RACE TO ROAD

HARNESSING SPORTING SUCCESS FOR THE ROAD

This whitepaper from AP Racing, the world-renowned brake and clutch supplier, examines the technology transfer from successful motorsport programmes to high-performance road applications. It discusses the current landscape and practices, existing challenges and what the future holds.

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FOREWORD

“From supplying the hydraulic brakes that secured Auto Union’s 1938 British GP win to Sergio Perez’s victory at the 850th GP, in Bahrain, AP Racing has worked incredibly hard to maintain its position at the forefront of braking technology. The company has a rich history of innovation and engineering success that dates back to 1920 but few challenges have been as significant as the horizontal transition from motorsport to road applications.

“Unrestricted by heavy regulation and budget minutiae, motorsport has always represented the frontier of automotive innovation. It has a well-deserved reputation as a proving ground for radical ideas. Indeed, some of the most significant automotive advances and technologies have been distilled from race cars, but road development is another challenge altogether.

“Road car braking systems require more testing, more production controls, longer duty cycles, greater durability, increased reliability, more safety technology, stricter budgets, logistics and supply chain management, larger volumes and an incredible focus on consistency. This whitepaper discusses AP Racing’s approach, difficulties and successes with the hope of inspiring other motorsport companies to innovate horizontally into the wider automotive industry.

“While the original Automotive Products of 1920 was very much in the business of road cars, the company evolved to have a much greater emphasis on motorsport. Taking that unrivalled heritage – lessons learnt over decades of competition – and applying it to modern road vehicles was anything but simple. In the context of overcoming horizontal innovation challenges, the introduction of AP Racing’s systems to the road market offers important lessons and insight for all motorsport innovators.”

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RACE TO ROAD

The transfer of technology from the world of motorsport to road-going vehicles is nothing new. The motorsport and automotive industries are perhaps the most well-practised horizontal innovators in the world. The simple fact that almost every global automotive Original Equipment Manufacturer (OEM) has, at some point, had a ‘factory’ racing team is a strong indication of that link.

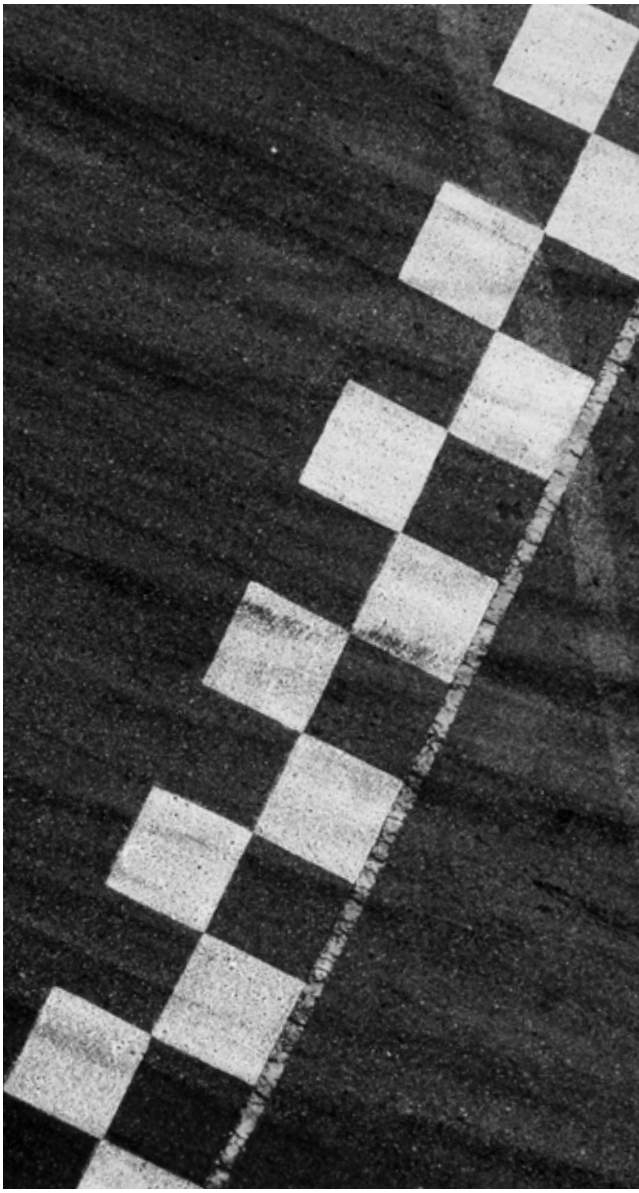
However, the technology transfer has not just been to automotive. There have been benefits to everything from rail and marine to defence. The extremely competitive nature and rapid evolution within motorsport require substantial investment, resulting in a multitude of impressive outputs. Time and again these processes and technologies have been shown to rapidly solve existing challenges in other industries.

