proActive

The official industry newsletter of Lotus Engineering

Issue 10
September/October 2005

Vehicle architecture

The ultimate road-track car

Welcome

It's true to say that decisions on Vehicle Architecture, often made at the outset of a vehicle programme, can have a profound effect on a vehicle projects' risk and profitability. This realisation, coupled with the need to reduce economic volumes of production, can add increasing pressure to large OEMs. This leads to the further exploration of alternative methods of vehicle construction and a possible move away from the ubiquitous steel monocoque.

Our experience for vehicles at volumes up to around 10,000 p.a. is that a wide range of vehicle architecture and technologies could apply. Each one will have its own downstream implications for cost, quality, manufacturing and timing.

This issue of proActive looks at vehicle architecture and explores these points as well as typical approaches to the problem. I hope you will find it a useful comparison to your own organisation.

In addition we are also featuring a master class session with Matt Becker where he looks at the problems associated with the loss of tyre adhesion.

I hope you enjoy this issue.

Daryl Greig – Vehicle Architect, Lotus Engineering

Group Lotus PLC is named "World Class Manufacturer" of the year 2005

The Manufacturer Magazine ranks Group Lotus as No. 1

"It is a real testament to our staff who have worked relentlessly to raise the standards of manufacturing, and we are committed to continually looking at ways to improve in the future to ensure we remain a 'World Class' Manufacturer."

Clive Dopson, Managing Director of Lotus Cars

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USA: Fuel cell specialist wields jobs axe

Fuel cell specialist Ballard Power Systems on Thursday (22nd September) said it had cut 100 jobs and was reducing discretionary spending in an attempt to stretch available cash.

The Associated Press (AP) said the cuts eliminated full-time positions at Ballard's plants in Vancouver, Lowell, Massachusetts, and Dearborn, Michigan and left the company with about 600 employees. Ballard said it achieved about half the reduction through normal attrition and the elimination of open positions.

The belt-tightening should reduce annual operating expenses by about 12%, Ballard reportedly said. The company will record a third-quarter charge of $2 million related to the labour cuts.

AP said the company said these expense reductions are in addition to savings it expects to realise from the recently completed sale of its fuel cell support systems business to DaimlerChrysler and Ford. Both automakers own sizable stakes in Ballard.

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The news agency said that, during the second quarter ended in June, the company burned through about $28.7 million in cash, up from $22.5 million in the year-ago period. Ballard ended the quarter with $231.3 million in cash and easily convertible assets, down from $240.3 million in December.

According to the report, Ballard's annual loss has grown from $96.2 million in 2001 to $175.4 million in 2004 as the company continues to pump funds into new technology. Yet, uptake has been slow as many automakers have opted to focus their investment on petrol-electric hybrids in the near term.

Source: just-auto.com editorial team

JAPAN: Nissan Motor to consolidate production engineering at home

Nissan Motor on Monday (26th September) said it would build a 5.1 billion yen facility near Tokyo to consolidate its global production engineering function in one place.

Construction on the 30,000-square-metre facility in Zama, Kanagawa Prefecture, will begin in October, with operations expected to start in March 2007, the automaker told Kyodo News.

Currently, Nissan's assembly plants around the world conduct their own trial production and quality analysis.

"The new global production engineering centre will focus on drastically improving the quality of new vehicles through the concentrated trial production and quality analysis of new vehicles in all stages of production, from press shop to trim and chassis," Sadao Sekiyama, a senior Nissan vice president for vehicle engineering production, told the news agency.

"This should further enhance vehicle quality levels at Nissan's plants in Japan and overseas."

Source: just-auto.com editorial team

USA: Chrysler planning SUV product offensive despite petrol prices

Chrysler Group is making a big bet on sport-utility vehicles at a time when rising petrol prices have focused attention on fuel efficiency, the Wall Street Journal reported on Monday, according to Reuters.

The newspaper reportedly said Chrysler is preparing five all-new SUVs for launch over the next few years as part of a product offensive that will also include a two-door Challenger sports coupe to compete with Ford's Mustang, according to dealers and consultants briefed on the company's plans.

The new SUVs mostly fall in the small and mid-size categories that have continued to sell well despite rising petrol prices that have hurt demand for larger SUVs, the Journal reportedly said.

According to Reuters, it said DaimlerChrysler's supervisory board is set to see a presentation of some or all of the SUVs and a half dozen or so redesigns of existing Chrysler Group models at a dinner meeting on Tuesday night at the US unit's design centre in Auburn Hills, Michigan though the plan is still subject to change.

Source: just-auto.com editorial team

USA: Car makers call for government energy summit

Ford, Toyota and other automakers say they want the Bush administration to take more aggressive action to cut US dependence on petroleum, the Wall Street Journal reported on Monday (26th September), according to Reuters.

