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The official industry newsletter of Lotus Engineering

Issue 17
November/December 2006

Lotus Engineering helping Chinese automaker

Racing success on the street

Welcome

A clear benefit of being an engineer at Lotus Engineering is that, interspersed amongst the diverse array of projects we do for our clients, there are also opportunities to work on developing new Lotus cars. I was lucky enough to be involved in the groundbreaking Elise project over ten years ago, and today, as the Vehicle Architect for the forthcoming Esprit replacement, the challenge is to produce yet another iconic car. It is interesting how the technologies and engineering have changed over the last decade, and in this issue we give you a glimpse at the evolution of the structure of the Esprit replacement, which is just one of a number of new products that we will launch over the next few years.

Like all our current products, aluminium is the material that Lotus will use for the vehicle structure of the next Esprit. It has been used to varying degrees within the industry over the years. Recently, more manufacturers are turning towards it, and Ian Adcock looks at who has done what and where things will go in the future.

Recently Lotus Engineering helped organise and host an IMechE seminar on Technologies for the Design, Development and Manufacture of Niche Vehicles. This extremely successful event brought together many senior executives and engineers involved in the production of niche volume vehicles to share knowledge. David Leggett of just-auto.com was kind enough, not only to present a paper but also to write an article describing the event.

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BEIJING SHOW: Volkswagen premieres two new designed-for-China cars

Volkswagen launched two new designed-for-China cars at Auto China 2006 in Beijing.

The highlight of Volkswagen's exhibition was the world premiere of the Neeza concept, a coupé/station wagon crossover. Designed in for China, the concept car is described as *"opening the window to the future of new models from Shanghai Volkswagen"*.

The name Neeza was derived from *"Ne-zha"*, a celebrated figure from Chinese history. Ne-zha was a small boy with magic weapons who fought against evil spirits.

Neeza is a coupé/station wagon crossover

Volkswagen also launched the large Magotan, which is based on the locally-built Passat and, according to Volkswagen, will be one of its top models in China. It goes on sale next year.

Volkswagen also launched four other new models in Beijing. They are the Concept A, which previews the forthcoming Tiguan SUV (smaller than the Toureg), the sport Golf GTi hatchback, the Eos coupé/convertible and the high-riding, pseudo-SUV CrossPolo.

Source: just-auto.com

BEIJING SHOW: Lotus Engineering helping Chinese automaker

Lotus Engineering is taking a key development role in the introduction of a new Chinese car company.

At the Beijing International Motor Show on Saturday, the UK-based automotive engineering specialist, owned 100% by Malaysian automaker Proton, announced it is the lead engineering and development consultant for Jinhua Youngman Automobile Manufacturing (Youngman) which is launching a new range of cars under a new brand name over the next five years.

Lotus Engineering managing director Albert Lam said: *"For the last two and a half years, [we have] been working with Youngman on a number of projects. We have built an excellent working relationship based on trust and the shared values of entrepreneurship and innovation.*

"It is on these foundations that we will be working with Youngman's engineers on the design and development of new vehicles to help them to establish their new brand in the Chinese automotive industry."

Youngman is a domestic commercial vehicle manufacturer and recently secured a licence from the Chinese authorities to produce passenger vehicles. Its senior management has aggressive plans for their new brand in the domestic and export market and plans to have a full four-strong range of models in place within five years of the first launch.

Lotus Engineering helps new Chinese start-up

Jinhua Youngman Automobile Manufacturing chairman Pang Qingnian added: *"Lotus Engineering is a globally recognised leader in automotive technology and vehicle engineering and in our recent work together we recognised its formidable professional capabilities. As a result Youngman identified [it] as the ideal consultant to support the development of our new range of cars.*

"With our British friends we will produce passenger cars designed, engineered and built to exceptional standards. I have no doubt this prestigious collaboration will be a momentous step towards a glittering future for Youngman."

Lotus Engineering claims to be one of only a few global engineering businesses with the skills and expertise to manage turnkey, full vehicle engineering programmes from concept to production and is one of only two consultancy companies that also design, develop, manufacture and sell their own cars globally (28 countries including the US).

Development work on the first model for the new car producer, a four-door saloon, is due to start early in 2007 and will be carried out at Lotus Engineering's Hethel, Norfolk headquarters in eastern England, and at its other engineering centres around the world. It is expected that the development of further new models will lead to a range of cars benefiting from the company's expertise.

Lotus Engineering is also working with a number of other clients in the fast-expanding Chinese and Indian 'emerging' markets. It opened a dedicated Chinese office three years ago and is planning on opening a similar office in India in the next six months.

As well as establishing an engineering centre in China, Lotus Engineering has a European technical centre at its Hethel headquarters dedicated to the Chinese automotive industry.

A UK-based spokesman for Lotus confirmed to just-auto on Monday that the consultancy is continuing to assist parent company Proton with product development engineering alongside its work for outside automakers.

Source: just-auto.com

UK: Antonov signs agreement with Geely

The board of Antonov plc, the transmissions technology company, has announced that it has signed heads of agreement for a production licence with Zhejiang Geely Automobile Gearbox Co; the transmission manufacturing subsidiary of Geely Automotive, one of China's leading vehicle manufacturers.

The licence would be for the production of the company's TX6 six-speed automatic transmission.

The Antonov board emphasised that a production licence agreement has not been signed with Geely at this stage, but said that *"an announcement is being made due to certain shareholder speculation that the board has become aware of"*.

Under the terms of the proposed production licence agreement, Antonov and Geely will work closely together in order to develop the TX6 to production to meet Geely's *"aggressive"* production timetable for its own vehicles and to make the transmission available to other vehicle makers worldwide.

Under the terms of the proposed production licence agreement, Antonov will receive both licence fees and production royalties.

Geely has already taken two models with conventional automatic transmission to production and the Antonov TX6 will be an addition to this model line-up.

The chairman of Antonov, Christopher Ross, has also been instrumental in securing the deal relating to LTI, between Geely and Manganese Bronze, where he is deputy chairman.

Mr An Conghui, vice president of Geely Automotive, said: *"Geely are pleased to have signed heads of agreement on this production licence for the Antonov technology, which will further strengthen Geely's transmission product range. We look forward to working with Antonov on their transmission technology."*

John Moore, CEO of Antonov plc, said: *"We are pleased to be working with Geely who have already developed their own transmissions and have the production infrastructure in place. This will enable a rapid programme to start of production."*

Antonov said that it *"expects to make a further announcement to shareholders in due course"*.

Source: just-auto.com

UK: Land Rover's new design strategy

The design of future Land Rover and Range Rover models will diverge into two different styling directions as part of a dramatic new design strategy already given the green light by the 4x4-maker, writes Julian Rendell.