A pertinent and well-known example of horizontal innovation is the Formula One kinetic energy recovery system (KERS), a variation of which is now integrated into almost every electric and hybrid road vehicle. Things like anti-lock braking systems (ABS), all-wheel drive (AWD), turbochargers, transmissions, suspension designs, tires, dual overhead cams (DOHC), safety structures, fuel efficiency and material advances have all come from motorsport.

What delivers horizontal innovation success?

As the name suggests, horizontal innovation is taking skills, concepts, or technology from one sector and applying it elsewhere to fuel progress. Whether it is a unique process or a pioneering design, horizontal innovation can help to reduce costs, improve operational efficiencies and accelerate research and development. Motorsport-driven advances in Computation Fluid Dynamics, for example, have found widespread use in the aerospace industry.

Horizontal innovation does not necessarily refer to technology either. For example, it could be an improved method of customer relations or a more efficient organisational structure. Fundamentally, it is about using existing knowledge to make improvements in another distinct area or sector.



Current landscape & challenges

The close similarity between motorsport and automotive has seen many horizontal innovation success stories, but equally, it has seen a great number of failures. Technology 'trickle down' into the automotive industry primarily comes in two forms. Vehicle manufacturers with high-level motorsport programmes that feed innovation back into the parent company and motorsport suppliers looking to get their technology into production vehicles.

Motorsport businesses or suppliers that are looking to apply their knowledge, services or products to road applications can face many hurdles. One frequent criticism from OEMs is that many of these companies have little appreciation for the significantly longer timescales and commitment to testing that the automotive industry requires.

There are many more things to consider when designing for the lifetime of a road car than the season, or less, for a motorsport programme.

Another sticking point for motorsport innovators is volume and warranties. Many motorsport suppliers seek out automotive contracts to stabilise and improve their cash flow, but few are prepared to scale their production without compromising quality or delivery times. Partnering with established automotive suppliers to refine motorsport technology for road vehicles and effectively scale up production is one path to success.

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OEM REQUIREMENTS AND BENEFITS

Before contemplating whether road car development could benefit from a motorsport technology, it is important to understand the objectives and concerns of vehicle manufacturers. Considerations and decisions that would not receive a minute of thought in developing a motorsport brake system could need months of validation on a road car.

Automotive considerations & requirements

A race team director is looking at past vehicle performance and ways to rapidly improve or maintain their standing within the field of competition. Depending on the ruleset, significant changes can often be made incredibly quickly. This high level of agility and innovation means that motorsport teams are constantly looking for ways to outpace their opponents. They want blistering acceleration, top speed, handling, and braking – anything that will cut their lap time. Everything else is an afterthought.

Road development, while competitive in its own way, is the complete opposite. Development lifecycles can be three to five years in length and there are conflicting priorities and considerations for almost every component. For road vehicles, cost is always a compromise, every O-ring and bolt must be considered and the supplier evaluated. Race teams, on the other hand, can invest as much as they would like in one element or system of a race car.

One of the most important differences between motorsport and automotive is the approach and intensity of testing. Automotive testing is not only looking to validate that a component performs as intended, but that it can do so for 15 years in a range of climatic conditions. This means that components must continue to perform throughout extensive safety, durability, corrosion, and environmental testing. There is a myriad of factors that must be considered, from maintaining operational temperatures in arctic testing to surviving the damaging desert heat and ultraviolet, salted roads, potholes, and crash impacts.