As Hurricane Rita bore down last week on US Gulf Coast oil refineries, Ford chairman and chief executive William Clay Ford Jr. sent a letter to president George Bush asking for an energy summit involving automakers, suppliers, fuel providers, consumers and government officials, the newspaper reportedly said.

According to Reuters, it quoted Ford as saying a summit would focus on what the auto industry can do to find solutions for alternative fuel resources and that the recently signed $17 billion energy bill *"is only the beginning."*

Separately, the Journal reported that Jim Press, head of Toyota's US operations, said he planned to go to Washington next month to lobby lawmakers to make energy independence an issue in the election campaign of 2008.

"We recognise the responsibility we have to come up with a solution to this economic problem," Press was quoted as saying, according to Reuters. *"As an industry, we should leave our individual companies' bags outside the door to work together on this issue."*

As oil prices rise is hydrogen the solution?

Potentially troubled times for William Clay Ford Jr

General Motors' Washington spokesman, Chris Preuss, reportedly told the newspaper GM welcomes calls by other automakers for more action on energy independence.

"We believe the US needs to begin aggressive energy policy moves away from petroleum toward hydrogen," Preuss was quoted as saying. *"We should diversify our energy stocks away from foreign sources."*

> *"We recognise the responsibility we have to come up with a solution to this economic problem"*

According to Reuters, the newspaper said Ford's call for an energy summit is another sign that the recent run-up in oil prices, and the post-Hurricane Katrina price spike that sent petrol prices above $3 a gallon, are forcing a rethink of energy strategy, particularly at GM and Ford.

The news agency noted that the big Detroit car makers have long resisted proposals to increase government fuel-economy mandates for sport utility vehicles, pickup trucks and other light trucks, arguing that consumers would not want lighter, smaller, less powerful vehicles.

Source: just-auto.com editorial team

The ultimate road–track car

What if you took an Exige S2 straight from the showroom and put it on the race track? How would it perform? Lotus enthusiast Rupert Laslett did just that.

My friends call me a petrol-head, which is a good description as I am mad about cars, especially sports cars. I blame this obsession on my father who in the late 60s worked as an aspiring engineer, for JW Racing (JW ran the Ford GT40 racing cars in the World Sports Car series). When I was only 3 years old, my father sat me in the 1970 Le Mans winning GT40. Well that was the start of my love for sports cars and motor racing. I have always wanted to own a real sports car, a car capable of true race track performance and handling with super car looks and, most of all, fun to drive.

> "the car would require a roll cage to be fitted as well as a fire extinguisher, an electrical kill switch and a seat harness"

I ordered a black Lotus Exige S2 with the optional Performance Pack just before Christmas 2004. Delivery was promised for late January/early February 2005. I couldn't wait. Over the Christmas and New Year period, my friends convinced me to race the Lotus. This was no hardship as I love motor racing and actively participate in it when money and time allow. I have raced all kinds of motorbikes and cars on and off over the last 15 years.

The team

My friends are local guys who all have the same enthusiasm for cars and motor sport as I do. For us racing is a hobby and every Tuesday evening we meet at the workshop to play cars. I say workshop but it is actually two sea containers that we have welded together. This all started as a small project a year ago when we did some racing in an old Ford Fiesta. We had done this with the help of a local professional team. So one Tuesday night in January we decided to race the 'yet to be delivered and I expect yet to be built' Lotus Exige. So the team Rapid Chariots was born.

Preparation

So what did we know about the Lotus Exige? Well apart from what we had read in the Lotus brochure, the usual magazine reviews and one TV episode of Top Gear, not much. So where do you start?

We knew that in order to race the car, it had to comply with the minimum safety standards as defined in the 'blue book' (MSA rule book). This meant that, the car would require a roll cage to be fitted as well as a fire extinguisher, an electrical kill switch and a seat harness. The Internet proved to be a great source of information, as did those friendly people at Lotus Sport. It soon became apparent that, because the car was so new, there were very few aftermarket motorsport parts available.

I took delivery of the car 5 days later and completed 1200 miles by driving the car up and down the motorway in my lunch hour and the car went back to the dealer for its first service. Time was running out; the first race was just weeks away on April 16th and our next priority was to fit the roll cage.

Ready to race complete with roll cage

Lotus supply a purpose-built FIA approved roll cage. Although there are many specialist companies who will build a custom cage, they are more expensive and time was running out. The Lotus cage arrived complete with detailed fitting instructions and the team had no problems installing it over two evenings.

If you order the optional Performance Pack, as I did, which includes four-point harness belts, these are already FIA approved and perfectly adequate for racing. The only change you must

The team Rapid Chariots' Exige takes to the Brands Hatch Indy track, Laslett at the wheel.

'The driver fits in here somewhere'. Preparation work at the team's sea-container workshop.

make is to bolt the harness to the car chassis and not the seat. Next we installed the electrical kill switch and fire extinguisher. Other considerations are the fitting of tow eyes, which must be clearly marked. We finished fitting all the safety equipment the night before the practice day for the first race.

