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From 'Whoosh-Bonk' to Formula One Systems and Specialists

A Modern Recipe for High-Tech Engineering Success

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Innovation is going to lie at the heart of Europe and America's ability to compete with China. And to do that, they will have to invest very heavily in people and equipment.

Rory Byrne, Ferrari and Benetton F1 Design Chief [1]

Executive Summary

South Africans have excelled at the top echelons of automotive engineering, the world of Formula One, Le Mans sportscars, NASCAR and other divisions of motorsport. This exceptional design and engineering record reflects the solid base of car production in South Africa (today a 300,000-unit, $3 billion industry annually), and the long history of competitive motorsport in the Republic.

Motorsport has become a global industry. In the United Kingdom, alone, the engineering side of Formula One turns over more than $6 billion, of which $4.3 billion is in exports, involving 4,500 mostly Small- and Medium-Size Enterprises and 38,500 jobs. The industry has been hailed by the House of Commons Business, Innovation and Skills Committee as a "crown jewel of UK manufacturing". Can contemporary South Africa, like other countries across the continent, today compete with other nations in building such a high-tech engineering sector, offering relatively high-wage employment for South Africans, thereby leapfrogging stages of industrial development?

Employing motorsport as a case-study, and drawing on interviews with key individuals involved in this sector since the 1960s, this Discussion Paper argues that the world of automotive high-tech has changed considerably over the past five decades. No longer is it possible for a highly-innovative individual or entrepreneur alone to succeed.

While there is no fixed model for growth, some elements are not negotiable, including the quality of institutions, governance and management. This not only requires a higher level of efficiency in government, imposition of the rule of law, the safeguarding of land rights, the ending of monopolies, and the (de)regulation of labour and credit markets, but the creation of the environment to spur an innovative and transformational culture. Here technical progress should not be confused with innovation. The former is taken for granted, and includes progress in elementary sectors such as power, telecommunications, roads, transportation, rural development, and sewage. Innovation also demands the promotion of excellence in higher education, a focus on R&D, and trust and confidence in the institutions and policies of government, including predictability and transparency. This requires open competitiveness to outside influences, ideas, technology, skills and capital. It involves a shift in power from companies and the state to consumers. Intrinsically, growth success and its sustainability is really about good politics.

The current record also shows South Africa has the raw material for success, both at its institutions of higher-learning and among its entrepreneurs. But it is important to realize that there is no magic bullet to achieve this goal. Rather it requires substantial investment in personnel and equipment over many years. If such talent is not available locally, then it has to be imported, at least temporarily.

The state has an important role to play both in providing the right overall policy environment, but more specifically in incentivizing the birth of such an industry through grants, encouraging apprenticeships to build a stock of hands-on skills, lowering import tariffs on machinery and specialist parts unavailable locally, and inculcating a realisation that being competitive is not a national but rather a global struggle. Act on these realties rather than rail against them, and it is possible to envisage jumping a few steps in the development ladder.

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BRUCE MCLAREN IS A LEGEND among motorsport aficionados and especially its engineers, a man of whom it is said that if he was to have arrived at the workshop one morning and said "'OK, guys, today we are going to walk across the Sahara desert" there would have been no moaning in response, instead simply "'Right, Bruce, when do we start"'.

Although Formula One was the pinnacle, then as now, of motoring mechanical engineering, it was still a rough-and-ready affair compared to the aviation industry for example. Bruce McLaren Motor Racing Limited, the firm that became today's McLaren International, started in a primitive shed in 1963 on a dirt floor in the corner of an earthmoving equipment storage shed in New Malden outside London. Its first two employees, mechanics American Tyler Alexander and Bruce's fellow Kiwi Wally Willmott built the first McLaren racing-car to a design drawn out by Bruce on the floor with a stick.[2]

To get to the cars you had to wend your way through all the earthmoving machines and in the far back corner was a little space with a workbench, a vice, a drill press and a set of welding bottles. It was one those 'Atcost' concrete buildings – a sort of concrete kitset thing that farmers used to build barns. There was just enough space for two cars. If you could weld, you were the fabricator – something one of us (McLaren employee number three, Howden) discovered having made up some chassis stands. When the others came in the next morning they asked who had made the chassis stands and, when he confessed that he had, they said 'You didn't tell us you could weld. Right – now you're the fabricator."

When Bruce McLaren, who was killed testing a CanAm car at Goodwood in June 1970, was approached in 1965 to turn his successful M1 sportscar design into a single-seater (Formula One car), the four-time Grand Prix winner insisted "You can take the suspension off the sportscar – 'Whoosh' – knock up a chassis and – 'Bonk' – there's the car." The resultant 'M3' became known as the 'Whoosh-Bonk', a successful Formula 5000, Libre and hillclimb design, and the camera car for the cult MGM film *Grand Prix*.

Today Formula One is a comparatively high-tech and capital intensive affair. Its systems and technology are as impressive as the aircraft industry it once lagged behind: indeed, both employ many of the same analytical, computational and aerodynamic tools, and build technologies of carbon-fibre, Kevlar, fluid dynamics and digital electronics, where performance is now measured in billions of dollars, wind-tunnel time and teraflops of information, not just horsepower and driver speed. As Rory Byrne, the South African-born designer whose Benetton and Ferrari cars have won a record 99 Grands Prix, reminds, his F1 budget went up 100 times from the $3.5 million two-car Toleman team in 1981 to the all-conquering Scuderia Ferrari in 2004. The engineering involved in car construction has progressed from the metalcraft and handiwork of a few talented individuals to an integrated approach involving many more specialists and carbon and other once space-age technologies.

Bruce McLaren winning at the wheel of his M8B CanAm sportscar at the US Laguna Seca track in 1969.[3]

And the McLaren name is now one of the most successful in Formula One history, winning a total, so far, of twenty world driver's and constructor's championships,[4] 56 'CanAm' sportscar races and five titles,[5] three Indianapolis 500s,[6] as well as the 1995 Le Mans 24 Hours. Today's McLaren Technology Centre in Woking, England is a far cry from the original storage shed, built at an estimated cost of £300 million in 2003 on a 500,000m^2 site. Officially inaugurated by Queen Elizabeth II in May 2004, the building housed 1000 employees previously spread over 18 sites. Not only does it include a 145 metre wind-tunnel and advanced underground workstations, but the facility is accompanied by a series of five artificial lakes. The idea was to attract the best and brightest in the business. As the team principal Ron Dennis explained in 2000,[7] "Put a man in a dark room, he's hot, it smells bad; versus a guy in a cool room, well-lit, smells nice... When you throw a decision at those two individuals, who's going to be better equipped to effect good judgment and take a good decision?" He publically hoped that the Centre could provide the right conditions to attract the very best designers and engineers, the right stuff as far as Formula One was concerned.

Why is this important, especially to a country like South Africa?

The Republic is among those countries which aspire not to follow the traditional development ladder of light-industrial manufacturing – pejoratively put, sweatshops – using low wage rates as the competitive advantage, as has been done most East Asian and, more recently, South Asian countries. South African labour unions say that they will not let their workers become 'the West's sweatshop' and in this see the global economy as a force to be avoided, not harnessed. As the Congress of South African Trade Union's (COSATU) General Secretary Zwelinzima Vavi put it over a decade ago, "The growing gap between the rich and the poor – within nations and between nations, the increasing attacks on the quality of jobs through casualisation and sweatshops, mounting poverty and disease are hallmarks of this monster called globalisation. As workers and the poor the face we know of globalisation is the blood-streaked one I have painted." But if globalisation is a disputed means, how is South Africa to break the mould of its 'two economies' in which its 47 million people exist: one comprising the five million individual South African taxpayers; the other the 13 million people who, by 2010, were locked into living on welfare payments? As Vavi further observed in May 2010, "Already, there is a significant number of youth who have never engaged in any type of employment. This situation shows that South Africa may be in an 'inequality trap'."[8]

But his is not the only view about how South Africa's economy should progress. Just as COSATU stated its opposition to 'Walmartisation' (in reference to the mooted takeover of SA retailer Massmart by US giant Walmart in late-2010), a senior SA Treasury official said that South Africans "must embrace globalisation instead of sloganeering and *toyi-toying* against it." He added: "We are busy exploring the demerits of globalisation while other countries are finding ways of benefiting from it."[9] Since COSATU's own growth proposals aim at creating an economy based on "job-creating manufacturing industry" in which the state has to play a leading role,[10] if sweatshops are out, comparatively high-tech industry and services are presumably in, along with finding the means to beneficiate mineral products.