Attention to managing noise, vibration and harshness (NVH) is another significant difference between motorsport and automotive. Driver and passenger comfort is a huge component of what makes for a successful road car but it matters very little for motorsport components. For example, brake systems in motorsport generate huge amounts of friction and are incredibly loud. This is accepted because the driver uses hearing protection and the threshold for NVH is much higher on the track. In a road vehicle, however, this kind of discomfort would be at odds with customer expectations.

What is the incentive for OEMs?

Having already done the legwork, motorsport pioneers offer relatively low-cost innovation to vehicle manufacturers. With limited research and development budgets, OEMs can turn to motorsport to find components, systems or processes that are already well established and validated in incredibly demanding conditions. No hybrid vehicle regeneration system is going to endure the same abuse as a Formula One KERS, so seeing it validated at such an extreme offers reassurance and evidence of its capability.

In a competitive industry like automotive, standing apart from the crowd is everything. Whether that is achieved by including new technologies or establishing industry-leading reliability, almost every area of differentiation could be enhanced by motorsport links. From emissions reduction and driver aides to performance and handling, motorsport has a multitude of advances to offer OEMs.

THE RADI-CAL 'RACE TO ROAD' JOURNEY

In 2007, the engineering team at AP Racing sought to revolutionise caliper design and production for top tier motorsport customers. The result was AP Racing's patented Radi-CAL design philosophy and product range. Radi-CAL perfectly illustrates the success of horizontal innovation, transitioning a motorsport-focussed innovation into broader automotive applications.

Radi-CAL philosophy

When first viewed, AP Racing's Radi-CAL brake calipers bear a resemblance to 'alien technology'. This is because they have been redesigned from first principles, achieving vast improvements through organic and non-symmetrical shapes. The first Radi-CAL design was for an F3 car and compared to its conventional predecessor, offered a 29% reduction in brake fluid displacement under hydraulic pressure; a 33% reduction in displacement when torque loaded; and achieved even distribution of stress loads throughout the caliper body.

This new design philosophy was applied to numerous race formulae, including those with highly restricted space envelopes. Its primary focus was efficiency – reducing caliper brake fluid consumption. This allowed for smaller master cylinders, thereby improving driver brake modulations and maximum caliper pressure and torque. The caliper's organic shape also significantly increased surface area, leading to improved cooling performance.

Radi-CAL design process

1. Radi-CAL caliper design starts with the package envelope specified by the customer. The size and dimensions of the packaging space are determined by wheel profile, knuckle, and brake disc sizing.
2. AP Racing’s optimisation software takes the packaging space and develops a three-dimensional computer-aided design (CAD) model to suit. This model is the result of significant research and development by AP Racing into caliper rigidity, strength, and weight reduction.
3. A rigorous Finite Element Analysis is carried out on the digital model. This is used to further refine and optimise the design through multiple iterations. It is common for there to be upwards of 20 design iterations at this stage of the Radi-CAL process.
4. The next phase is a Computational Fluid Dynamics (CFD) analysis of the disc, bell and caliper assembly including the vehicle ‘corner’ assembly. The priority of this step is to understand the thermal behaviour and performance of the design, including both steady-state and transient thermal loads.
5. The design is finalised and prepared for manufacture.

Formula One & NASCAR

Advances in 5-axis machining and a relative lack of cost cap allowed AP Racing to develop ‘no compromise’ Radi-CAL calipers for Formula One. These truly optimised products allowed designers to target stiffness characteristics to suit specific car and braking system requirements, resulting in further weight reductions of 14 per cent over the space of several years.

In NASCAR, AP Racing was able to exploit the design envelope to significantly modernise caliper design with considerable weight and stiffness improvements. This was critical to NASCAR’s contemporary concern with integrated cooling packages.

Radi-CAL forging

Radi-CAL’s most significant drawback was the expensive and lengthy process of aluminium machining, which also resulted in considerable material wastage. Replacing aluminium casting with forging has allowed AP Racing to achieve Radi-CAL’s complex geometries while simultaneously reducing cost. The level of quality and consistency that this process achieved, in combination with the lower cost, led to AP Racing’s first Radi-CAL high performance road calipers.

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CASE STUDY:

BUGATTI CHIRON

Following the success of the Veyron, Bugatti sought to create a successor that exceeded expectations and redefined high-performance luxury road cars – the Chiron. With their eyes set on a top speed above 300 miles per hour, Bugatti's engineers knew they needed incredible braking performance to match.