Ford-owned Land Rover wants to increase design separate of its two nameplates to give each one a much stronger brand identity, thereby increasing coverage of the expanding SUV market and boosting sales.

The strategy could help Land Rover sales to move over 300,000 units in the next decade, a 50% increase over next year's forecast of 200,000 sales.

Range Rover Sport has been a huge success for Land Rover

That's because by widening the coverage of the SUV market, Land Rover will be able to compete better in a larger number of market niches.

The Range Rover range, for example, could be expanded by a three-door Sport model in the mould of the Range Stormer concept.

The Land Rover range could expand with niche models, plus add sales in the North American market with the Defender replacement, which will be engineered to modern crash and emissions standards.

This creative revolution at Land Rover is the work of design director designate Gerry McGovern who takes over from Geoff Upex, scheduled to retire at the end of 2006.

McGovern, formerly studio chief at Land Rover in the mid-90s and the architect of new designs explored by Lincoln in 2000/2003 but killed by Ford's past money worries, has been working on the new themes for 18 months as Land Rover's head of advanced design.

Under McGovern's direction, designers have coined buzz-words for the two new design directions – *"premium adventure"* for Land Rover and *"premium sophistication"* for Range Rover.

"Land Rover design will be all about clever body structures and platforms. It won't be agricultural or utilitarian"

The vision behind premium adventure will take Land Rover up-market, its new vehicles evolving a more up-to-date interpretation of go-anywhere, all-terrain.

"Land Rover design will be all about clever body structures and platforms. It won't be agricultural or utilitarian," says McGovern, *"but clean and contemporary with a level of premium-ness about it."*

Change is coming for the already expensive-looking Range Rover models, too. Although the design changes for *"premium sophistication"* will be more evolutionary.

"For Range Rover it is all about the ultimate in refined, progressive and powerful design," says McGovern.

One of the aims with Range Rover is to reduce the visual bulk of the cars, while maintaining a luxury air. Another target is to improve fuel efficiency and reduce the cars carbon footprint.

To that end the company is very close to adopting new bond/riveted alloy body architecture borrowed from Jaguar.

If the weight savings made by Jaguar are repeated by Land Rover, the future Range Rover, due on sale in 2012, could lose about half a tonne from the current car's 2.7 tonne kerb weight.

In the meantime, designers and engineers are working flat-out to make production a reality. McGovern's basic vision has been OK'd by Land Rover and Ford high-ups, although the vehicles and their technologies are some years from the green light.

Land Rover, for example, has to find new chassis technology to fit in with McGovern's exposed *"safety-cage"* body skeleton that features on the official sketch released by Land Rover. Otherwise traditional body-on-frame construction will have to be adapted to the new design direction.

Range Rover is a bit farther ahead with such key developments, the unit being very close to switching to a new aluminium chassis with technology borrowed from sister company Jaguar.

The final step in McGovern's strategy is to tidy up the *"faces"* of Land Rover and Range Rover's models, which have become confused with insufficient differences between grille and headlamp designs to easily identify, at-a-glance, the different models.

"We need to bring more clarity to it, and within the new themes give different types of vehicles different faces," says McGovern.

Source: just-auto.com

BRAZIL: Fiat and Tata join hands in Argentina

Although Fiat Mercosur has not yet confirmed details, the Italian automaker is apparently on track, as announced in Italy recently, to produce a medium-size one tonne pickup truck with standard and crew (double) cabs, and two- and four-wheel drive, from mid-2008 at its under-used Cordoba plant in Argentina.

This deal between Fiat and India's Tata will allow the former to compete in rich market segments from which it has been absent so far, and the Indian group to introduce its brand and products to Mercosur countries in South America, exempt from import tax.

Work to recalibrate suspensions and make a few minor styling changes to the 207 DI pickup is already under way – in Brazil at Fiat's development centre in Betim. Fiat already produces a range of cars in Brazil.

The accord outlined in Italy includes producing the Tata Safari SUV – which shares the pickup truck's chassis – in Cordoba. The

Argentine government has been applying pressure for the project to proceed because the Cordoba plant hasn't built a vehicle since 2000, though it does still produce stamping blanks and make engines and transmissions.

The Brazilian Fiat unit would not confirm any development work on a Tata pickup truck model, but examples of the Safari SUV have been seen around Belo Horizonte with executives driving. The only disguise was tape over badging on the grille, wheel hubs and exterior spare wheel.

Introducing the Safari would very cost-effectively give Fiat another vehicle type that it neither makes nor imports itself for South America.

Argentine-built versions of both the pickup truck and the SUV will have some updates and changes, compared to the models already sold in India and Tata's other export markets, and there will be specific design changes to distinguish the Fiat-badged versions from those for and Tata.

Source: just-auto.com

CHINA: Cadillac lengthens sedan for local market

General Motors' luxury brand Cadillac has launched a version of the STS sports sedan specially tailored for Chinese buyers.

The brand was launched in China two years ago and the new SLS sedan, lengthened 100mm to add rear seat room in a market where most buyers employ drivers, joins the CTS sedan, XLR roadster, SRX crossover – and the Escalade SUV also being launched now.

"The SLS interior is designed to meet specific local needs in this primarily chauffeur-driven luxury segment," GM said.

2007 Cadillac Escalade

"Cadillac reacts to country specific requirements and is proud to offer the SLS to Chinese luxury customers who demand extra space in the rear and other features"

Three engine options will be available – 2.8-litre V6, 3.6-litre V6 and Northstar 4.6-litre V8.

The new SLS is built at the Shanghai GM plant.

"The Cadillac SLS is a very important addition to our line-up in China as it meets very specific market needs," said Jim Taylor, general manager of Cadillac. *"Cadillac reacts to country-specific requirements and is proud to offer the SLS to Chinese luxury customers who demand extra space in the rear and other features."*

Earlier this year, Cadillac introduced the new Swedish-made, Saab 9-3-based BLS sedan in Europe and other international markets to satisfy the need for a smaller Cadillac model and a turbodiesel engine option.

"The new Cadillac SLS and Escalade as well as the new offering from Wuling will strengthen our position as the market leader in China. GM's multi-brand approach in China enables us to successfully compete in all important segments of the fastest growing market in the world. I am looking forward to finishing 2006 as another year of record growth for GM in China," said Kevin Wale, president and managing director of the GM China group.

Source: just-auto.com

Racing success on the street

The autumn has seen a busy period for Lotus Cars – normally a time associated with sports car makers *“shutting up shop”* until the spring

This year, in partnership with the Cadena racing team, Lotus entered 18 rounds of the British GT3 Championship with the stunning new Lotus Sport Exige GT3 racecar. The season finished with the Lotus Sport Cadena Race Team being crowned British GT3 Team Champions, with one race still remaining from their inaugural season of competition.