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If high-tech offers an attractive solution to those for whom the traditional lower rungs of low-cost manufacturing on a long development ladder of export-led growth among developing countries is politically unpalatable, but what will it require to establish such a high-value addition, high-wage industrial advantage – and what does this 'world' currently look like? Motor-racing is one example of such a high-tech sector, and one at which South Africans have excelled. As Nick Fry, today the Chief Executive Officer of Mercedes GP (their current F1 car is pictured below) and with 20 years prior experience at Ford and Aston Martin, contends, "Formula One is the pinnacle of the automotive sector, and the automotive sector is at the pinnacle of engineering."

A Record of South African Excellence

Southern Africa has been blessed with an abundance of motor racing driving talent which has excelled on the international stage, from Woolf Barnato and Pat Fairfield before the Second World War to the Scheckters, Tony Maggs, Sarel van der Merwe, John Love, Kenny Gray, Rad Dougall, Roy Klomfass, Trevor van Rooyen, Wayne Taylor, and, more recently, Alan van der Merwe and Etienne van der Linde after it. A number of these driving careers progressed hand-in-hand with local engineering talent, notably Klomfass, Gray, Dougall and van Rooyen with Rory Byrne at Royale, the latter subsequently going on to excel at Toleman, Benetton and ultimately Ferrari; Maggs and Derrick White at Cooper; and first Ian Scheckter and later Sarel with Ken Howes. And this is not forgetting those other South African engineers who have 'made it', including Gordon Murray with Brabham and McLaren and Al Gibson at Reynard and Honda.

When Rory Byrne designed his first Formula One car for Toleman in 1981 he had four people working for him and 42 overall; today there are 150 specialists in Ferrari's research and design team and more than 350 employees overall. It has been a long road from racing Anglias at Johannesburg's Kyalami race-track in the 1960s.

Things fortunately got better. The Byrne-prepared Anglia tests the limits of its roadholding at the GP curtain-raiser at Kyalami in March 1969. (John Duncan)

Born in Pretoria in 1944, Byrne was schooled in Bedfordview where his parents, George and Gwen, now in their nineties, still live. His technical interests found expression early on in model gliding, though he studied industrial chemistry at Wits University. After graduating in 1964, he worked, first, at Kolchem in Germiston as an industrial chemist. During this time he "became interested in motoring" and converted his Ford Anglia 105E into an Onyx Production car with the help of friend Graham Ross, and another friend Eric Adamson, doing the driving. After finishing second and breaking the lap record first time out, he thought "This is fun – we'll have some more of this". After a bad accident Eric retired but with support from his brother Gavin, Rory refused to give up and the completely rebuilt car was driven instead by Barry Flowers with Progress Performance sponsorship. In 1969, Rory set up a branch of Auto Drag and Speed Den in Alberton in partnership with Doug and Ronnie Bennett (who already had a similar outlet in Malvern) and ran the business until he left for the UK in 1973. "In those days, on a Saturday morning, one could hardly get into the shop. People were there waiting to give you their money to make their car go faster – with Richie Jute cams, Tiger wheels, our own cylinder heads, and Weber carburettors. It was an incredible business to be in those days."

By this time Rory (pictured above) had started preparing a Formula Ford for sometime saloon-driver Roy Klomfass. The first car, the Fulmen (Latin for 'lightening') was built on the East Rand with the help of friends Quintin Maine and Mike Hutchinson. While competitive enough to achieve a few podium finishes, "the car was too slow accelerating on the straights, the reason being it was overweight. Rather than re-engineer the whole car, we bought a Lotus 69 for the next year in which Roy was right up there."

When Roy decided to try his luck in the UK in 1973, Rory went over with him, selling his share in Auto Drag and Speed Den. "My father thought I was completely crazy doing so as it was a really good business. But even he now thinks it was the right decision" he says with a smile on his lips.

During 1973 Roy raced a Royale RP16 Formula Ford. But by the end of the season he had run out of funds and moved to Hawke where he had both a job and a drive. On the strength of his preparation of the Royale, Rory was offered a job ("on about £3000 per year") as Royale's designer when owner Bob King suffered a nervous breakdown and the business was purchased by his accountant Alan Cornock. Rory carried out updates on the existing cars and designed the all-conquering RP21 for 1975. With his customary clarity Rory explains, "I tried to achieve a car with sufficient stiffness, on the weight limit and with good straight-line speed. I was surprised at how competitive it was." The car swept the championship in the hands of Geoff Lees, harried by the Van Diemen works driver South African Kenny Gray. During 1976, another South African, Rad Dougall, had come to England to break into the racing scene, also buying a RP21. The same year Ted (who was also SA-born) and Bob Toleman, who ran a car transport empire, and their company manager Alex Hawkridge, all bought RP21s. Although Bob Toleman was killed in a FF race at Snetterton, the partnership was formed that saw Rory move to Toleman to engineer a March 782 for Rad in 1978, but only after he had designed the successor to the RP21, the RP24, and its FF2000 bigger-brother the RP25, all of which cleaned up their respective championships, the former in the hands of Trevor van Rooyen, the latter in Rad's.

The presence of a dynamic and hyper-competitive SA motor-racing scene produced a seemingly unstoppable well of talented drivers – and their activities fed off and into the SA engineering scene. Necessity was, back then as now, the mother of all invention.

By 1981, the ambitious Toleman team decided to step up to Formula One with their own chassis, Pirelli tyres and turbocharged Hart engines. However, it proved a big jump, with the overweight, unreliable and unwieldy car ultimately being nicknamed the 'Belgrano' after the Argentine cruiser sunk in the Falklands conflict. "It deserved it," says Rory, "it was a shitbox, really." Already F1 cars were progressing from "being laid-out on the basis of experience and ideas and the feedback of their drivers to the results of data acquisition systems and wind-tunnel results." Another "critical tool was finite element analysis, structural calculations by which one can design correctly a part based on its composition and geometry."

For this reason Rory thinks that he probably would not get a job today in motor-racing – "I certainly would not give me a job at an interview given my chemistry background." Motorsport has become much more specialised, with fluid dynamic, aerodynamic, electrical/electronic and structural specialists required, "even though it's still an exercise in mechanical engineering."

Ferrari is the product of an annual operational budget running into several hundred million dollars at its peak, and huge investment in knowledge and capital equipment. "There were just 30 personnel in the aerodynamics department when I got to Ferrari in 1997," reflects Byrne. "Today there is probably a hundred."

Ferraris have been produced on the same site for the last sixty years. But where there were once men with tinsnips, grinders, pipe-benders and pop-riveters, now there are five autoclaves producing carbon bodywork at 100psi, a multitude of giant five-axis milling machines carving bucks and other items whirring away, a rolling-road windtunnel capable of running full-scale models at 180mph, endless computer workstations, and more than half a dozen dynamometers including a complete (engine and gearbox) power-train dyno in 'Cell 8', all in spotless surrounds. A short walk away from where the cars are assembled is the 'virtual garage', where during each race the cars' telemetry is monitored in live-time by a team of 25. In the same building are the two simulators, including the giant extra-terrestrial looking 'Hexapod' which can simulate G-forces and movements like a real car. With the restrictions on track-testing, it is where the three [2010] test drivers Giancarlo Fischicella, Luca Badoer and Andrea Bertolini were constantly hard at work supplementing the feedback of the 2010 team of Felipe Massa and Fernando Alonso.

Rory's stress on the importance of systems and innovation apply equally to engineering fields other than Formula One. As he puts it, "[Fiat and Ferrari president] Luca de Montezemolo is always saying 'innovate or die'. It is of course not enough to spend money on the infrastructure, you cannot race a facility."

Byrne's 2010 responsibilities included working on the 2013 regulations in conjunction with Patrick Head. The aim is to improve fuel efficiency and the ratio between mechanical grip and power. "A Moto GP bike spends about 15% of the time on full-throttle," says Rory, "and a F1 car about 60%. We have to bring that percentage down, essentially by reducing the aerodynamic grip." At the same time there is a need to make the cars greener, to use expended energy better (not just from braking but also from exhaust gases). “Only about one-third of the energy available from the fuel is converted into power at the flywheel by the engine; the rest is wasted out the exhaust or in the form of heat.” This is why the engines are going the way of turbocharging with strict fuel-flow controls and better energy usage.

Durban-born Gordon Murray, 64, who designed championship-winning Formula One cars for Brabham (1981 and 1983) and McLaren (1988-91), highlights these technological and personnel changes. Echoing Rory’s admission, he says: “What it takes to be successful in F1 today is very different to my era; no-one would hire me today. I could design all aspects – the car, aerodynamics and even the gearbox and engine if pushed – do all the testing, structural analysis, and testing, run the company including hiring and firing people, and run the team on race-days as well. Where there would once have been three or four in a design team led by the chief designer who would actually sit at the drawing board, now the chief designer now does not draw the car but rather orchestrates a large group of specialists.” Rory Byrne, he says, “is also one of this old school, even though he was a generation – which in Formula One terms is a decade – behind me.”