Having designed and manufactured the calipers for the original Veyron, AP Racing was the ideal partner for Bugatti's new vehicle. Bugatti expressed its desire to increase the stiffness of the calipers while cutting weight and reducing brake pedal travel. To achieve the necessary performance, AP Racing developed a set of forged monobloc Radi-CAL calipers.

One hurdle for AP Racing's engineers was that Bugatti wanted to keep the Veyron's wheel diameter but increase the size of the brake discs and pads. This left so little space that it would not have been possible to fit a conventional caliper, only the forged Radi-CAL design could meet such packaging constraints.

Performance was not the only focus of Bugatti's brief; aesthetics were also crucial. With only a few Bugatti logos on the car, ensuring that the calipers visually matched the design DNA of the brand was paramount. The Radi-CAL forging process ensured consistent and high-quality caliper surfaces while seamlessly incorporating Bugatti's branding.

Despite the Chiron's incredible top speed and performance, it was important for AP Racing's engineers to not lose sight of the fact that, first and foremost, the Chiron was also a road car with the character of a Gran Turismo. As such, significant time was spent ensuring that the calipers had robust NVH management and mitigation. This would provide the desired occupant comfort and meet the expectations of Bugatti's customers.

With such a high performance vehicle available to untrained drivers, the braking system needed to be easy and intuitive to operate at low speeds but safe, predictable, and responsive at high speeds. AP Racing's expertise in application engineering meant the calipers were fully integrated into the wider braking system, including aerodynamics as well as safety features like anti-lock braking system (ABS) and electronic stability control (ESC).

Using the Radi-CAL philosophy and technical competence earned over decades in leading-edge brake development, AP Racing was able to deliver calipers that fulfilled Bugatti's durability, reliability and comfort requirements while providing predictable, safe, and substantial braking performance.

Jachin Schwalbe, Head of Chassis Development at Bugatti, commented: "AP Racing's dedication to engineering excellence has seen them excel in top level motorsport around the world. Just as they designed and manufactured the calipers for the Veyron, we decided to work with them again for the Chiron. The Chiron's exceptional acceleration and world-record top speed of 304,773 mph (490,5 km/h) for the Chiron Super Sport 300+ meant that it required an extremely high specification braking system.

"However, it was not enough for their solution to just slow or stop the vehicle – the brake system had to achieve incredible performance while still respecting our customers' expectations for world-class refinement. Climbing into the Chiron and comfortably decelerating at 1.6 times the force of gravity with smooth and predictable brake control makes it immediately clear that AP Racing understood our requirements and engineered the perfect solution."

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LOOKING AHEAD

The automotive industry is undergoing a period of radical transformation as the world acts on climate change. The quest to significantly reduce emissions has given rise to alternative powertrains while the push for safety and convenience has led to widespread investment in autonomy.

Some aspects of this transition have been mirrored in motorsport. The switch to hybrid powertrains in Formula One and the establishment of Formula E are two examples. While some see the link between motorsport and road vehicles as diminishing, that is not the case. Driven by the need for sponsorship, motorsport will continue to adapt to the changes in public opinion.

The emphasis on efficiency, sustainable materials, and changes in duty cycle are all areas of potential horizontal innovation. Autonomy, for example, will change the way vehicle braking systems are developed. In an autonomous car, braking will be far more consistent. While a driver may have 100 different ways they can brake based on modulation, foot position, complex movements and reactions, an autonomous vehicle may only have five. This could allow for significant changes in brake design and production.

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CONCLUSION

Motorsport will continue to be the pinnacle of vehicle performance and a spark of innovation and inspiration for the automotive industry. With shifting priorities, making pioneering motorsport technologies relevant to OEMs will be the key to horizontal innovation over the next decade. Motorsport businesses must recognise the dual focus of vehicle manufacturers on emissions and autonomy, as well as the broader requirements of road car development.

Much like racing, pushing the frontier of road car design and performance is essential to remaining competitive. For OEMs, actively seeking out relevant motorsport technologies like Radi-CAL can reduce R&D burden, fast-track ground-breaking technologies, accelerate vehicle development timescales and build consumer interest.