To celebrate this outstanding success, Lotus launched the Lotus Exige S British GT Special Edition. Based on the phenomenally quick standard-production Lotus Exige S, the Lotus Exige S British GT Special Edition pays homage to the success of the Lotus Sport Exige GT3 racecar. Each vehicle features a quad-stripe paint scheme and is individually identifiable by uniquely numbered *“British GT”* badges, Lotus Sport Cadena supplier decals and silver 7 twin-spoke forged alloy wheels, along with unique sports seats, door trims and Lotus Sport floor carpets. The Lotus Exige S British GT Special Edition is powered by a six-speed supercharged 1796cc engine using advanced VVTL-i technology, enabling the car to sprint to 60mph in only 4.1 seconds and on to a top speed of 148mph.

For those of our customers who can never have too much of a good thing, the optional GT Pack is just the ticket. Designed to specifically enhance the car’s performance it adds another 25hp (from 218hp to 243hp) and 15.4ft.lbs of torque (from 158.6ft.lbs to 174ft.lbs). This increase drops the 0 to 60mph sprint to less than 4 seconds and increases the top speed to 155mph. This increased performance is back up by an uprated braking system, two-way adjustible Öhlins dampers with uprated springs and an Accusump™ oil control system.

Exige GT3 and Exige S British GT Special Edition

Barrie Whight and Gavan Kershaw - Champions

Must be nearly Christmas, it’s awards time of year

Like many other walks of life, you know the end of the year is nigh when the awards start being announced. The automotive industry is no different – some are of interest, others are best avoided. To a sports car manufacturer, one that is definitely of interest is what our journalist friends at *EVO magazine* consider their Car of the Year or eCOTY.

Divided into two sections, the first featuring the year’s top 12 *“affordable”* sports cars contained both the new Elise S and Exige S. Without taking away from some great writing, backed up with amazing photography, suffice to say however that the Elise S ran away with first place with the Exige S in fourth.

This first place, meant the Elise S was then pitched into the automotive Lions’ den in Part Two by challenging nine exotic supercars for the overall title. Without giving the game away, the Elise S humbled more than a handful of vehicles whose higher prices prove that the Lotus tag line of *“Less is More”* applies financially as well in the field of weight reduction.

Source: Simon Croft

Lotus Engineering wins prestigious industry award for Versatile Vehicle Architecture used in the APX vehicle

"The jury recognised that Lotus used its knowledge in lightweight material such as aluminium to its advantage..."

In September the aluminium industry converged on Essen for Aluminium 2006, World Trade Fair and Conference. 685 exhibiting companies from over 80 countries presented their product and services relating to the material aluminium. These spanned a bewildering array of disciplines from raw materials, semi-finished products, finished products to surface treatments and producers of machinery, plant and equipment for aluminium processing and manufacturing, consultancy and expert opinions. Whatever you could conceivably want to do with aluminium, someone was there who could help.

The centrepiece of the show was the European Aluminium Awards 2006. The awards recognised innovative use of aluminium in six different categories: Automotive and Transport, Building and Construction, Environment and Sustainability, Machinery and Electronics, Design, and Innovation.

Lotus APX

Lotus awarded for innovative aluminium use

Within the Automotive and Transport category the nominees included BMW, Audi and Porsche amongst others. It was in this category that the jury awarded the European Aluminium Award to Lotus Engineering for Versatile Vehicle Architecture (VVA) used in the APX vehicle.

The jury recognised that Lotus used its knowledge in lightweight material such as aluminium to its advantage to create the VVA and APX and that Lotus satisfied the judges' key criteria of originality, functionality, design, durability and recyclability.

The innovative VVA technology offers a fast-to-market, cost-effective approach to highly differentiated niche products by spreading the development, investment and bill of materials burden across a range of niche variants without the compromise that comes from conventional *"platform sharing"*. The key to VVA is the extensive use of aluminium in the form of high-pressure die-cast corner nodes that are combined with extruded and pressed aluminium via bonding and mechanical fasteners.

This is not the first time that Lotus has won this award. Back in 1996 it was given to the Elise chassis, at the time a ground-breaking technology in itself.

Peter Morgan

Aluminium in the automotive industry – its history and its future

The year 2008 will mark the 200th anniversary of Sir Humphry Davy discovering the existence of aluminium. Yet it would be a further 78 years (1886), before two scientists working independently and unknown to each other – Paul Louis Toussaint Héroult in France and American, Charles Martin Hall – developed the electrolytic process that forms the basis of today's aluminium manufacturing.

Prior to this, aluminium was considered a precious metal more valuable than gold or platinum but, as production increased, its value steadily dropped and in 1893 aluminium was deemed sufficiently inexpensive for the statue of Eros in London's Piccadilly Circus to be cast from it.

Compared to other metals in use today – copper, lead or tin for example which have been used for thousands of years – mankind's use of aluminium is still quite young.

The Ultra Lightweight Steel Auto Body (ULSAB) project

Its main advantage of lightness was immediately recognised, but it was some time before that property was transferred to the equally nascent automotive industry.

At first, aluminium was used in components such as pistons. One of its earliest proponents was W.O. Bentley who used aluminium alloy pistons in his modified D.F.P. and then in World War One, he helped develop aluminium pistons for the Rolls-Royce Eagle aero engine.

In 1913, however, NSU produced an aluminium bodied version of its 8/24, whilst in 1920 Alcoa sponsored the build of several aluminium-bodied cars designed by Laurence Pomeroy and built by Pierce Arrow; they used a combination of aluminium castings and stampings clad with aluminium panels.

However, its use as a structural material was restricted and it continued to be used more for bodywork. One of the earliest examples was the odd looking Bjering, a tandem two-seater with aluminium panels attached to a wooden frame built in Norway in 1925.

Between the Wars the lightness of aluminium panels was widely used in competition cars including, amongst others the Auto Union Silver Arrows, but its application in mainstream manufacturing was limited.

The breakthrough came in 1934 when the French engineer, Jean Albert Gregoire – who invented the Tracta constant velocity joint with his partner, Pierre Fenaille, that was used by Ford and Dodge during the war years – in co-operation with Aluminium Français designed a car using a cast aluminium frame. This directly led to the Hotchkiss Compound, a four-seater with a cast aluminium structure.

Years later the AFG concept was developed into the Dyna Panhard, with more than 50,000 units built before it was discontinued. Ironically, by 1957 most of its aluminium had been replaced by steel making the car heavier and slower – the reverse of current trends.

Prior to this, the first Porsche prototype built in 1948 used aluminium as did the first Land Rover that appeared the same year.