Murray, left (with arms folded around the clipboard standing at the rear of the Brabham BT45-Alfa), followed up his F1 success by penning two legendary road cars: The F1, which held the title as the world’s fastest road car for years (and won Le Mans in 1995), and the gull-winged Mercedes SLR McLaren. He is now engaged in developing an entirely new manufacturing concept, iStream, for which his Citycar is the demonstrator. Realising that current methods of making cars are not environmentally or cost sustainable, Murray has instead developed a method that avoids the use of stamped, welded and painted steel. The three-seater 575kg, 2.3m T25 Citycar, smaller than a Smartcar, is built using composite materials, like a F1 car. The lightly-made steel space-frame is reinforced with glassfibre. “Very little steel is dug out of the ground in the process. We use a tiny bit – about €35 euros, or 60kg worth per car – of mild steel, which involves a very low energy process.”

None of the need for money, technology and specialists should, of course, discount the need for entrepreneurship. As Murray, who worked for more than a decade with F1 supremo Bernie Ecclestone at Brabham, notes, “Deep down, the entrepreneurial and character traits required are the same.” If anything, such traits have increased in importance as, to quote Michael Schumacher’s one-time coaching guru Balbir Singh, over the fourteen years of his involvement “F1 has moved from a sport to a business.” But as Patrick Head, the co-principal (and designer) of Williams F1 for the past 33 years argues, “F1 is largely about engineering, and trying harder doesn’t get the job down on its own.”[11]

Picture the Robert Duvall character 'Harry Hogge' from the Tom Cruise flick *Days of Thunder* and you have Ken Howes. Soft-spoken to the point of diffidence, but an engineer to his fingertips, his laid-back demeanour just about masking an intense, burning competitiveness. Today he is the head of the competition's department of the most successful contemporary NASCAR team, Hendrick Motorsports, which has scooped nine championships in the last fifteen years. It has been a long but enormously rewarding road travelled for this self-acknowledged high-school dropout from Florida in Johannesburg's western suburbs.

Ken, known by his contemporaries as 'Kaunda' (for obvious reasons), left school "which was a waste of time" early, preferring to take an apprenticeship at VW agents Lindsay Saker. But this was part of a grand plan to get into racing, 'never as a driver, always as a mechanic'. A short spell with Basil van Rooyen's *Superformance* concern in Johannesburg in 1968 working with Gordon Littleford on Basil's F1 Brabham BT24 was followed by a stint (mostly unpaid) fettling Formula Vee World Champion Tony Jefferies' aged F1 cars.

Thereafter he worked for Peter de Klerk and Luigi D'Ovidio at the Italian Cars Tune-Up Centre in Johannesburg's Green Street. "It was a very small workshop. Some of the time we would have the cars outside on jack-stands." For 1969 he started preparing Dave Charlton's cars out of Charlie's Marshall Street premises, first the unsuccessful 'SAS Oranje' orange Lola-Chev Formula 5000, and for 1970 the Lotus 49 and later the Lotus 72. The association brought three domestic F1 championships between 1970 and 1972. "By then it was time to move on."

For 1973 he joined Team Gunston who had taken delivery of three Formula Two Chevron B25s. "Eddie Pinto wanted to work with John Love, so I was 'given' Ian [Scheckter]." It was the start of an enormously rewarding partnership. The 1973 F2 championship was followed by two near-miss F1 championship years in 1974 (with the Lotus 72) and 1975 (Tyrrell 007), and then six SA driver's championships in Formula Atlantic (1976-1979; 1983-84).

A spell running the Kreepy Krauly-sponsored March in the United States, which won the Daytona 24-hour with an all South African driver line-up (Sarel van der Merwe, Tony Martin and Graham Duxbury), followed in 1984 and 1985, before he was recruited to engineer the IMSA Corvette for Hendrick Motorsports, with Sarel doing the driving. That lasted until 1989, when Howes moved over the NASCAR operation. Hendrick has dominated present-day NASCAR, with championships for Terry Labonte (1996), Jeff Gordon (1995, 1997, 1998, 2001) and five-in-a-row with Jimmie Johnson (2006-10).

NASCAR (National Association for Stock-Car Auto Racing) was formed in 1947 in an attempt to regulate the sport which had grown out of the bootlegging antics of drivers running moonshine and evading the law in the Appalachian mountains. Driver and owner Junior Johnson was, for example, pardoned for such activities in the mid-1950s by President Ronald Reagan in 1986.

From such humble roots has grown a sport with a global following. Yet its current base of activities remain in the American south in North Carolina around Charlotte where twenty NASCAR teams (and a further 30-plus sprint-car, drag and other motorsport shops) are based. No moonshine stills today though. It's a multi-billion dollar industry; high-tech, and hardly hicksville.

Hendrick's is an industrial scale motorsports' operation. Hendrick's four teams (for Gordon, Johnson, Dale Earnhardt Jnr and Mark Martin in 2011) require 56 race-cars annually and 200 engines. The gap between the 36 annual races is too short to prepare the cars properly between them, while different circuits demand a variety of chassis and engine set ups. For example, there is a difference between the staggered oval and symmetrical road-cars. Moreover, the 3400lb cars are built 300lbs below the limit, enabling weight to be kept low and shifted in the form of dense tungsten pieces around depending on the circuits.

Ken Howes with four-time NASCAR champion Jeff Gordon's mount.

"The technology involved is second only to F1 – and that relates only to the amount of money available" notes Ken, 62 in 2010. These are hardly stock-standard cars or engines, but rather space-frame, finely-engineered, computer-designed race-cars. The pushrod six-litre engines rev to around 9000rpm and produce 800bhp, indicating the extent of their modifications and in spite of the continued use of four-barrel carbs rather than fuel-injection.

All engine parts are purpose built, the pistons (used for one race-meeting only) being milled from a solid block of alloy, the heads being cast in Germany and the blocks in the UK. And not only are they dyno-tested, but friction-tested and run-in on Spintron (electronic dynamometer) machines.

Each race is simulated on a seven-post test rig to get the best chassis set up which changes dramatically during the race depending on fuel loads and weather. "With their relatively narrow tyres and limited aero-downforce, the cars are on the very limits of adhesion. Thus even half a pound of tyre-pressure or subtle changes to wedge [cross-wheel loadings] and sway [anti-roll] bars can dramatically alter the performance." And the limited grip places a premium on driver skills, something that F1 and Indycar stars such as Jacques Villeneuve, Juan-Pablo Montoya and Dario Franchitti have recently discovered to their chagrin.

All of this has to be done within NASCAR's very carefully monitored rules, which are designed to ensure that teams will not gain an unfair advantage and ruin the spectacle. "Unlike Formula One, NASCAR long ago realised that people – the drivers and the spectators – had to be put first. They did not turn their back on the paying crowds, but rather regulated technology very closely." This means that all cars are built, certified and regularly checked according to a set of carefully-proscribed rules, including a physical template for the bodywork.

This does not make it an inexpensive business. Driver's salaries aside, a privateer team doing things on the relative 'cheap' will require between $30-40 million for a season.

Ken says modestly that the technology has advanced to the level today that a generalist such as himself is increasingly redundant. With 450 employees overall, there are no fewer than 120 people working in Hendrick's engine shop alone, around 50 more building chassis, 160 in the race teams and a further hundred or so in administration and in the flying operation required for the three 45-seater aircraft needed to transfer the team to each race. It is a technology-driven logistics business.

The level of R&D, preparation and even physical training is awesome. Each car's seven-man (two tyre changers, two tyre-carriers, two refuellers, and one jack-man) pit crew, many of whom are recruited from college sports teams, train endlessly on a 'retired' car to get their times down to the standard 12 carefully choreographed seconds to refuel 18 gallons and change four tyres on five-stud wheels. The nuts are glued into place with contact adhesive to ensure that the operation goes smoothly; one slip could mean the difference between first and twentieth place given how evenly the cars are matched. The pit crews spend at least 90 minutes each day training in a purpose-equipped gym.

It's all a far cry from Florida, Green Street and jack-stands on the pavement.

South African-born Wayne Taylor, who has won five World Sportscar championships, built Team Cadillac in partnership with General Motors, and today runs his own GRAND-AM sportscar team from its Indianapolis base, agrees on the people aspect. "Today technology is moving at such a rate and such a speed that without the commercial side in place, without the resources, you won't make it" he says. "But even with the right financial resources, we would have to go to Penske or Chip Ganassi Racing [two of the established US Indycar teams] to obtain the latest technology. It is impossible to get that suddenly and on your own." Thus, he says, "The single most important thing in any business is the people – and it takes a very long time to build a team with the right people and the right culture."

Wayne Taylor (extreme left) and Team Cadillac, Le Mans 24-Hour Race, 2002.