We had all been working so hard to get the car ready that I had not remembered to organise a trailer to take the car to the circuit. No problem, the car was taxed and fitted with number plates so I drove it to the circuit but there were still other challenges ahead — I was concerned that the standard brake pads may not be able to cope with the demands of racing.

The race — Brands Hatch (Indy)

We arrived at Brands Hatch for the practice day. The weather was sunny and dry: perfect conditions for testing. After the first session the car had more body roll than we would have liked, although this was not surprising as we where still running on the standard suspension units. The normal method to correct this would be to harden the springs and anti-roll bars, neither of which was an option. So we removed the shims from inside the suspension uprights and this had the effect of increasing the negative camber at the wheels. By doing this we hoped to neutralise some of the body-roll effect. With the weather forecast for race day being sunny and dry, we also decided to fit slick tyres and some cooling ducts on the front brakes.

On race day I took the car out for qualifying and the changes we had made had transformed the handling of the car. The overall grip levels had improved immensely, enabling me to lap 2 seconds faster. We qualified on the back of the grid, although this was not surprising as we were punching well above our weight in a class full of Porsche GT3s, Ferrari 360s and BMW M3s. Our goal was to finish the race.

A big thumbs up; the Lotus performed faultlessly.

During the race the Lotus ran faultlessly and never missed a beat with the brakes performing well. We finished 12th overall out of 24 — and very happy. We had taken a standard Lotus Exige, fitted the required safety equipment and completed a 2-hour endurance race at Brands Hatch against professionally prepared race cars.

We were all very impressed with our little Lotus and enjoyed the racing so much that we are keen to do more.

Rupert Laslett, Lotus Club International member, UK

Article first published in Lotus Club International Magazine

Cruising without bruising

I was very much aware of my jaw dropping when I first clapped eyes on my new 'toy', but try as I might, I just couldn't close the gap. I was also aware that Gavin, the sales executive at Murray Motors in Edinburgh, Scotland was going through the delivery check-list but, despite my best intentions, I just couldn't pay enough attention to what he was saying. This was even better than the Christmas in 1983 when I woke to find that I was the owner of the best BMX bike in the whole village!

My new Lotus Exige S2 looked that good.

I instantly fell in love with its every minute detail, but what topped it for me was the raw driver's appeal of this road legal race car. It got me thinking though… would our relationship survive an 18-hour continent-busting road trip?

You see, I work in Bosnia-Herzegovina at the moment and my plans were to take the car over for the summer.

Would I tire of that bark from the Stage 2 exhaust?

Would my insides turn to jelly after being rattled incessantly by that firm suspension set-up? Would my slipped discs protrude that bit further into my spinal canal due to the tightly fitting sports seats? And most worryingly of all, would my patience be tested by the reliability problems sometimes associated with hand-built sports car ownership?

Who knows? Who cares? My mind was made up and the Lotus was going on its hols!

First things first, this car draws attention. All the way down from Edinburgh to the Channel Tunnel, car passengers were craning their necks to get a proper look at what had just streaked past them. I'm not a lip-reader, but I can now clearly understand the movements for *"What the hell was that?"*.

And it didn't stop there. On board the train, a 911 owner made his way down the carriageway to lavish praise on the Exige. I recall him saying, *"I've always wanted one, but it's too full-on for me"*. That was probably the greatest compliment any car of mine has ever received (and the fact that it came from a 911 owner made it all the sweeter!).

I was surprised at how comfortable the car was when cruising along at speed on the autobahns. The noise was perfectly bearable and the ride quality was firm but certainly not harsh. All the right boxes were ticked so far, but when was it all going to come unstuck?

It never did.

And so on to Croatia, and then into Bosnia-Herzegovina itself. The roads in the region are far improved from the years gone by

Absolutely stunning… and the scenery isn't bad either. Scott Higgins' Exige in Bosnia-Herzegovina.

and they are rarely straight for more than a kilometre — this is prime Exige territory and a grin was never far from my face.

I've since enjoyed a few trips down to the Croatian coast and the car goes, stops and turns just as I hoped it would. I'm an ex-biker and after a number of years I still hanker after that two-wheel-rocket adrenaline rush, but the Exige comes oh-so-very close and to my mind that's a remarkable achievement for a road car.

So, all in all, the Lotus was an absolute joy to drive across Europe. My epic journey was much more pleasant than what I had anticipated and, what's more, the Exige didn't squeak, rattle or have one single tantrum.

I've owned Lotus products before and, even though I've always been very satisfied with them, I felt that this car, more than any other, demonstrated a significant step forward for Lotus in terms of build quality.

If nothing else, my experience has proven that this particular car can be 'full-on' when you want it to be, but a pussycat for those (very few) days when you just want to glide along. That'll be two thumbs up from me then!