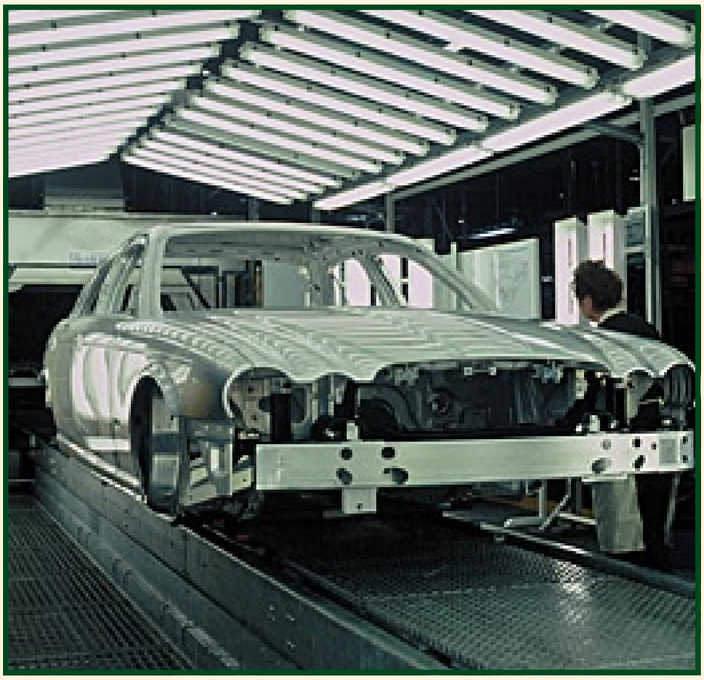
Then in 1989, Honda revealed its aluminium NSX sports car, but it could hardly be classed as a mainstream product.

There was a long wait until the 1993 Frankfurt Motor Show, before the next major step forward in aluminium vehicle structures was revealed. Dominating the Audi stand was a glittering aluminium concept saloon, the Audi ASF. Developed in conjunction with Alcoa it was a unique combination of extrusions connected by die-cast nodes and integrated with aluminium panels. It was obviously very close to production even though it was claimed to be a concept and at the following year's Geneva Salon, the Audi A8 debuted. A new era in aluminium cars had arrived.

At around about the same time, Ford built 40 Taurus/Sable Aluminium Intensive Vehicles that were about 46% lighter than comparable steel bodied versions. Yet it was Audi again which took the next brave step, launching the A2 in 1999, a much smaller car in higher build numbers compared to the A8 (15,000 a year compared to the A2's planned 60,000).

With emissions and fuel economy becoming even more important, it was increasingly obvious that lightweight vehicles manufactured from aluminium could offer major benefits in these areas not only to manufacturers but also to the consumer.

Aware of this growing interest in aluminium, 35 steel companies initiated the US$22 million Ultra Lightwieght Steel Auto Body (ULSAB) project. The result was a steel structure weighing only 203kg, or 25% less than the average benchmark. This was subsequently followed by research into lightweight closures and, with Lotus Engineering, suspension systems.



Jaguar XJ aluminium body structure

Lotus released its aluminium chassis Elise in 1995, and then in 2000 came Aston Martin – its Vanquish also using an aluminium bonded chassis. Ever since then there's been a steady release of cars with aluminium intensive structures from the Honda Insight through to the Rolls-Royce Phantom and including cars from Ferrari and Aston Martin. However, all of these are low-volume, niche products the only exception to this being the Jaguar XJ and XK series that employ a unique aluminium manufacturing and assembly process that combines riveting and bonding with a more conventional structure and production techniques than those employed by Audi in its A8 models. Even so, output manufacturing capacity is still limited to under 35,000 units a year – hardly mainstream.

And that's the challenge aluminium has faced throughout its involvement in the automotive industry – manufacturing hundreds of thousands of aluminium cars is never likely to be feasible. Aluminium Intensive Vehicles (AIVs) will remain niche products, but that's not to say steel has won the war. Far from it.

With increased content, more safety features etc., even the smallest car is getting heavier – and that's not good for fuel consumption and tailpipe emissions. Cars must get lighter and that's where the judicious use of aluminium will play an increasingly important role.

The latest BMW 5-Series is such a car; aluminium accounts for about 15% of its structure, primarily forward of the 'A' posts where the shock towers are cast aluminium as are panels, the front (and rear) subframes as well as much of the suspension componentry. The result? A new BMW that actually weighs less than the outgoing model, even if it's only by 20kg.

Much more dramatic, in terms of weight loss is the approach that Audi has taken with the latest TT that incorporates best practices from both steel and aluminium structures. Driven as much by dynamics and the need for its traditionally front- or all-wheel drive configuration to equal the rear-wheel drive dynamics of its BMW and Mercedes-Benz rivals, Audi has used its aluminium experience and knowledge to create a lightweight structure forward of the 'B' posts accounting for 69% or 140kg of the bodyshell's total 206kg weight. Audi claim that if it had used conventional steel the TT would have been 48% heavier, whilst an all-aluminium shell would be only 12% lighter.

Interestingly, Audi also claims that, having investigated ULSAB techniques, the results achieved in one-off prototypes could not be maintained on a series production run whereas this hybrid structure can be effectively and economically employed in production runs up to at least 250,000 units.

So, where does this leave the aluminium vs steel debate? Who wins? In the final analysis, both do. It's like the debate over which powertrain is best: petrol, diesel, hybrid? It all depends on local needs and costs.

It's the same with steel and aluminium – plus other materials like magnesium etc. that aren't part of this article – it's a case of which is the best, most cost-effective material for the application. It's not a case of one solution fits all.

Aluminium's usage will grow of that there's no doubt; Drucker Research predicts that by 2010 vehicles will average 144kg of aluminium compared to 124kg today.

In some instances an AIV will be the answer, in others it will be steel, yet another – and, probably, increasingly so – it will be a combination of the best of both worlds.

Ian Adcock

Report from IMechE seminar: Technologies for Niche Vehicle Design, Development and Manufacturing

Proliferating OEM model lines and fragmenting vehicle markets are two sides of the same coin – niches are on the rise. In Europe, we need look no further than the decline of the upper-medium saloon market segment – not so long ago *"bread and butter"* for the volume makers – for dramatic evidence of how quickly the market can shift. Car buyers are increasingly interested in lifestyle and statement vehicles like SUVs and sports cars, or they are attracted to the greater utility inherent in one-box designs such as the segment-busting Renault Scenic.

Meeting a myriad of customer needs is a growing challenge for niche vehicle engineers in both the big car firms and small specialists.

Vehicle manufacturing technologies and processes have developed to facilitate lower volume niche production among the large manufacturing groups, who lever low-volume niche models off high-volume platforms. Platforms or *"vehicle architecture sets"* are the common vehicle DNA that often underpins vehicles across vehicle group brands and a multiplicity of body styles.

However, niche vehicles are nothing new. There have always been specialist manufacturers of low-volume products – most typically upscale luxury and sports performance vehicles – frequently employing specialist and higher spec materials and engineering methods.