All this demands, Taylor observes, a commercial mindset that sees sponsors as long-term partners not just as sources of money. Sponsorship for a high-tech (and costly) enterprise such as motorsport demands the entrepreneur putting sponsors together to do business with each other, and thus benefitting as a consequence of their profits. This demands exceptional business acumen and hands-on application.

The rise and collapse of Tiger Wheels as a wheel-manufacturing business is a story of entrepreneurship and sacrifice, hard work and acumen, good emerging from bad, of the challenge in running and growing an African manufacturing business in an increasingly competitive globalised environment, and ultimately of the perfect storm of factors leading to its demise. Fate, politics and fortune all, too, played their part in building what became a global business with operations in five countries across three continents.

Eddie Keizan's shrewd investment of the R3,000 prize from winning a South African motor-racing championship in buying Tiger Wheels for R14,000 in 1972 saw the company grow to among the top ten alloy wheel manufacturers world-wide, with a peak annual production of seven million wheels. Listed on the Johannesburg Stock Exchange, by 2006 Tiger Wheels Limited had a market capitalisation of R1.3 billion, and turned over R3.8 billion.

By the time of the company's demise as a manufacturer in 2007 amidst a perfect storm of technical and financial overstretch, unfavourable banking covenants and a hostile motor component supply industry, virtually all Tiger's aftermarket wheels – about 600,000 annually – were by 2006 manufactured in China because of lower costs and the greater flexiblity required for the aftermarket, albeit at longer lead times. Wheel manufacturers supplying the OEM markets remain largely protected from China's growing involvement in the industry because of the short, just-in-time lead times required to supply motor vehicle manufacturers with original equipment. Problems in the South African operations ratcheted through up 2005 and 2006. Due to a change in production at the Richards Bay aluminium smelter, the lack of suitable local pre alloyed aluminium (with the necessary ten percent silicon content) which had to then be substituted by expensive local or imported alternatives. However use of the latter threatened the status of Tiger's MIDP (Motor Industry Development Programme) rebates (in lieu of tradable export credits to offset punitive import duties). Applications and presentations to the South African Department of Trade and Industry to obtain an exemption, known as a deeming provision, were declined, essentially making the South African manufacturing business unprofitable.

From Tiger's experience, the challenges of building manufacturing capacity in Africa are daunting. It is a difficult place to run a manufacturing business, even though export-driven manufacturing is supposedly central to the government's plans for growth and job-creation. The high cost of skills, militant and inflexible labour, and an overvalued exchange rate makes this an almost hopeless task. Tiger's South African operations were not only uncompetitive when measured against Chinese counterparts: its factory at Babelegi had the highest manpower-to-wage costs when compared to its other plants in Germany, Poland and even the USA. And South Africa's skills shortage meant too that blue-collar skills attracted a premium. For example, an unskilled floor sweeper in Babelegi earned more than a graduate fresh out of university in Poland, another of the Tiger factory sites. South Africa's uncompetitiveness also partly related to the difficulty in inculcating a 24/7, 365 day-per-year work culture and environment. Because of the refusal by trade unions to co-operate, Babelegi only operated for 235 days per year (compared to 360 in Poland and 330 in Germany); the number of public holidays being especially problematic for a heat process business preferring continuous production.

All this contains perhaps the most salient lesson of all. Globalisation means doing things where they are done best globally. African countries need to decide what they want to be best at, and design their infrastructure, transportation, laws, policies, skills and technologies around that. Otherwise African countries will remain caught out and be left behind.

In March 2011, Boksburg-based Bailey Cars first track tested its LM2 racing-car, a South African-designed and built machine aimed at the Le Mans 24-hour. The result of more than two years hard work, a further year of testing and racing it is aimed will lead them to the 2012 Mulsanne classic.

Peter Bailey sold his share in a door manufacturing business 12 years ago. By then, however, he had already built himself two AC Cobra replicas and, "wanting to race something, and seeing that the Ford GT40 kit-cars were very basic and production-car based," he decided to construct a GT40 of his own. Fast forward a decade. Since the car production business was registered in 2002, Bailey Cars has built 46 cars, all bar the LM2 challenger based on an existing design. This includes 24 GT40s, just under ten Porsche 917s, and the remainder an assortment of 'Ferrari' P4s, Lola T70s and Chevron B8s. Employing 15, the business has benefitted from students testing their skills on the designs. The suspension of the first GT40 was designed by a Wits University student; the LM2 car has had students from Wits, Pretoria and Cape Town working on various aspects from the aerodynamics to the wiring loom. Bailey's son, Greg, studied megatronics at Tshwane Institute for Technology, and is the chief designer on the LM2 car. The use of local talent is critical to keeping the costs low, with overseas consultants coming in at around R20,000 daily.

Bailey Cars' LM2 challenger under construction in 2011. (Greg Bailey)

With each production car (not the LM2) costing around R1 million, unsurprisingly the biggest constraint to growing the business has been the lack of customers. Hence an export market has been created, with cars now in the United States, Sweden, Australia, Germany, Finland, Holland, England and "even Zambia". But with many of the components (notably the engines, gearboxes, brakes, instruments, and some wheels) being imported, high SA import tariffs drive up costs. "It is uncertain what domestic industry we are protecting by this," say Peter Bailey, "since none of these items is made in SA."

However, the LM2 initiative has benefitted from an innovation grant from the parastatal Industrial Development Corporation, amounting to 50% of R2.5 million. The percentage available to Bailey Cars was limited by Black ownership stipulations – a criterion seemingly wholly misplaced in this area, where the aim is to encourage scarce high-tech skills and enterprise *per se* in the Republic not increase the already formidable barriers faced.

Regardless, Bailey Cars shows what is possible against the odds – that South Africa has the entrepreneurial energy and skills alongside the passion to make this sector work. The challenge is to maintain it on a sound commercial footing.

Birkin Cars was started in South Africa 1983, and has gained a significant global market share as a high-quality producer of a global icon – the Lotus Seven.

Born in Wales and the son of a veterinarian, John Watson was four months old when his parents emigrated to Rhodesia. After schooling in (then) Salisbury and three years in the Rhodesian Army, John studied engineering at Salisbury Technikon. With an abiding interest in motorsport, during his military service he purchased a dilapidated Lotus 7 for restoration. Fearing the impact of his military background as the country transformed to Zimbabwe, along with many of his white countrymen he moved south to South Africa, taking his skills and entrepreneurial talents with him. Having had to leave his beloved '7' behind, after looking at the prohibitive costs of importing another car and failing to attract the interest of Caterham (who built the '7' in the UK having bought the rights from Lotus) in a South African joint-venture, John set about building his own car. Soon the hobby turned into a business as “the car-for-me project multiplied for friends and, before I knew it, I was building to order and the business evolved rapidly.”

Birkin is principally export-oriented. By 2011, close to 7,000 Birkins had been sold worldwide, only about 10% of which were to South African customers. Based in Pinetown, today Birkin employs 40 workers (down from a peak of 170) and produces 70 cars annually (with a capacity of 800).

The Birkin production line. (John Watson)

There are a number of reasons for the contemporary downturn. These relate to the global financial crisis, and to the increasing challenge of “worldwide homologation, especially given more stringent emissions and side-crash testing laws” says Watson. Essentially the company is restricted to exporting complete, turn-key cars where “the regulations are less stringent.” Nonetheless, Birkin has built up a large following in the United States, Australia, Japan and Europe.

Birkin is continuously innovating to get around these challenges, developing new products for the road and race-track. But in addition to a shortage of skilled craftsmen, critical to a hand-built product, reliable sources of material supply prove difficult to find, “where a small operation like ours is often at the back of the queue. Local bureaucratic demands are also onerous, the company employs two people just to handle (South African) Department of Trade and Industry, customs and other regulatory requirements. For example, like other vehicle manufacturers, Birkin has to lodge a customs bond as security for any default on duty payments, which represents a large sum of capital tied up. The high costs of compliance, Watson says, are geared to protecting the bigger players.

Watson believes that government could assist his and like operations by relaxing the onerous compliance regime. Such exemptions for low volume vehicle producers (for example under a 1000-unit annual benchmark) could include the acceptance of SABS (SA Bureau of Standards) testing on components rather than a vehicle as a whole. The cost of such testing for a new model can be up to R5 million, again a large sum for a small operation.

Overall, for a small business like Birkin, keeping abreast of changing and tightening global regulations is only part of the challenge, as is the imperative for continuous innovation. If it is to successfully compete abroad through Small and Medium Enterprises, South Africa will have to match its rhetorical commitment to their incubation and to export-led growth by removing the cost and bureaucratic hurdles that make such SME operations difficult.

The Need for the Right Stuff: People, Labour and Government

The late Tony Rudd’s autobiography, *It was fun! My Fifty Years of High Performance*,[12] is an extraordinary tale of an exceptional advanced engineering career.

