on with PWR previously that runs through our battery system to maintain the cell temperature. After we built the first pack, we carried out load testing in parallel with Cosworth's verification of the motor and the control system."

The danger was that a cooling system that worked more effectively in a particular installation could convey a performance benefit. Delta Motorsport evaluated a range of different circuits and deployment strategies to identify the worst-case duty cycles and ensure that the battery would perform consistently over the whole of that range.

As it is, the cooling portion of the hybrid system will be supplied as an identical package for all installations. Part of the reason for this was to prevent a 'cooling war', Parker notes: "We've already seen how much some of the teams spend on optimising their engine cooling and we didn't want the better-funded outfits to have more options for their hybrid system. We also didn't want a situation where the first person to pull out of the slipstream got penalised. As a result, we've specified a system that's probably 10 per cent larger than it would need to be for perfect thermal conditions every lap."



ABOVE A schematic of the driveline for front-wheel drive (top) and rear-wheel drive

CONTROL STRATEGY

The hybrid control system is based around Cosworth's next-generation ECU, which will become mandatory from 2022. This features a separate partition, within which the teams can construct their own control strategy for the hybrid system using an open-source platform based around Simulink.

It's likely that control strategy will be left largely ▶

ABOVE It is a vital requirement that the system fit existing cars. The test mule is therefore based around a Speedworks Motorsport Toyota Corolla that has already raced in NGTC specification

to the teams, Dopson explains: "The only constraint that we plan to have on the deployment of the system is a minimum vehicle speed to avoid some cars using it while others are still traction-limited. Beyond that, it will be up to the teams. It could be completely controlled by the button on the steering wheel or it could be pre-set to provide assistance under certain conditions. We're still to have some discussions around that, but currently all those strategies are there in the ECU and they can all be switched on or off."

This 'push to get ahead' function looks set to add a whole new tactical element to touring car racing. "At present the performance of the cars is very close. One of the metrics we look at for our existing balancing process is how many cars qualify within one per cent of the fastest time. We average somewhere between 15 and 20 cars," comments Dopson. "If you look at the straight-line performance during a race, the cars generally get to the end of each straight in the same order as they came out the last corner, so the point when the drivers deploy the system will be crucial; there will be strategies to help them attack and strategies to help them defend."

> *"Do we adjust the hybrid system's benefit in terms of lap time or track position?"*

Dopson points out that the optimum solution for track position could be completely different to that for setting the fastest lap time. This has clear implications for the drivers attempting to fight their way through the field, but it also presents a dilemma to the series organisers who are planning to use hybrid assistance in place of success ballast. "Do we try to adjust the hybrid system's benefit in terms of lap time or track position? Track position is easy, it's just straight-line maths, but lap time is a lot more complex, that's one of the things we're looking at currently," he notes. "The first race of the year in 2022 will see all the cars running full hybrid assistance, but from then on it will vary."

A further implication of this approach is that the successful teams will have to get used to running varying levels of hybrid assistance. (This is similar to the current system, where the more successful cars already run with varying levels of 'success ballast' during the season.) Another challenge will be communicating the level of hybrid power to the spectators and the commentators. This is likely to be a light system that's visible from the side of the track.

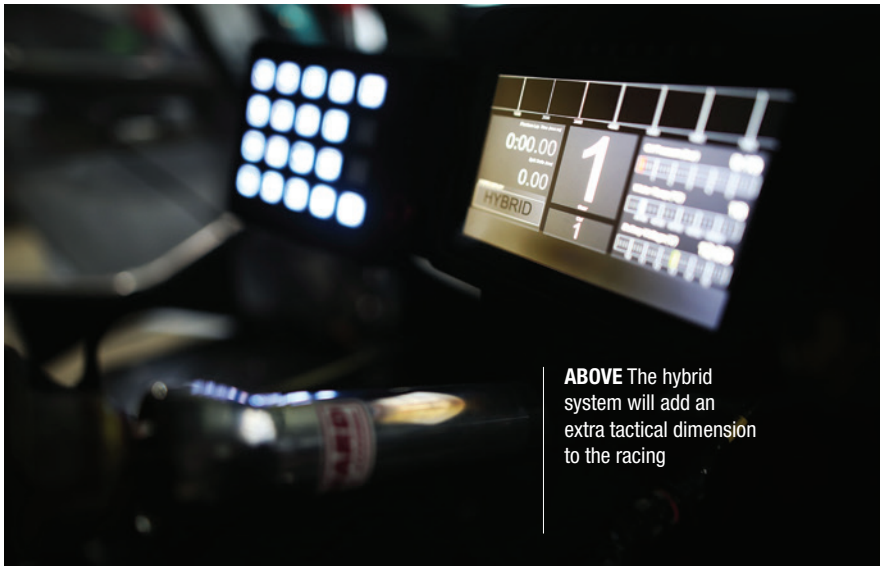
The specification requires the battery to be capable of being charged both on and off the vehicle, and the expectation is that the teams will fully charge the cars before they go to the grid. Thanks to its relatively small capacity this should be a straightforward process, with a full charge taking around an hour from a conventional 240-volt wall socket.

TESTING TIMES

At times, the possibility of bringing the introduction of the hybrid system forward to 2021 had been discussed. This was deemed technically feasible but commercially and logistically tricky, so the target remained the start of the 2022 season, and plans were laid down to begin testing in 2020.

Work began with Speedworks Motorsport to develop a test car based around the current Toyota Corolla hatchback design that it had already raced in NGTC specification. Despite the massive disruption caused by the coronavirus, the team was able to prepare the car in time for airfield testing at the beginning of the summer. With sports car ace Darren Turner at the wheel, the engineers started looking at things like safety strategies and failure modes, before the work moved to track testing at Snetterton in July, as part of the official BTCC tyre test carried out with Goodyear.

"In a way it's fortunate that the Corolla is probably the smallest car on the grid. It has the smallest overhangs and there's a lot of existing electrical hardware in the passenger footwell, which is where the battery has to be accommodated," notes Riches. "It was also good to work with Darren as he's a very experienced driver who was able to give the engineers the feedback they needed."



ABOVE The hybrid system will add an extra tactical dimension to the racing

Turner lapped the Snetterton 300 circuit in both dry and wet conditions as he made his return to BTCC machinery for the first time in more than a decade. "It's an historic moment for the series and we're all delighted to have completed an extremely successful test," he commented after the test. "The system works really well – it will undoubtedly add an extra and exciting dimension to both the defensive and attacking aspects of the racing.

"We will of course be developing the system and integration further and further – this is just the beginning of the car's track life – and we'll be getting more and more miles in the car over the coming months. Every bit of information is vital at this point to ensure we have a robust system that enhances what the BTCC is all about, and I'm absolutely convinced we will achieve that."

Given the project's progress so far, he has every cause to be confident. TOCA is on track to bring affordable hybrid racing to the world of touring cars. And if past experience is anything to go by, it looks sure to be spectacular. RT

ABOVE The BTCC drove into a fresh era when the Cosworth-developed TOCA Hybrid car successfully completed its maiden track run at Snetterton