Scott Higgins, Lotus Club International member

Article first published in Lotus Club International Magazine

Fuel economy proposals for the US: business as usual?

Given the recent hysteria in the United States caused by fuel prices surging towards $3 a gallon, the first overhaul of fuel economy standards in three decades might have been expected to cause a considerable stir. However, the proposed new rules, which were recently issued by the National Highway Traffic Safety Administration, have raised barely a whisper of interest outside the usual environmental groups, writes David Robertson.

The reason for this appears to be that the new fuel economy measures will not really make much difference at the petrol pump – or the dealer forecourt. Even the Bush Administration admits that the new rules will save only 10 billion gallons of gas over four years, compared with 11 billion gallons consumed per month at present.

What the new fuel economy rules will do, however, is allow Detroit's big three auto manufacturers to compete more effectively with the likes of Toyota, Honda and Nissan. Industry commentators have questioned whether the new fuel economy rules are, in fact, backdoor protectionism rather than a serious effort to alter America's gas-guzzling culture.

The 1970s oil embargo by OPEC prompted the first set of fuel economy standards in the US. Called the Corporate Average Fuel Economy Program (CAFE) the rules were designed to encourage automakers to wring more miles from each gallon of petrol consumed.

Fuel economy measures would involve major changes

Environmentalists have long complained that the difference in fuel economy requirements for light trucks and cars is one reason that automakers have marketed their larger vehicles so heavily. (In 1975, 80 per cent of the autos sold were cars but today more than half are light trucks.)

Under the National Highway Traffic Safety Administration's new proposals, light trucks will have to reach a fuel economy of about 24 miles per gallon by 2011 (cars will stay the same).

But the Administration is complicating the system by splitting the light trucks category into six subcategories, each with different fuel economy requirements.

So, for example, a small SUV like the Honda CRV will have a fuel-economy requirement of 28.4mpg. A small pickup like the Ford Ranger will need to hit 27.1mpg. But at the other end of the size-scale, a Chevrolet Suburban will only need to get 21.9mpg and the Dodge Ram, 21.3mpg.

Light trucks weighing more than 8,500lbs like the Hummer H2, which gets 9-12mpg, will be completely exempt from the fuel economy requirements because they are classified as commercial vehicles.

Not surprisingly, environmentalists are unhappy with these proposals – and particularly the exemption, or low requirements, for huge SUVs. After all, they argue, SUVs and light trucks account for 40 per cent of all the oil consumed in the US and produce more than 20 per cent of the country's total carbon dioxide emissions.

"These proposals really do not go far," said Don MacKenzie, a vehicles engineer at the Union of Concerned Scientists. *"Not even close."*

The US Department of Transport will spend the next three months consulting on these proposals and it will issue its final recommendations next April. The new rules will then be phased in from 2008.

When the first CAFE rules were introduced in 1975, automakers responded by reducing the weight of many models. There have been sporadic bursts of publicity ever since about the safety hazards of doing this with some research claiming fuel-economy regulations have cost more 1,000 lives a year.

As a result, the new requirements will prevent automakers from reducing weight to gain fuel economy. Instead, each of the six new light truck classifications will be determined by the vehicles *"footprint"* – established by multiplying the length of the vehicle's wheelbase by the tyre track width.

The US Government is hoping that this will force fuel economy improvements in the engine, or encourage the introduction of more hybrid electric systems, or encourage more efficient transmissions.

However, these new rules may also encourage auto makers to upsize their products: if a small change in a vehicle's dimensions will allow it to slip into a lower fuel economy category this might be an easier solution than tinkering with its engine or transmission. For example, an extra inch on the Ford Sport Trac would cut its fuel-economy requirement to 23.3mpg from 24.5mpg.

Given that these new proposals will save just a month's worth of gas over four years, and that there are numerous loopholes that could encourage even bigger vehicle design, why has the US Government bothered rejigging CAFE?

The answer lies in Detroit, where the Big Three: General Motors, Ford and Chrysler, have been struggling.

The Japanese-owned manufacturers have historically not moved into the light truck category in a big way, offering only smaller pickups, minivans and smaller SUVs. This has left the profitable heavy pickup/SUV market to GM, Ford and Chrysler – but this is changing.

Toyota, for example, is building a factory in San Antonio, Texas, to increase production of its heavy pickup, the Tundra. And because the Japanese manufacturers have historically produced smaller vehicles with better fuel efficiency, they have easily hit the light truck CAFE requirement and built up a large number of *"CAFE credits"*.

An automaker can use these credits to offset against future increases in fuel economy requirements.

Detroit is worried that the Japanese manufacturers will move into the lucrative heavy pickup/SUV market using these credits to offer big horsepower vehicles at a time when the US-owned manufacturers are cutting horsepower and engine size in order to meet tougher fuel economy requirements.