Developments in niche vehicle technologies was the theme of a recent Institution of Mechanical Engineers (IMechE) seminar hosted by Lotus Group and held at the Hethel Engineering Centre, just outside Norwich.

Lotus Engineering's APX

The day event – attended by around 80 delegates – was broken down into a number of sessions.

Session 1: materials and joining technologies

Bob Dorney-Smith, Head of Automotive Structures at Hydro, discussed aspects of different joining systems for aluminium materials and the advantages of employing structurally bonded vehicle architectures. Hydro has been manufacturing bonded aluminium structures for 12 years, the first being the Lotus Elise. Dorney-Smith explained that there were four essential parts to a well-designed Elise joint:

- aluminium substrate (grade);
- pre-treatment type;
- adhesive material;
- mechanical fixing type.

Aluminium is used on the Elise in both extrusion and sheet form and various pre-treatment types were initially investigated – the chosen technology needing to form a corrosion preventative layer and visually acceptable surface, as well as acting as a compliant interface for the adhesive and aluminium materials.

The adhesive is the primary joining mechanism but only works in combination with selectively placed mechanical fasteners that act as peel-stoppers. The overall conclusion from Dorney-Smith was that the four parts needed to be carefully selected, validated, and applied to offer a single engineering system.

Mark White, Chief Technical Specialist BIW, Jaguar and Land Rover, discussed niche vehicle design and examined how niche meant different things to different manufacturers. Four distinct groupings could be identified based around production volumes, he said:

- Volume niche vehicles from manufacturers who normally produce in the region of one million units or greater. These are derivatives of higher volume vehicles that fill a gap in the market. Examples include Audi TT and VW New Beetle.
- Premium niche vehicles from manufacturers who normally produce between 50,000 and 500,000 units. These are vehicles that are aspirational products and appeal to many. Examples include Jaguar, Land Rover and Porsche.
- Low-volume niche vehicles from manufacturers that operate in the 1,000-50,000 unit range. These products are emotional propositions and primarily have a strong heritage. Examples include AML, Lotus and Rolls Royce.
- Specialist very low volume manufacturers that normally produce up to 1,000 units. These are often unique products and expensive. Examples include Bugatti, Pagani and Spyker.

White went on to analyse how manufacturers would use different approaches to carry over parts, shared parts, investment strategies, and pricing strategies depending on which segment they were operating in.

He also identified aluminium as a preferred material for manufacturers creating niche vehicles and went on to examine how Jaguar had used aluminium extrusions, sheet and castings in the XJ and XK body structures.

Session 2: niche manufacturing

Dave Leggett, just-auto.com's editor, began the session with an overview of the differentiated global car market and the place of niche volume vehicles within that. He noted that in Europe, the light vehicle market has fragmented in the last ten years, giving rise to greater interest in a wide variety of niche vehicles. There was also some consideration of long-term trends affecting the vehicle market and niche segments, such as the ageing of baby-boomers and growing environmental pressures on car usage. He raised the possibility of entry to the auto industry on a new business model, possibly involving niche vehicles.

Neil Hopkinson, lecturer at Loughborogh University, described industrial techniques in rapid manufacturing (RM). His paper demonstrated that it can be economic to produce parts in batches of one and that rapid prototyping uses a variety of techniques and materials that make such parts visually and functionally relevant.

Rapid prototyping has had a long gestation, through stages of visual representations in paper and resin to increasingly useful parts. The application examples described were varied from aerodynamic ducts to football boots and lampshades.

An intricate example of an automotive door handle demonstrated the power of 3-D visualisation prior to release of the intricate tooling required to make such parts.

The claim of rapid manufacture is a new and bold step. Dr Hopkinson claims to have obviated the need for tooling for many parts by making a series of individual parts. Techniques used include stereolithography, Fused Deposition Modelling and Selective Laser Sintering. But the economic issues and the investment steps required as volume increases appeared to merit further examination (maybe the solution requires the RM machines to replicate themselves as well as the parts!).

Session 3: vehicle layout and architecture

Two papers were presented in this session, each with its own distinctive theme. The first paper, presented by Richard Rackham of Lotus, described how Lotus has evolved its bonded aluminium based body architecture from the Elise, over ten years ago now, to the proposed Esprit replacement.

He traced the development from Elise in 1995 through the Versatile Vehicle Architecture (VVA), which was demonstrated in the Lotus APX show car, through to the upcoming Esprit replacement. This latest car will make extensive use of aluminium extrusions and simple folded aluminium sheet components. Options for either sheet metal or composite exterior panels have been left open and provision has been made for both convertible and coupé options.

The Gibbs Aquada amphibious car

The second paper, presented by Paul Jaggers of Stadco, was entitled *"Art to Part"* and gave us a very rapid journey through the development of a niche product. An underlying theme was the necessity for making key decisions correctly early in the product development cycle. He also pointed out that the architectural and material options for niche vehicles are far greater than for a mass-produced vehicle, where conventional pressed steel monocoque falls out almost immediately as the construction of choice.

Niche vehicle business cases are very investment sensitive, and require a fast to market approach and Jaggers outlined a range of digital tools which can be used to reduce time in the product design phase, leading to a shorter time to market.

Session 4: vehicle development

The final session of the day was aimed at development of niche vehicles and especially the development challenges for niche vehicles. It was introduced by Paul Harvey, the Head of Chassis Engineering at Lotus who is therefore responsible for development of all new product for Lotus cars as well as for external projects. Lotus, it was pointed out, has supported the development of niche vehicles for a large number of the major OEMs around the world and has been confronted with all of the challenges that confront niche vehicle makers today.

The nature of the niche development challenge was outlined. Niche models have to abide by the same rulebook as mainstream models alongside huge constraints on budgets and timescales. And the end product is still supposed to deliver something *"special"*.

This made the presentation by Malin Kjelberg particularly relevant. Kjelberg has recently joined Chalmers University of Technology in Gothenburg as a research engineer but was previously manager of the certification group at Koenigsegg.

She emphasised that the rules on the certification and development of low-volume cars are the same for all players both large and small if you wish to gain full approval. As the only alternative is the single vehicle approval route – valid for volumes up to a few hundred – then low-volume and niche models need the same approach as high-volume mainstream cars.

The only advantage for some of these niche models is to use carryover approvals for items such as powertrain in order to minimise the costs involved in running huge fleets of development cars.

These issues have certainly made it extremely difficult to enter certain markets with any radically new niche vehicle. Complex legislation such as FMVSS 208 (smart airbags) and the European pedestrian impact regulations impact niche vehicles disproportionately because of lower volume to spread such costs.

There may be a rationale for this approach in terms of mainstream models, but the approach and level of legislation and regulation threatens the development of truly interesting niche vehicles.