The interesting part, however, is not in the stories about building Formula One cars or of racing derring-do. Rather it is in the training that Rudd enjoyed, especially as an apprentice at Rolls-Royce before, during and after the war.

Rudd joined Royce’s (as it was universally known by those who worked there) in 1938, aged 15. At the time there were three grades of apprentices among the 10,000 employees at Derby: 300 who were being taught a trade (fitting, machining, forging, etc.), 50 engineering trainees (of which he was one), and graduates. Applicants were weeded out by a rigorous Selection Board, and spent three months at a time learning from various departments for two-three years; thereafter if they passed another selection they were given further practical and academic training until they were 21. Only then did they go on to a ‘proper’ job.

Despite his relative affluence, one of Rudd’s first jobs was hand burr a job-lot of 1600 bolts holding the flywheel to the crankshaft of Silver Ghost armoured cars. Thereafter he was given 1200 cotter pins to also file for Kestrel aero-engines. Pay was just 23p a week for a day that started at 7am and could, with their extra-mural commitments at Technical College, go onto 930 at night. Anyway “Social life,” he wrote, “was impaired by extreme deafness, and a unique form of BO from a mixture of 100 octane petrol and oil.” During the war he worked in the Defect Investigation Department, working out why the Merlin engines (which powered all the important aircraft of the day) broke down in an effort to make them more reliable. Rudd only left (originally on secondment) Rolls-Royce for British Racing Motors (BRM)to try and sort out their engineering problems with the hitherto highly-unreliable supercharged V16 Formula One car in 1951 where he stayed until 1969 before joining Lotus until his retirement in 1993. Developing cars, engines and realising high performance demands long hours and long-term application, and no rolling stones.

By the mid-2000s machine shops in the UK had extreme difficulty in attracting apprentices. “We used to have two or three a year,” said one destructive engineering (Austin-Rover) specialist then, “and now we are lucky if we can attract one every two or three years.”[13] This is a vicious cycle. In the 1940s and 1950s, car-building and machining in Britain was mostly done on a one-by-one, stage-by-stage basis, when the ratio of labour to machinery costs was very much different to today. As labour costs rose, such manpower-intensive manufacturing became unthinkable even for small-volume production, and the demand for skills dropped. In short, the higher the labour costs, the greater the intensity of capital (rather than labour) in manufacturing processes.

Little wonder that Britain’s manufacturing industry has declined to less than one-fifth of national gross domestic product, from 35 percent in 1960, even though it is still responsible for around 60 percent of British exports. Employment in the sector has halved from seven million jobs in 1980. The UK is not alone in this trend among developed economies, but its decline has been among the steepest.

Four reasons are generally given for this decline. The first is the relative increase in expenditure on services and luxury goods. Second, mass production has shifted to lower cost countries, where improvements in technology and manufacturing techniques have also served to reduce margins. The third reason concerns the small investment in R&D made by the UK (1.8 percent of GDP) compared to Germany (2.5%), the US (2.7%) or Japan (3.2%) in 2005 for example.[14] Finally, all this has paralleled cultural changes in some societies, where working in the factory is now seen negatively relative to working in the office, thus reducing the number of applicants and workers in manufacturing.

The net result of all this is declining balance of trade for the UK. It is mired in deficit, one that is predicted to increase from 1.7 percent currently to nearly five percent over the next decade (despite the cheaper pound) as the revenues from North Sea oil and gas decline. (SA’s deficit was 4% in 2009.)

There are two prevalent opinions about the impact, both wrong. One is that the rate of industrial job-shedding is alarming, and should be stopped through all means, including protectionist tariffs or the subsidizing of domestic industry. The other is that this is the inevitable impact of globalization, that these figures do not take into account the benefits of lower cost imports to the economy or of intra-industry transfers, and that services and higher-value addition manufacturing is the way forward to compete against China and those who enjoy cheaper labour and other overheads.

The bottom line is that British and other consumers do not buy British because it’s too expensive or they don’t make what they and others want to buy.

Regardless, Britain retains certain comparative advantages in high-tech, despite this high-cost environment. “Three-quarters of the F1 grid,” Nick Fry reminds, “are made in the UK.” This amounts to a $6 billion annual motorsport industry, of which $4.3 billion is for export, involving no fewer than 4,500 companies, mostly SMEs and employing 38,500 individuals. Little wonder that the industry has been hailed by the House of Commons Business, Innovation and Skills Committee as a “crown jewel of UK manufacturing”.[15] As Fry notes, “In part this is because racing started in Europe, in part because engineers in the UK," he believes, "display a unique set of qualities – a high level and understanding of the theory, while being very good at practical implementation. This means, that unlike Germany for example which is very process-driven, that British engineers rely more on innovation and application, and can be very fast-moving in terms of applying ideas." He says that this is down to "our UK history of 200 years of 'design education' – teaching people how to design things. This explains why the Chief Designer at Apple, Jonathan Ive," he mulls, "is British." Fry, who has been appointed as an ambassador for British industry by Prime Minister David Cameron, says "if you have not got this [cohort], you will have, at least initially, to import such skills."

Changes at the Summit

David Richards has made the transition from World Champion rally navigator to CEO of Aston Martin over thirty years. Along the way he established Prodrive, whose Subarus made an indelible mark on world rallying with Colin McRae, Richard Burns, Tommi Makinen and Petter Solberg in the 1990s and early 2000s.[16] In March 2007, he led a consortium including Investment Dar and Adeem Investment of Kuwait, which raised $925 million to purchase Aston Martin from Ford, with Richards, 59, subsequently became chairman of the car company. In 2011, Prodrive relaunched Mini on to the world rally stage.

Prodrive's Aston Martin at the 2010 Le Mans 24-Hour Race

Of the transition from rallyist to entrepreneur and CEO, Richards says: "The role of a rally co-driver is much misunderstood. While the public face maybe of the person who simply reads out the driver's pace notes, their role involves many, many hours of background work before a wheel even turns. Rally co-drivers have to be meticulously organised; they have to pay the upmost attention to detail; and most importantly they have to be able to manage all the relationships around them in a highly pressurised environment.

"After I won the WRC in 1981 with Ari Vatanen and then went on to set up my business, Prodrive, I have continued to use these fundamental skills on a daily basis.

"With Ari, I only had to manage one person, at Prodrive we now employ nearly 600 people and one thing I learnt very early on was the art of delegation. We have built a strong management team around me who are all experts in their own field and each takes responsibility for key facets of the business. Indeed, I remember the turning point for me was when, one particular weekend, we had Prodrive teams competing at three different events. It was impossible for me to be at all three races, so instead I decided to spend the weekend at home with the family; and guess what – everything was fine. Sometimes the hardest thing to do, particularly when you have built up a company, is to step back and put your trust in others to run the business day-to-day. Had I not learnt that early on, I am sure Prodrive would not have become the international business it is today."

Richards' worked closely with Nick Fry at Prodrive, who moved there in 2001 from his post as managing-director at Aston Martin. Having worked on the BAR-Honda F1 team at Prodrive, he moved to Honda in 2004 after the Japanese giant bought out the F1 team until 2008 when Honda pulled out of the sport. The team was taken over by Ross Brawn and Fry, winning the 2009 World Championship with Jenson Button. Mercedes bought 75% of the team at the end of 2009, and the remainder was sold at the beginning of 2011. Today the F1 team, which employs 450 people, is owned 60:40 by Mercedes and an Abu Dhabi investment company.

Fry, left (courtesy Mercedes GP), highlights four components for success in Formula One: "The first thing you need in F1 is a first class engineering team with the appropriate facilities to support them. The quality of the engineering staff, numbering 200 each in design and manufacturing at Mercedes GP, is a key determinant.

"The second is the need for absolutely top-level teamwork. Unless you can get the whole team – both in the engineering and commercial sides – all working in harmony with one aim, you are not going to get very far.

"The third aspect is commercial stability. This requires good shareholders, since like all sports there will be ups and downs, and if you are continuously dealing with the short-term and searching for money, you will have inevitably to make compromises in order to survive.

"And fourth, you need superb drivers. They are not going to drive only for money, however, just as engineers will not only work for money. They need to believe that you have a chance of winning." This may explain why a team like Toyota, who spent freely in Formula One, was never able to attract the very best to its effort.

"All these things are linked," says Fry. "You need the best tools to attract the top engineers, and the best car to attract the top drivers. Thus putting all of this together is very time consuming, and thus its no surprise that all the top teams have been around for a long time. Mercedes had its genesis in BAR-Honda which was built on the rump of the Tyrrell team. Similarly Red Bull was once Jaguar and, before that, Stewart. And Ferrari and McLaren have been around for decades."