By splitting the light truck category into six subcategories the heavy pickups and SUVs built by GM, Ford and Chyrsler will only have to reach a fuel economy of 21 or 22mpg rather than 24mpg. Also, the Japanese-owned manufacturers will no longer get so many extra credits because their lightweight trucks will be competing against higher mpg targets.

Hummer H2: A commercial vehicle, not a light truck

Charles Preuss, a spokesman for General Motors, explained: *"If you sell a substantial number of vehicles in the 16mpg range, and that's where the bulk of our heavy pickups are, that is going to heavily weigh on your CAFE number. Six new categories means a vehicle only has to hit the average for its subcategory, not the whole sector. We are being penalised because we have been supplying the market for many years and haven't built up these credits. That's a threat to us and it's a job threat to the US. We are not limiting anybody's ability to compete in this market; we simply want a level playing field."*

Some commentators believe these new CAFE proposals could be considered protectionist as they remove a competitive advantage that Toyota, Nissan and Honda have been building up, in credit form, for many years.

"The Administration is clearly addressing the concerns of the US-owned manufacturers with these new proposals but unfortunately they haven't done anything for consumers," said Don MacKenzie.

All this effort to rewrite the fuel-economy rules in favour of Detroit might, however, be undone by the State of California.

Three years ago California passed legislation that demanded auto manufacturers cut emissions that contribute to the greenhouse effect. This effectively means that automakers will have to reach a combined fuel economy for cars and trucks of 33mpg by 2016.

Seven other states in the North-East USA as well as Washington and Oregon plan to follow California's lead.

If they do, it would force GM, Ford and the others to improve fuel economy regardless of what the Federal mandates are.

The automakers are challenging California's right to impose emission requirements and they got some help from the National Highway Traffic Safety Administration, which added, at the end of its 150-page report on the proposed new fuel-economy requirements, a section attacking state-by-state limits. This Federal support may help the auto industry overturn California's law.

Of course, the new Federal fuel-economy rules and even California's tougher standards might become unnecessary if gas prices continue to rise. As consumer awareness increases so does the marketplace pressure on manufacturers to start adding fuel economy measures as standard.

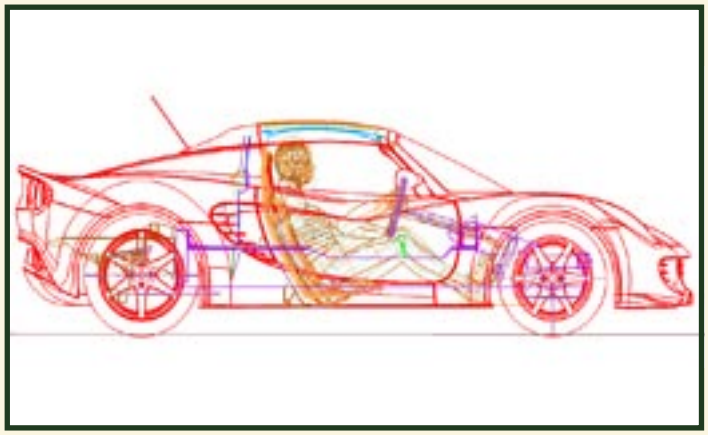
"More will happen if there is a significant shift in fuel price than any government can dole out," admitted General Motors spokesman Charles Preuss. *"If consumers want more fuel efficiency our very survival will be predicated on providing that option."*

As often happens, Government regulation may yet be overtaken by consumer demand.

Source: just-auto.com editorial team

Vehicle architecture

Defining the concept and basic layout of a vehicle is the usual starting point for decision making on vehicle architecture and body construction. The decisions involved are amongst the toughest to make in the automotive industry. The outcome not only defines the product but can have a bearing on brand and company position in the market place. In addition, there could be risks involved that could affect the profitability of the project and the company. Even in a small company, the decisions can be difficult and often controversial as the various options are compared.



Elise package

The growth in niche vehicle volumes has resulted in increasing interest from larger OEMs in technologies that offer economically viable options for lower volumes, particularly those up to 10-15,000 p.a. This makes the question of the best way to realise lower volume cars relevant even to higher volume producers.

In general, the established OEMs attempt to use the same technology for lower volume cars as they do for their mainstream ones. This can have advantages for product quality and technical risk, but may be more expensive in unit amortisation, and potentially lead to a compromised product. The alternative, is to use less expensive tooling technologies and manage the risks of new technology development to suit quality levels required in today's auto retail market.

One option used to reduce the cost of lower volume production is to subcontract the manufacture of the vehicle to a smaller division, or even outside the group altogether. Examples are the Porsche Boxster in Finland, the Audi TT in Hungary and the numerous transplant ventures for new factories to locally produce established products.

In addition to outsourced manufacturing, product design and development may also be subcontracted. This can have a beneficial effect on costs and time to market since smaller companies can sometimes achieve such projects with greater efficiency.