In fact the follow up discussions suggested that it would be in the interest of many in the room to get together and lobby for some relaxation of some of the more recent regulations to provide a fairer and more representative set of regulations for low-volume niche models.

The next speaker was Neil Hannemann, who is currently Executive Director of Engineering, McLaren Automotive Ltd. Hannemann had previously been with General Motors in Detroit and has amassed some 20 years of experience in engineering mainstream and niche vehicles. He listed his career highlight as Chief Engineer of the Ford GT programme but he does not only engineer cars, as he was national drivers champion for the US Endurance and Touring Car series.

His paper was the intriguingly titled *"Driving Expertise in the Vehicle Development Process"*. A central theme was getting real engineers back involved with the development processes and was illustrated by a mathematical formula:

$$D = VC + EE$$

Which translates into: Driving = Vehicle Control + Everything Else.

The key message here is that to be totally successful in developing a rewarding vehicle we should maintain a focus on the Everything Else part and to do this we need the best engineers with the best (driving) skills so that they have plenty of capacity left to evaluate the *"Everything Else"* part.

Hannemann maintained that engineers have spent a lot of time developing tight procedures around which cars are developed to the extent where test engineers are becoming more like automatons or robots performing development in a very restricted way towards preordained targets.

He made the point that engineers strive to meet these targets and sometimes forget to ask the simple question: is the vehicle any good? And this, he added, is often the very thing that differentiates mainstream vehicles from niche vehicles. Often mainstream cars have had their souls developed out. Niche vehicles need to make sure that the soul is vigorously protected.

Last, but not least, we had Neil Jenkins from Gibbs Technologies, maker of an amphibious sports car – the Aquada. Jenkins' background in both automotive and marine engineering highlighted the challenges in developing the Aquada, as it had to comply with not only vehicle regulations but a whole host of marine regulations also. This, he said, was on top of having to invent a whole raft of new technologies just to overcome the issues of taking a road-going vehicle onto the water and the inherent engineering conflicts that involves.

One of the biggest breakthroughs by Gibbs was the development of its own jet drive because most of the available jet drives were either too big or did not have the power that Gibbs required. Another was in the design of the underside of the vehicle (or hull perhaps…) such that it would function on the road but would still be capable of getting good performance on water. All previous efforts had been constrained to very low speeds on water due to the drag effects of a vehicle's under-gear. These had been resolved for Aquada with its retractable wheels and hull that allowed it to get up on the *"plane"* such that it is capable of around 30mph on water. In total the development team had realised over 400 patents as a result of needing to solve the problems of this truly unique niche vehicle.

In fact, this was a key message for all niche vehicle teams. Development engineers in the niche vehicle business all have a common strength and this is as problem solvers. Whether it is coping with shortened timescales and limited budgets, stringent and demanding regulations, cost and content issues or even if it is just ensuring that the soul of the vehicle is maintained, it is the job of the niche vehicle development engineer to make sure that all of these problems are solved. Tough brief.

Oh, and that we get a car with a soul that we can be proud of.

Source: Dave Leggett

A glimpse at the new Esprit structure – and how it got there

Most contemporary car structures are made of a number of complex steel or aluminium press-formed panels, which are typically welded together to form what is known as a monocoque. The investment required to support this technology can only be justified at typical production volumes of hundreds of thousands over the vehicle lifetime. Lower volume vehicles, often termed niche, require different technologies needing much lower investment. 13 years ago, when the Elise was conceived, Lotus identified that aluminium structures that were adhesively bonded and riveted together not only required low investment but also met the fundamental requirement of low weight whilst remaining extremely durable. Since then much has been learnt, resulting in the latest structural concept to be used on the forthcoming Esprit replacement. This article discusses the major technical milestones during this period, hopefully showing the logic that has led us to where we currently are.

The term *"structure"* in the context of this article refers to the underlying structural elements of a vehicle, sometimes in layman's terms called the chassis, frame or tub. It is the multifunctional *"monster bracket"* that supports and connects major systems such as the engine and gearbox, suspension, seats, steering and doors, which in order to operate correctly must have mounting points of the correct stiffness. The structure must provide enough space around the occupant for ergonomic comfort whilst being strong enough to resist crash loads. Peripheral to the occupant cell the structure must be soft enough to absorb crash energy at levels prescribed by legislation aimed at reducing injury. Even the normal use of a vehicle puts huge forces into the structure, and any perceived flexing and bending is unacceptable. On the subject of noise, vibration and harshness, or NVH, all things can be made to resonate when given the right excitation, but vehicle structures have to be designed to be *"dead"* when subjected to the inevitable vibrational inputs from the road, suspension and engines. Finally, due to the customer's demands all these areas have to be addressed in a repeatable way, so that the *"monster bracket"*, when adorned with the rest of the car results in a product with a consistent high perceived quality. Figure 1 shows the evolutionary structures that will be discussed in this article.