With all the increased investment, Fry notes, "the pressure to succeed is very great. No longer can one get away with a small design team around an inspirational designer." Moreover, the pace of change and development is such "that you cannot compare even the cars of 2004 with those of 2011 – the whole sport has moved on massively." In this era, Fry reminds, sponsors have many options, "from the Olympics to football, where they can put their money. Unless you can achieve success, high level long-term partnerships are difficult to establish, and long-term development difficult to instigate."

Tony Southgate has designed a large number of successful racing cars, including Le Mans cars for Jaguar (as pictured below[17]), Nissan, Toyota, Ferrari and the all-conquering Audi R8, along with Formula One cars for BRM, Shadow, Arrows and Osella, with stints at manufacturers such as Lola and Chevron. His career spanned over four decades, having started in the late-1950s as a member of the 750 Motor Club, which had been a training ground for Lola's Eric Broadley and Lotus boss Colin Chapman. He started as a draughtsman at Lola in 1962, working on everything from F1 designs to the Lola T70 sports-car. He then moved to Dan Gurney's All-American Racers, based in California, penning the 1968 Indy 500 winning Eagle chassis for Bobby Unser. And he did not limit his talents to the track, being responsible for the chassis design of Ford RS200 Group B rally-car. His career has spanned the era of crude if light spaceframes, drawing boards and dimly-lit workshops to that of carbon-fibre, seven-post test-rigs, and 24/7 wind-tunnels.

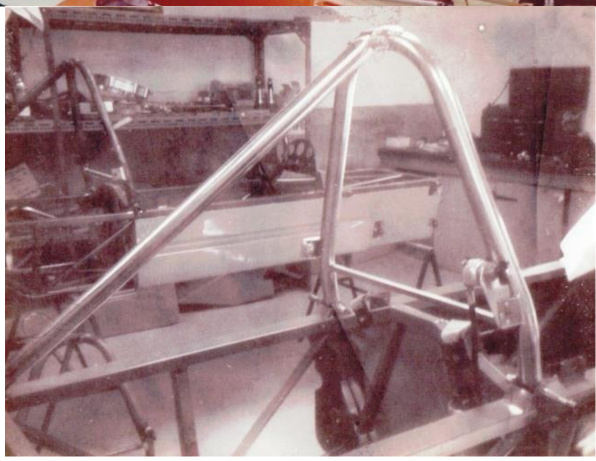
Southgate says that the changes of his more than forty years in full-time motorsport were "enormous". In the early days, in the 1960s, Britain was alive with new race car manufacturing companies and the post-war breed of designers and engineers. Britain was and still is an extremely easy place to design and manufacture race cars, with a wealth of small companies devoted to the production of specialised components and in tune with the requirements of the industry, which is essential for it to work. There is a steady flow of budding new designers and engineering talent from the universities.

"In those days however money was very scarce, and sponsorship almost non-existent" reminds Southgate, 70 in 2010. Designers were required to be very efficient and get value for money. The companies lived off the money made from selling the cars which meant they needed to win! This meant a very tough environment. Compared with today, where the money available and used is phenomenal and the design teams of a F1 car manufacturer comprise as many as 130 designers/engineers, in the '60s you would have had between one and five. Controlling this amount of talent becomes very difficult so top management is needed. I come from the one man band era, where I would design and help build if necessary the whole car, this approach would be impossible today due to the greater complexity of the modern race car. However I know which one I prefer: Even though a lot more money can be made nowadays, the job satisfaction was much greater."

Regardless, according to Southgate, "The qualities required to succeed today in motorsport are just the same as yesterday, except, the competition between the personnel involved is greater. The reason for this is simple, there are a lot more of them now, plus, it is more difficult for the new recruit to shine through. For me I had an overwhelming passion to create cars of my own design and see them race. It had very little to do with money although some was needed to live on. Compare this with the approach of Audi, who I worked for on their Le Mans prototype cars. To Audi it was an engineering exercise, a very good budget, a team of their best engineers and a plan. The passion was smaller but the overall result the same, in spite of two very different approaches."

Unsurprisingly given this environment, motor-racing production companies have come and gone over in droves over the years. Even the most successful ones – March, Lola, Reynard, Royale, Hawke, Chevron, and Ralt among them – have all fallen on difficult times and been taken over, sold or gone into liquidation. It's a difficult business, with continuously increasing demands for capital investment, high research and development costs, and an extremely fickle market-place.

TIGA Racing Cars Ltd was started in January 1976 as a production racing car company, having taken over the assets of Motor Racing Enterprises. Over the next 11 years, it produced nearly 400 cars in a variety of categories, from Le Mans Group C sportscars to entry-level Formula Ford single-seaters. At its peak, it has around 35 employees, and made money every year. Although the two original proprietors (TIm Schenken and Howden GAnley) amicably went their separate ways after six years, and one (Ganley) had to absorb the bulk of design as well as administrative and engineering oversight tasks, its success was built partly on the ability to keep costs down and by the nurturing of design talent, a number of whom went onto prestigious design and management appointments.



The Way Things Were. TIGA at the start:
Left, Bob Earl and Howden Ganley; Right, the factory 'production line'.
(Martin Read)

TIGA was bought in 1987 by people who of course believed they could run the business better than the former drivers who had started it. It lasted two more years. They were not the first to learn that the high-tech motorsport business is one where you are only as good as your last result, where the R&D costs are driven up by the need for continuous (at least annual) major design changes, and where the manufacturing costs increase exponentially in the pursuit of new technologies and manufacturing processes. Whereas TIGA did most things in-house, including the bodywork, much of which was designed 'by eye', even by the mid-1980s there was increasing use of CNC machines and wind-tunnel time in manufacturing and design.

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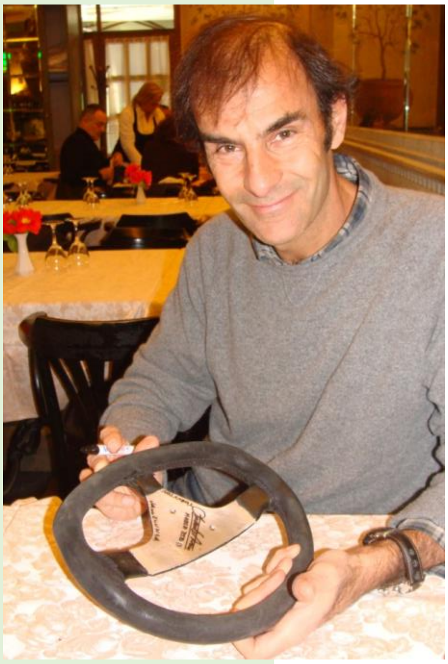
Ferrari has built up a huge store of capital investment and knowledge in the sixty years of its operation. Even so, today Ferrari employees are recruited from around the world, including Australasia, India, North and South America, and South Africa. And the salaries are high: entry level specialists will earn €60,000, department heads at least three times this amount. Compare this to an entry level salary (in real terms) at TIGA in the 1980s of just over €10,000. These skills are in high-demand, and there is no room at the top for second-best.



And this talent is not that easy to find, at least from a driver's perspective. Former F1 driver Emanuele Pirro, left, has won five victories for Audi (2000-02; 2006-07) at the Le Mans 24-hour classic. He says: "In my career I have probably some across more high quality drivers than high quality engineers." The latter skills are today, he argues, at a premium.

"Before data acquisition, the engineers had to have the ability to extract information from the drivers. If you wanted to be a good driver, you had to spend many hours with the engineer to give him the full understanding of the car. He would then put this into a set-up, and the mechanics would change the car. In those days, the engineers went to bed early, and the mechanics late, though the engineer would have to possess the right sort of psychology to get the best out of the drivers. Now," he reflects, "things have changed. The engineers have access to an enormous amount of information – each lap produces a huge amount of information via telemetry, more than any person can conceivably go through at the race track. Thus the engineer is the one now having the late nights, since they have a triangular relationship – between the data, the driver and themselves. But this makes it even more important that the engineer understands the complete concept of the car, rather than possessing the specialised knowledge of the individual mechanics. It also stresses their ability still," Emanuele emphasises, "to get the best out of the driver given the volume or data and pressures of time. The engineer needs to be like a sports-coach, using the right keys to quickly unlock the information from the driver."

*

Some Things Remain the Same

The sportscar legend John Wyer hired John Horsman from Aston Martin in the middle of 1964 to assist with the development of the Ford GT40. Horsman became chief engineer with Ford Advanced Vehicles and, later, a director of JW Automotive Engineering, where he oversaw the build of the Mirage M1 and the Gulf GT40s. He engineered three Le Mans victories (two with GT40s, and one with the Gulf GR8), and the cars he prepared won three sports-car world championships, in 1968, 1970 and 1971. Upon Gulf Oil's sponsorship withdrawal from international sports car racing in late 1975, American entrepreneur Harley Cluxton purchased the Mirage team. Under Horsman's management, from 1974 to 1978, the Mirages never finished outside of the top-ten positions at Le Mans, posting a first, two seconds, a third, a fourth, a fifth, and a tenth.