Examples of subcontracted niche vehicles are abundant. Two such projects at Lotus are the Opel Speedster / Vauxhall VX220 and the Lotus Carlton. Both were developed and produced by Lotus for General Motors.

Methods employed by smaller companies vary, but one thing they have in common is their use of their smaller size to react flexibly and quickly to problems as they arise. They are also able to mobilise their smaller teams quickly and use their experience to manage areas of high risk.

The Lotus project management roadmap shows how early simultaneous engineering is used to launch the vehicle programme aggressively from the start.

The range of viable, low volume vehicle architectures and design is increasing, as materials and tooling technologies broaden their reach to lower volume manufacturing facilities, and as the price of steel – the traditional high-volume favourite – continues its rise. Also, the greater number and improving quality of composites application technologies means more options on material selection for the vehicle engineer.

For example, composites can improve crush space efficiency, reduce weight and reduce parts count through integration. These factors can allow the vehicle engineer to respond differently to the demands of safety, weight distribution and ease of assembly.

VX220

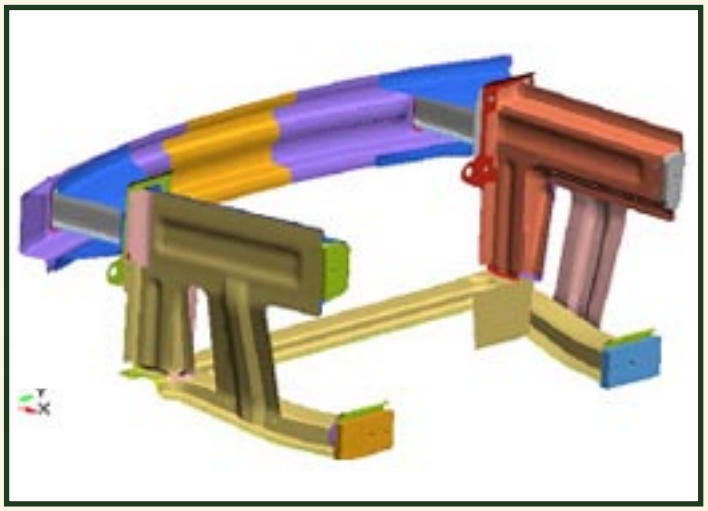
So how is the decision made on the ideal solution for vehicle architecture? Normally, a range of possibilities is narrowed to two or three options, with a single recommendation to senior management. Some companies prefer to run parallel studies for a prolonged period before making a decision. This is good for making an informed decision, but can be costly, as one of the studies must eventually be dropped. The option of making an early decision is good for cost, but risks dropping the best route for factors not yet clear in the early stages of the project.

Attempts have been made to automate the vehicle architecture decision process using computer software applications. The advantages are clear, in that sensitivities can be studied and consistency can be guaranteed. However, the possibility to automate such a complex problem clearly depends on how well the problem is defined in the first place. An analogy could be a decision on a medical condition. Consistency is good, but the consequences of a wrong decision can be serious.

What constitutes a viable option? What happens if you conclude that the best way forward is with an unproven but promising new technology? The assessment of this risk is company specific. Smaller manufacturers tend to take higher risks with technology, as they have the flexibility to deal with problems as they arise. Larger OEMs tend to have more inertia and can find risks more expensive to manage. In addition, their products are made at higher volumes and by definition will have broad appeal. They will tend to be more risk averse in both their products and their technologies.

Versatile Vehicle Architecture

We use new technologies, particulary in our own products, to promote innovation and performance outside of normal envelopes



Ecolite Front End Structure

Lotus is no stranger to the risk of new technology in vehicle programmes. We use new technologies, particularly in our own products, to promote innovation and performance outside of normal envelopes.

On the Elise, for example, bonded aluminium, metal matrix brakes, composite crash structures and an integrated aluminium dash structure are all features that would be unlikely to be included in a mainstream high volume car. By using these technologies and working with them in small series production, we can explore the pitfalls and risks, before offering them to our engineering clients as possible solutions.

Daryl Greig

Modern vehicle architecture

Here's an interesting tale about vehicle architecture. Two years ago, General Motors appointed Bob Lutz as its new product czar. Lutz, the architect of Chrysler's 1990s product offensive and a veteran of BMW and Ford, cut through the quagmire of GM's product development process and pushed a new platform to the top of the development list.

Called Kappa in GM's Greek-alphabet system for platform naming, it was to be a front-engined, rear-drive platform with a compact footprint of around 4.0m, wheelbase of 2.4m and width of 1.9m and underpin a new family of image-building affordable sportscars and sport coupes. In just eighteen months, the platform and the Pontiac Solstice, the first of at least four vehicles planned for the Kappa architecture have been developed in double-quick time. A new suspension designed, powertrains borrowed from elsewhere in the GM empire, suppliers squeezed to hit impossible deadlines.