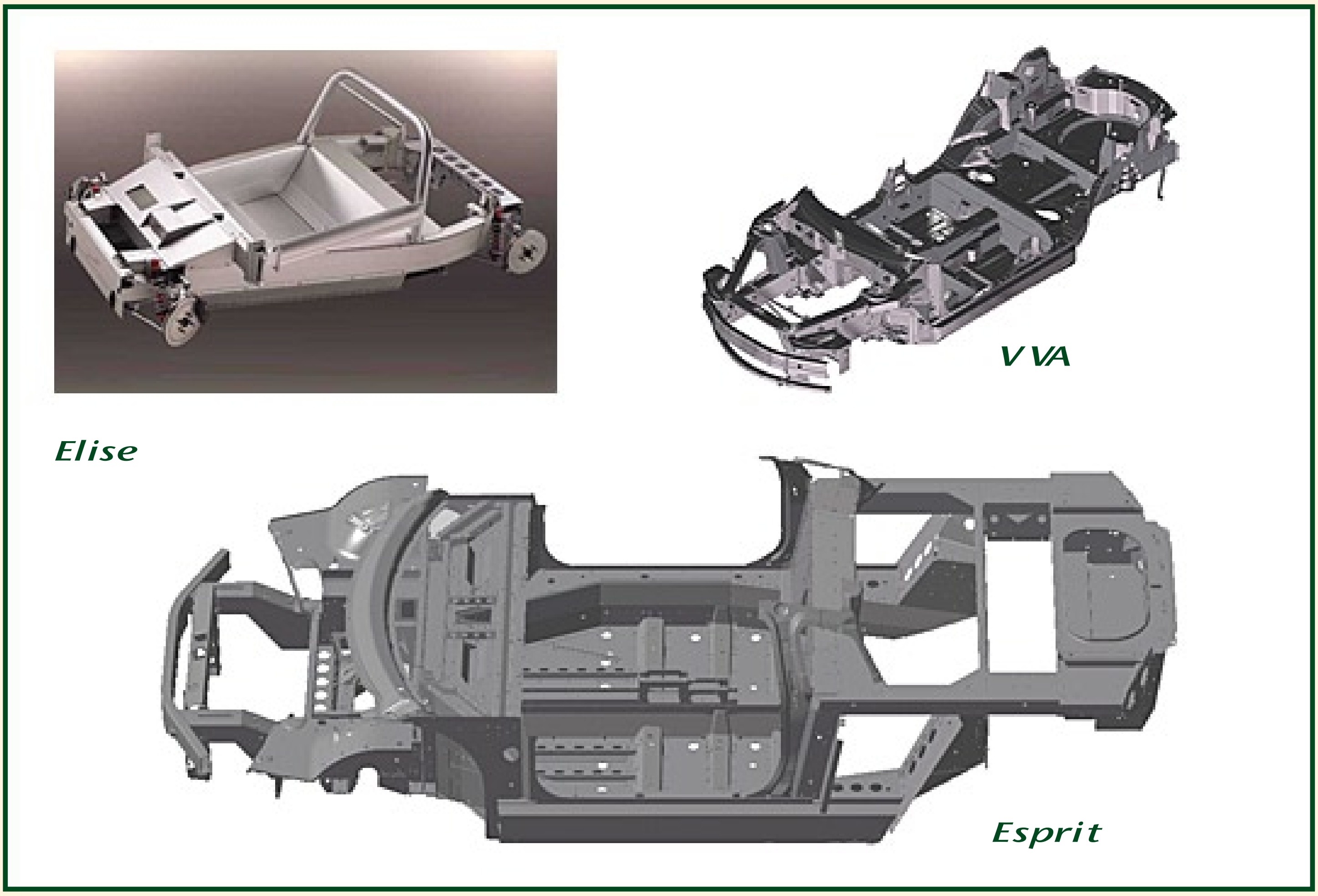


Figure 1

It is ironic that the best-loved classic cars fail miserably in all areas of contemporary structural design. The stirring concept of wrestling with a steering wheel to keep in a straight line under full acceleration because the chassis is winding up in reaction to the engines torque thus pointing the axle slightly sideways isn't really on. Similarly, feeling the steering wheel judder every time you encounter a bump isn't the sort of steering feedback that we hanker after nowadays. Doors that have to be lifted into position, or harshly slammed, are symptomatic of poor local stiffness, as are fuzzy images in the mirrors at certain revs. As for the crashworthiness of classics, it is simply best to assume that there is none.

The Beginning – Elise

The Elise was a milestone vehicle for Lotus. Its aluminium bonded structure weighed just 67kg and the aesthetical acceptability of the extrusion dominated design enabled most of the interior trim to be omitted, offering further vehicle weight and cost savings. This was acceptable given the original product profile, which called for a back-to-basics road car suitable for track use, the stripped out appearance fitted perfectly being reminiscent of aluminium structures found in competition sports cars prior to the adoption of advanced composites such as carbon fibre. It excelled in the areas of crashworthiness, stiffness and weight due to its structural purity. The side rails either side of the occupants ran perfectly straight from the front where an energy absorbing composite crash structure was attached, to a point beyond the occupants where a bend occurred enabling the rails to terminate in the correct position to attach a rear suspension subframe. From the Elise structure in Figure 1 it can be seen that frontal crash loads are largely taken past the occupants by these rails. In the event of side impact, the high nature of the original rails offered great protection. In simple terms, these rails were joined together laterally with box like structures. At the front, the *"box"* consisted of a series of extruded crossmembers which accepted the front suspension and steering, and at the rear the box surrounded the fuel tank. In practice, a torsional stiffness of 9500Nm/deg was achieved.

When considering the complete suite of structural requirements earlier discussed, it is apparent that the areas of excellence of Elise were at the expense of ingress/egress, package efficiency and NVH. The high siderails were a long way in from the side of the car which made getting in an out more like a race car than a road car, and their position compromised interior space. The extruded crossmembers are space consuming which left limited volume for HVAC packaging at the front, and limited fuel tank capacity at the rear. The multitude of flat panels resonate at the slightest chance. However, it should be remembered that these compromises were totally acceptable within the vision of the original Elise. Subsequent Elise derivatives have addressed these shortcomings to the point where more than ten times the original volume have now been produced.

Figure 2

Versatile Vehicle Architecure

Following the launch of the Elise, Lotus Engineering consulted on many vehicle programmes for both Lotus Cars and external engineering customers. Notable successes were the Opel Speedster/VVX220 for General Motors which shared the Elise structural concept and many of its components. Lotus was the design and development partner to Aston Martin for its Vanquish which displayed the aluminium technology of Elise but introduced more exotic structural composites for the crash structure, screen pillars, transmission tunnel and strut tower brace.

These technologies were fine for these low-volume vehicles, but in 2002 we started to investigate a way to develop diverse aluminium vehicles with a higher combined volume. This demanded a different strategy. The challenge was to find an approach to deliver three diverse vehicles with a total of 40,000 units per annum. The first would be a front engined 4x4 crossover with seven seats, the second a mid-engined supercar and the third a front-engined executive saloon as shown in Figure 2. In order to reduce the overall programme costs of realising these different vehicles the necessity of sharing key structural elements, components such as as HVAC and steering, and manufacturing facility was identified. This concept developed was named Versatile Vehicle Architecture (VVA).

The heart of the VVA structural element was driven by the fact that vehicle design always throws up challenges in the footwell area. To achieve contemporary ingress/egress the simple Elise type load path cannot be adopted. A more complex side rail design is required that hugs the wheel house. To effectively manage crash loads, it requires thick section in places. This can be achieved by the joining of several formed sheet panels so that the voids between them form load bearing members; or by complex high pressure die castings, or HPDC. These large castings incurred a high tooling cost, but this was acceptable given the projected VVA volume and the opportunities that they offered. A similar philosophy supported the use of castings around the rear wheelhouse. These castings are shown in red on Figure 3 as part of the first VVA structure. Extruded members are shown in blue. The majority of the remaining grey components are conventional press-formed, which although needing expensive tooling were again justified by volume. The red and blue components were such designed that they would suit all three vehicles. Figure 3 also shows these combined with simple low investment folded sheet or extruded components to realise the structure of the second planned vehicle, the mid engined supercar of which the final design is shown in Figure 4. A similar design exercise achieved the third model.