Howden & Judy Ganley with Len Bailey, designer of the Gulf Mirage, and John Horsman, Team Manager of Gulf Racing, Le Mans 24-Hour, 1973.

Horsman reflects today: "Improvements in machining precision and accuracy have led to greatly improved engine and transmission life, but this was after my time. Similarly, the computer designing of the race cars shape came later, and this I believe has ruined sportscar racing, as the computer decides the optimum shape aerodynamically. Hence every car looks the same, innovation has been killed, and individual ideas eliminated, except in minute details. An army of engineers is now required to run a team, whereas in the past one, or possibly two, would suffice. That engineer would be in charge of the whole car; now each of the many look after only a small area. So I'm not sure real progress has been made by the advent of electronics. Certainly the engines are machinery to be admired for their ability to turn over at previously incredible speeds, producing amazing power from those speeds, but aesthetically the body shapes of all racing cars have diminished in this computer-controlled age, to the point of being downright ugly!"

Regardless, Horsman feels "the qualities to succeed are the same as always, but the competition between individuals has increased due to the number of personnel involved in the sport. The top engineers are now brighter and smarter than in my generation, and that includes myself!" And he adds, to be successful, today as yesterday, "You just have to be first class in everything you do, including verbal communication."

Of course every era looks different. Tim Schenken co-founded TIGA, and was a F1 driver with Brabham, Surtees, Trojan and Lotus. He also drove sportscars for Ferrari and the brutal Broadspeed Jaguar XJC. Today the Director of Racing Operations for the Confederation of Australian Motorsport (CAMS), he reminds "whilst looking back now at how F1 cars in the '70s were designed and teams run, and the money involved looks pretty tame by today's standards, it was the 'state of the art' at the time. In fact, we used to look back at racing in the '50s and thought that was pretty much 'amateur hour'."

The amount of investment in the sport has gone hand-in-hand with the level of detail inherent in car designs. "I think what has changed the most," observes 1987 Le Mans and three-time GP winner Benetton, Lotus, Jaguar and Sauber F1 driver Johnny Herbert (pictured below, right, with one of the co-authors in March 2011), "is the level of specific detail on the cars. They are now perfectly sculptured down to the tiniest part. Whereas twenty years the basics were there, now the amount of money in the sport has allowed focus on the smallest areas in the search for advantage."

Nick Heidfeld, who has driven more than 260 GPs for a variety of top teams including Williams, Sauber, BMW, Jordan, Prost and in 2011, Lotus-Renault, and who has scored no fewer than eight second places (and the highest number of points sans a GP victory by March 2011), agrees in principle with Herbert's observations, though he notes that regulation changes (especially to the increased weight of the cars and the tyres) has made them much easier to drive. Properly regulated technology can be used to bring costs *down*.

Martin Read has worked for virtually every major high-tech motoring concern in his career, starting in F1 in the early 1970s with Ganley Cars Ltd., before moving onto Frank Williams Racing, Theodore, Walter Wolf Racing, Hesketh (on both cars and motorcycles), BS Fabrications, Dallara, McLaren, TWR Jaguar on the Le Mans sportscar projects, Reynard and Panoz, and with Vern Schuppan Ltd for the Porsche 962 CR road-car project. He also had stints at Ford and Daewoo and various contracts in the aerospace field. It is a world, however, that he reflects “has changed beyond all recognition. When he “worked on the Ganley F1, literally it was me and Howden doing everything. I would draw the panel, mark it out, cut it, fold it and rivet it. Even so, it was a very advanced car for its time, with inboard brakes and suspension. Similarly, when I worked at Williams, Patrick Head and I designed a new car in three weeks, the car that later became the first Wolf. Of course we did not take into account aerodynamics that much – we looked at how the shape seemed and if it looked right, it was left as such. Only later did we start going into wind-tunnels, and even then in a rather crude way with tufts of cotton to measure air-flow.”

Fast forward thirty years, and the “motor-racing world had not only caught up to the aerospace industry but in some respects, such as in the development of carbon fibre brakes, overtaken it. As one result, staff ratios have changed. Where you had one or two people, now you have whole departments. And where there was once a mechanic with a box of spanners adjusting things in the pits, they have been replaced by technicians using wifi. Yet,” he adds, “the same skill set which was used in the 1970s is still applicable today.” Martin’s background was with a machine tool company making testing equipment for Rolls Royce turbine blades. “Even in the computer age, you still need a knowledge of engineering to make things work. While CAD-CAM enables you to model parts, you require an old-fashioned 2D drawing to exact tolerances and make parts fit. People are still very important.”

Poacher turned Gamekeeper

Chris Amon, 68 in 2011, is regarded as one of the best F1 drivers never to win a championship Grand Prix, always seemingly driving for the right team – including Ferrari, March, Matra, Ensign, Tecno, BRM, Tyrrell, and his own Amon marque – at the wrong time. His bad luck was such as that Mario Andretti once joke that “if he became an undertaker, people would stop dying”. Though he is measured by many according to his absence of fortune, he did enjoy considerable success, winning the 1966 Le Mans 24-hour with Bruce McLaren in a Ford GT40, eight non-championship GPs, the Silverstone International Trophy, the 1000 km Monza, the Daytona 24-Hours, and the Tasman Series. In his 96 Grands Prix he achieved five pole-positions, leading 183 laps in seven races, reaching the podium 11 times and scoring a total of 83 championship points. Unsurprisingly, perhaps, Amon disagrees with most commentators, the issue of his bad luck, since he survived a decade and a half in the most dangerous Formula 1 era, while many friends had not.

Amon is also regarded as one of the best ever test drivers ever to have sat in a F1 car. Firestone technicians told a tale against themselves when they played a trick on Amon during testing at Goodwood one day in 1966. They made a play of fitting a new set of tyres when in fact they had shuffled the wheels about and re-fitted those they had taken off. As the McLaren rumbled down the deserted pitlane, the technicians suddenly realised the enormity of what they had done. They could have permanently compromised Amon’s career if he came in to give different information. They agonised until he came in again, and sat there puzzled, silent. Then he said: “I don’t know how to say this, but those tyres felt exactly the same as the ones you just took off.”

In the early 1990s, Amon was contracted to Toyota to test and improve their road cars having earlier inferred that Toyota New Zealand’s cars handled so badly they should be issued with a government health warning. Amon says: “We were testing a mixed bag of European and Japanese cars and I was very critical, with justification, I think, of the handling of Japanese cars. Toyota suggested I put my money where my mouth was and advise them on development.”[18]

Amon feels that the most notable changes to the engineering side of the sport during his time “including aerodynamics” was “in tyres”. During his fourteen years in F1, “we went from very narrow, treaded tyres to wide slicks – which enabled aerodynamic improvements given the greater contact patch with the road. Over my time in the sport, the advances in engine technology were not that great: I started in 1.5 litre cars making 180bhp on a good day, terrible cars really. By the time I left F1 [in 1976], we had little more than doubled the horsepower and doubled the capacity. Since then, improvements to metallurgy, which have reduced reciprocating masses, and ignition have enabled even 1970s engine to substantially increase their output. In my day it was still ‘mechanical everything’.”

In 1971, after a year in with March which had produced a customer car with very little development potential, Chris moved to Matra, a car built by the French aerospace concern. Yet, in terms of aerodynamics, “there was no advantage really. This side of things was still far from appreciated. What they did do, however, was to bring Matra’s construction methods into the sport, particularly in chassis production, which were far more advanced than say Ferrari,” the latter which was built in a sort of “controlled chaos”.

Chris Amon in the Matra V12, 1971 South African GP. (David Pearson)

After driving for Ferrari, March, Matra and Tecno, Amon went it alone for 1974, building an eponymous car penned by Gordon Fowell, “a sort of mad genius”, who had made a career from designing in toasters, kettles and forklift trucks. The car, pictured below, was advanced for its time, with titanium torsion bar rising-rate suspension (which essentially kept the car level as the fuel load lessened), a side- rather than centrally-mounted rear wing, side radiators, and a single fuel-tank between the engine and driver, all of which were later copied by other teams and became F1 *de rigeur*.

The innovative if unsuccessful 1974 Amon F1 car.

The Amon team eventually perished as a result of not having enough money "unfortunately coinciding the effort with the first major oil shock" and because of elementary reliability problems. The design, "while individually very advanced, was let down by some of the basics, like wheel bearings, which caused me to lose a front wheel at my first test at Goodwood, and a rear wheel at the second at Silverstone, and driveshaft breakages." Much of the design was down to innovative guesswork, the team being just six people, "very small and very backyard" even by the standards of the day. "Fowell had a friend who was an aerodynamicist, yet the car was built without a wind-tunnel in sight. Rather like fluid-dynamics' modelling today, the theory is fine, but it needs to be tested in practice."