"Developing Kappa has been a huge achievement," says John Middlebrook, GM's head of product planning, *"Kappa will go global and it's taken just 18 months to develop. Terrific."*

Late next year, GM will launch Saturn, Opel and Vauxhall version of the Solstice, possibly followed in coming years by a Solstice coupe. For Europe, the Vauxhall and Opel chassis will be re-tuned for keener drivers, with a new supercharged 2.0-litre engine with *"in excess of 200bhp"* slotted under the bonnet for stronger European performance.

As a specific example of a company putting vehicle architecture – the core of all product development – at the top of its agenda, there isn't a better example than the Kappa. GM is streamlining its vehicle architectures in an effort to save costs and launching new platforms like the new unibody Lambda architecture for a range of more fuel efficient 'cross-over' SUVs. Saturn, for example, is being re-positioned away from its no-haggle, consumer-friendly focus into a more sophisticated, European-flavoured import-fighter. As a result, future Saturn models will be co-developed with Opel, Saab and Vauxhall models on common platform architectures; even sharing their styling with Opel and Vauxhall. The move will add a combined parts-buying group of over 300,000 Saturns to Opel/Saab/Vauxhall's 1.5m. Transantlantic platform sharing will mean that a new mid-size saloon from Saturn will use the front-drive Epsilon platform also used on the Opel Vectra and Signum and will share a new Delta platform being developed for the next-generation European Astra.

GM is streamlining its vehicle architectures in an effort to save costs and launching new platforms

Bob Lutz

But such transatlantic vehicle architectures pose their own difficulties, too. Ford, for example, has split its European and US Focus models onto separate platforms. The reason? The differing requirements of the two markets. In the US, compacts like the Focus are cheap entry-level cars, in Europe they are family cars and as a result the engineering cost structures can be very different. So instead of sharing architecture between the same brand on different continents, the C1 Technologies involves different brands that are closer-aligned in design need – an interesting twist on vehicle architecture.

So the new European Focus shares with the Mazda 3 and Volvo S40/V50. The combined parts buying on these three model lines comes to around 1million globally, with around 600,000 in Europe alone. *"With an industry-typical target for a minimum of 60 per cent common parts across the three models, that's a major cost saving and engineering saving for Ford,"* said Adrian Whittle, chief car line engineer for the Focus at its launch.

Like most cars, the C1 architecture has 30 per cent of its value in the front-engine compartment. That's where high-value parts like the engine/transmission and crash structure and instrument panel are situated, so from the B-pillar forward, the Ford, Mazda and Volvo are *"common entirely"* said Whittle.

To give an insight into the near-forensic detail needed to make a huge car program like the Focus and its common vehicle architecture into a sales success, just soak-up this stat – no less that 20,000 individual engineering targets had to be satisfied before management sign-off. Mind-boggling.

In this world of change and constant development there is, however, one major constant in the world of vehicle architecture – the steel bodyshell. *"The basic structure of a car's body architecture hasn't changed for a long time and I doubt it will change significantly in the future,"* says Professor Jon King, director of Corus Automotive. Surprisingly in an industry obsessed with counting the number of parts in a car, sharing them between model lines and trying to cut tooling and assembly costs, King says that the number of parts in a steel car body isn't changing. *"There's still between 250 and 300 parts to a body-in-white and while car-makers have brownfield assembly operations set-up to do so many spot welds and fix 250 parts together, it's difficult to see it changing."*

King and his team of researchers have done work suggesting that a body-in-white (BIW) could be reduced to around 130 parts – 100 major panels and 30 smaller brackets, largely by the use of welded, tailored blanks, which can combine two or three panels into a single part while also adding more strength. *"The cost savings could be in the order of five to 10 per cent,"* he says.

In an industry that measures savings in parts costs by fractions of a cent, it seems that advances in the BIW element of vehicle architecture is a development the industry will pursue more vigorously. King reckons that Volkswagen is the current world leader in parts integration, a process that has to be led by better engineering analysis and design modelling.

General Motors' Saturn Curve with Kappa architecture

Time is of the essence in the car industry and the future holds an increasing pressure on common use of parts, lightning-quick engineering and time-to-market

"Progress will come when engineers can use analysis tools with increasing sophistication so that computer predictions get closer correlation to real-world performance in crash tests and so on," says King. At the moment, cautious engineers often over-engineer the BIW to ensure a strong-enough structure, but he believes that weight, manufacturing complexity and cost are often added unnecessarily.

The increasing importance of public crash safety-tests and fuel economy – which push vehicle architecture engineering in opposite directions – is likely to encourage ever-more sophisticated computer design, particularly for small cars. *"I think we will see ever-more structure-led design, and small cars will push the design envelope,"* says King. A vehicle's architecture still needs at least 500mm of front structure crush; the advent of airbags has reduced that by only 100mm in the last ten years. So new materials might be needed in front structures to get the length down a little more, to reduce vehicle weight and footprint. What is also likely is the wider integration into vehicle architecture of crash sensors programmed to detect an accident and prepare the airbags for the impending impact. *"But all this has to happen in the R&D department first,"* says King, *"because vehicle architecture engineers, like most in the industry, are applications engineers. There is no time today to develop new technology on a program."*

Which brings us back to where we started – the time given to development of GM's Kappa architecture. Time is of the essence in the car industry and the future holds an increasing pressure on common use of parts, lightning-quick engineering and time-to-market. Who'd be a vehicle architecture engineer?

Julian Rendell

Master class: A session with Matt Becker

Analysing and developing the dynamic behaviour of a vehicle is a delicate combination of science and art, and is a discipline in which Lotus has gained worldwide recognition.

This master class, where a different ride and handling engineer from Lotus offers a valuable insight into the skills that have helped Lotus to develop some of the most responsive vehicles on the roads today, covers one of the more advanced handling issues. We appreciate that each of you will be at different stages of the learning curve. Therefore, the aim of the series is to offer tips that will be as beneficial to the novice as well as the seasoned track day enthusiast, and will help you get the most out of your car on road or track. Matt Becker looks at road handling, with particular advice on the reasons behind the loss of tyre adhesion and how it can be overcome. As always, any feedback on the series or any specific requests that you might have would be much appreciated, and we will do our best to feature them in future issues.

Safe driving.

Martyn Anderson Chief Engineer, Lotus Vehicle Dynamics

Matt Becker

Driver profile

Name: Matt Becker

Date of Birth: 2 April 1972

Job Title: Principal Engineer Vehicle Dynamics. Been at Lotus since 1988.

Lotus Projects: Ride and handling and vehicle development on all Series 1 and 2 Elise variants including 135 Sport, 190 Sport and 340R.

Esprit Sport 350 brake development.

Ride and handling development for many confidential vehicle clients.

Racing History: Small amount of Kart racing in 100cc Junior Britain when I was 13–14 years old. Main hobby is water skiing (slalom) in which I competed last year and came within the top 100 in the UK.

Loss of tyre adhesion

Loss of tyre adhesion occurs when the forces acting on a vehicle exceed the level of friction between the tyres and the road surface. Loss of tyre adhesion can be caused by many factors:

- Excessive speed for road conditions, especially cornering and braking.
- Aggressive steering inputs.
- Aggressive use of engine performance, especially in lower gears.
- Aggressive braking applications.
- Vehicle condition, especially tyres.
- Road surface conditions, particularly water, ice and snow.

Poor levels of driver concentration, awareness, observation, smoothness and mechanical sympathy can be contributory factors in loss of vehicle control.

Tyres have a maximum level of grip dependent on type, wear condition, temperature, road surface condition and vehicle characteristics. This grip has to accommodate longitudinal and lateral forces such as those generated in acceleration, braking and cornering. A vehicle that is being cornered at the limit of tyre grip (lateral) will have little grip remaining to provide acceleration or braking (longitudinal). Tyre grip needs to be balanced between lateral and longitudinal to optimise safety, therefore steady-state cornering and straight line braking and acceleration provide the most stable vehicle condition.

Understeer is a handling characteristic where the vehicle front tyres are working at a greater slip angle than those at the rear. This gives a condition where the vehicle travels on a wider path than that steered during cornering. Understeer can be caused by excessive speed into and during cornering, especially when excessive throttle application is used, particularly in front-wheel drive vehicles. In the extreme, this generates loss of front tyre lateral grip. To recover from an understeering condition, progressively reduce throttle and steering angle until the desired cornering line is achieved.

Understeer, where the front tyres are working at a greater slip angle than those of the rear.

Oversteer is a handling characteristic where the vehicle rear tyres are working at a greater slip angle than those at the front. This gives a condition where the vehicle travels on a tighter path than that steered during cornering. Oversteer can be caused by excessive speed into and during cornering combined with throttle release, steering application and/or braking. This can apply to both front and rear wheel drive vehicles. In the extreme, this generates loss of rear tyre lateral grip. Reduction of steering angle and application of throttle can recover front wheel drive vehicles from this condition. In rear wheel drive vehicles, oversteer can also be induced by excessive application of throttle during cornering. To recover from this condition, application of corrective steering and progressive reduction of throttle is required.

Oversteer is the complete opposite - spectacular, but not always the fastest way around a track!

One of the joys of owning a well-balanced and responsive car like a Lotus is that with time and practice you can explore the limits of your car's handling and learn to induce and then correct both understeer and oversteer. Public roads, however, aren't the place for this; there are too many unknowns, from variable road surfaces to the actions of other road users. The moral is clear – explore your limits on a track where the only penalty for a mistake is likely to be dented pride!

Matt Becker, Principal Engineer for Vehicle Dynamics Lotus

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