Success with his own F1 car required "the structure of a team and the checks and balances that it offered, and a decent budget" to be successful reflects Amon. Though this is what most F1 teams have today, there is, he argues, much less scope for technological innovation, apart from in aerodynamics. "I find contemporary F1 a real mixed bag. There is a lot of high-tech stuff which I don't fully understand. Yet, in other areas, such as in engines, they are totally dumbing it down. The KERS [Kinetic Energy Recovery System] for example, offers less recovery horsepower to a F1 car than the Lexus I have in my garage. No longer do they make the best tyre, but they make the most entertaining one. Regulation has ground technology to a halt apart from in aerodynamics. Now they want to go to 1.6-litre, four-cylinder turbocharged engines which will sound like constipated vacuum cleaners."

But, he adds, the success of designers such as Adrian Newey at Williams, McLaren and today Red Bull, shows that there is still room "for individual brilliance to make a difference, even in the high-tech world of Formula One."

Some More Answers

Answers to these dilemmas lie, in part, in recalibrating the expectations of consumers and producers in terms of their living standards and benefits. There is a link here, too, with the constant need for competitiveness, innovation and design, and thus with education – especially the way in which technical skills are championed.

In Germany, for example, students are split between those university-bound and those headed for trades. Unlike Britain, the latter are given specific education for their future occupation, rather than simply not going to college. By the last two years of high-school, German students on a technical rather than academic path are already part-time apprentices in companies, in combination with their formal schooling, not unlike the system Tony Rudd enjoyed. By the time they graduate from high-school, they are typically highly productive and employed. In following this 'blue-collar' choice, neither stigma nor lower income awaits them – unlike in some societies.

Harvard University's former president Derek Bok famously said that "If you think education is expensive, try ignorance."[19] He is dead right, though proper education is not necessarily that from Ivy League or Oxbridge schools. It is about gaining practical as well as theoretical knowledge, about gaining experience. While digitisation may have changed what we learn and how we learn it, and shortened personal patience horizons, the period required to gain ten years of experience remains roughly ten years. Managing these expectations – and the salaries and consumer goods that go with it – is fundamentally a political task, and an unpopular one to boot.

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Adam Smith's golden rule of economics is that transactions will take place if both sides mutually benefit. Put differently, it is about price and technology competitiveness – for the manufacturer, this requires being able to supply something the market cheaper than their competitors.

For countries starting on a development path, catch-up growth depends on elements of social and political stability – essentially, peace – plus the factors of labour and capital. If you are poor, small adjustments make growth possible and easy.

For the masses living in abject poverty absent even basic skills , sweatshops are likely an – and possibly *the* only – attractive option for industrial development, diversification away from natural resource production and agriculture subsistence, and formal jobs. This requires, of course, rich countries willing to accept such goods, likely undercutting their own industries, and accepting that the labour of poor people is behind such products. And it requires the producers being willing to be flexible, fundamentally, about wages, in the expectation that as employment increases, wages will increase to (more politically acceptable) higher levels. Countries cannot get rich without exporting goods, and widespread sustainable employment is unlikely with only a commodity base to live off.

But the next stage, of going from a low- to middle-income country is more difficult. While there is no fixed model for growth, some elements are not negotiable. The bulk of Chinese growth, for example, during the 2000s, was down to Total Factor Productivity,[20] neither capital nor labour, but improvements to the quality of institutions, governance and management. This not only requires a higher level of efficiency in government, imposition of the rule of law, the safeguarding of land rights, the ending of monopolies, and the (de)regulation of labour and credit markets, but the creation of the environment to spur an innovative and transformational culture. Here technical progress should not be confused with innovation. The former is taken for granted, and includes progress in elementary sectors such as power, telecommunications, roads, transportation, rural development, and sewage. Innovation also demands the promotion of excellence in higher education, a focus on R&D, and trust and confidence in the institutions and policies of government, including predictability and transparency. This requires open competitiveness to outside influences, ideas, technology, skills and capital. It involves a shift in power from companies and the state to consumers. Intrinsically, growth success and its sustainability is really about good politics.

And if the world of F1 and motorsport is anything to go by, the option of creating a high-tech, high-wage industry is out of this world – at least for a generation. Building the necessary design and manufacturing expertise is, as Nick Fry reminds, "a generational endeavour". Romantic notions of dirt-floor to space-age or from dusty township classrooms to designing F1 cars, should not be discounted altogether, for ambition is an important element to realising any vision. But there are stark realities that have to be faced up to in order to succeed in this world: The need to attract and accept the best and brightest skills from world-wide; a feeder system of high-technology education establishments and industry which, in turn, are dependent on the correct long-term incentives to be somewhere rather than somewhere else; and a realisation that being competitive is not a national but rather a global struggle. Act on these realties rather than rail against them, and it is possible to envisage jumping a few steps in the development ladder.

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[1] This article is based on a series of interviews conducted with Eddie Keizan in Johannesburg in 2008 and 2011; Ken Howes in Charlotte and Las Vegas in June 2010 and March 2011 respectively; Rory Byrne in Maranello in October 2010; Emanuele Pirro in Rome in December 2010; Wayne Taylor in Orlando in March 2011; and Johnny Herbert, Balbir Singh, Nick Fry and Nick Heidfeld in Australia in March 2011. Interviews with Gordon Murray (October 2010); David Richards (December 2010); John Horsman (February 2011); and Martin Read, Tim Schenken, Chris Amon, Peter Bailey, John Watson and Tony Southgate (March 2011) were done by email and/or telephonically.

[2] See, for example, Eoin Young's *McLaren Memories: A Biography of Bruce McLaren*. Somerset: Haynes, 2005.

[3] From http://www.bruce-mclaren.com/the-cars/canam.html.

[4] 8 Constructor's Championships: 1974, 1984, 1985, 1988, 1989, 1990, 1991, 1998; 12 Driver's Championships: 1974, 1976, 1984, 1985, 1986, 1988, 1989, 1990, 1991, 1998, 1999, 2008.

[5] McLaren won the Can-Am title in 1967 and 1969, then team-mate Denny Hulme in 1968 and 1970, and Hulme's team-mate American Peter Revson took the title in 1971 after Bruce's death in a testing accident at Goodwood on 2 June 1970.

[6] 1972 with Mark Donohue; 1974 and 1976 with Johnny Rutherford. Donohue and Revson were both later killed in F1 cars, the latter in a Shadow testing at Kyalami in March 1974, the former in practice for the Austrian GP in a Penske-run March in August 1975.

[7] Brad Spurgeon, 'TAG McLaren Group Revs Up Off Track', *International Herald Tribune*, 24 June 2000.

[8] At http://www.cosatu.org.za/show.php?include=docs/sp/2010/sp0513.html&ID=3318&cat=COSATU%20Today.

[9] At http://www.fin24.com/Economy/Treasury-urges-embrace-of-globilisation-20100930.

[10] At http://m.news24.com/fin24/Economy/Cosatu-charters-new-growth-path-for-economy-20100914. See also Zwelinzima Vavi's address to the SACTWU National Congress, Cape Town, 23 September 2010, at http://www.cosatu.org.za/show.php?include=docs/sp/2010/sp0923.html&ID=4006&cat=COSATU%20Today.

[11] Cited in *Motor Sport*, 87, 4, April 2011, p.29.

[12] Tony Rudd, *It Was Fun! My Fifty Years of High Performance*. London: Motorbooks International, 1993.

[13] Interview, Andrew Duncan, Maxperenco Engineering, Didcot, September 2006.

[14] Norbert Sparrow, 'R&D Funding: Mind the Gap', at http://www.emdt.co.uk/article/rd-funding-mind-gap.

[15] At http://news.bbc.co.uk/2/hi/business/8579884.stm.

[16] In 1995 Subaru/Prodrive won both the Drivers' and Manufacturers' World Rally titles. The partnership went on to win two further Manufacturers' titles in 1996 and 1997, and Drivers' titles with Richard Burns in 2001 and Petter Solberg in 2003.

[17] At http://archive.dailysportscar.com/free/tour/history.htm.

[18] Eoin Young, *Autocar & Motor*, 1 January 1992.

[19] At http://thinkexist.com/quotation/if_you_think_education_is_expensive-try/188916.html.

[20] This is partly drawn from the presentation on 'Uprising: Will Emerging Markets Shape or Shake the World Economy?' by George Magnus at the *Bankinvest Emerging Markets Investor Conference*, Hotel D'Angleterre, Copenhagen, 10 March 2011.