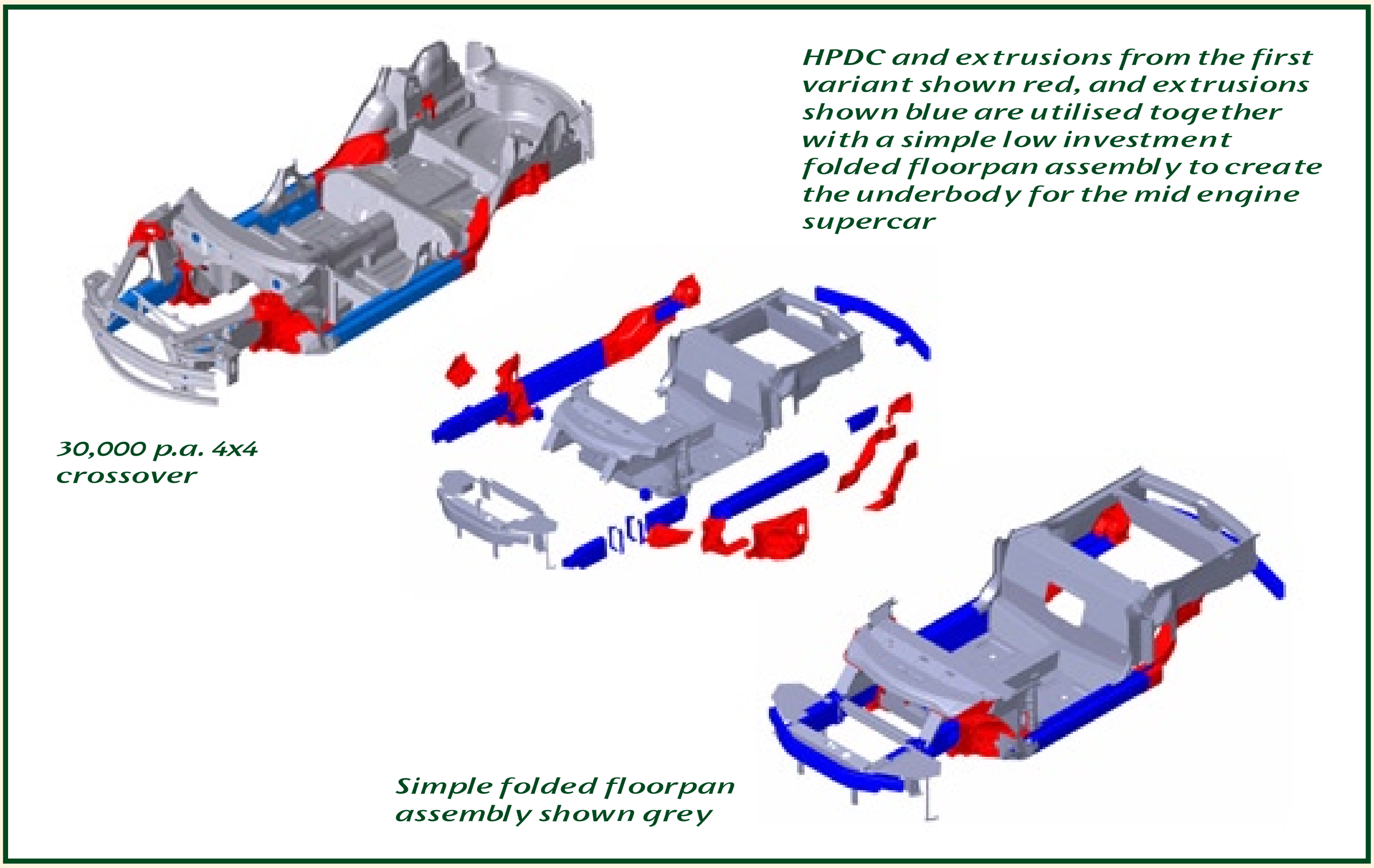


Figure 3

Figure 4

A VVA for the Esprit replacement and other future Lotus Cars

In 2004, Lotus Cars wished to embark on a replacement for the Esprit. Much of the learning, know-how and solution from VVA was well suited to this new challenge. However, a fundamental shift was that the volume requirements were greatly reduced. Certain technologies such as the high investment HPDCs of VVA were not viable for the lower-volume requirements. The result was an evolution of the VVA approach to develop a new sports car focused structure that should be morphable to cater for future Lotus and client requirements at volumes of up to 5,000 per year. and the first variant would be the Esprit replacement.

Immediate attention was given to the critical footwell area, and a design which showed a great improvement over Elise was conceived, where the siderail was slimmed down beside the feet but then it was supplemented beside the occupant to increase the member size in the area critical for vehicle stiffness. This supplementation also offered a load path for the wheel and tyre during frontal impact. The final embodiment of the design is shown in Figure 5.

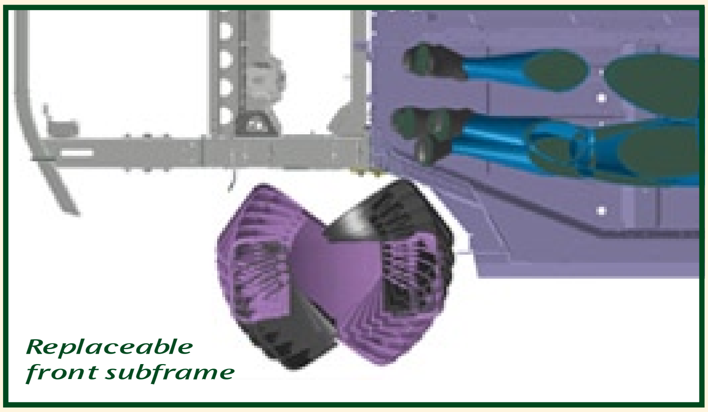


Figure 5

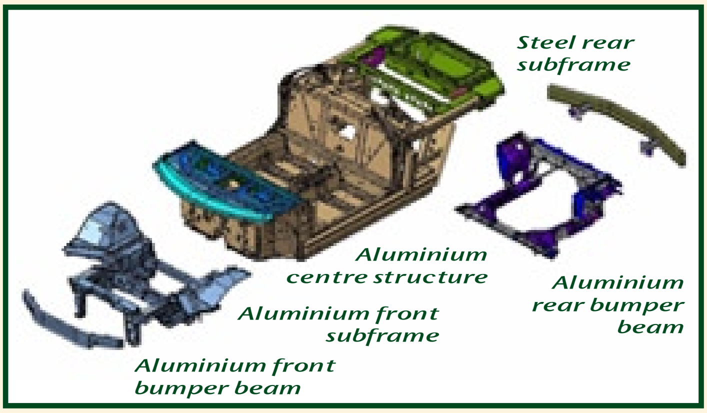


Figure 6

Figure 6 shows the Esprit replacement structure exploded into elements that are bolted together. At the front, there is a separate subframe. This is to enable its replacement in the event of accident damage when suffering a frontal impact or when the suspension mounting points become damaged. Also shown detached is the front bumper beam which can be replaced if required after a minor frontal impact. The front wheel house panels are integral with the subframe, and provide support to the side mounted radiators, bonnet hinges and headlights.

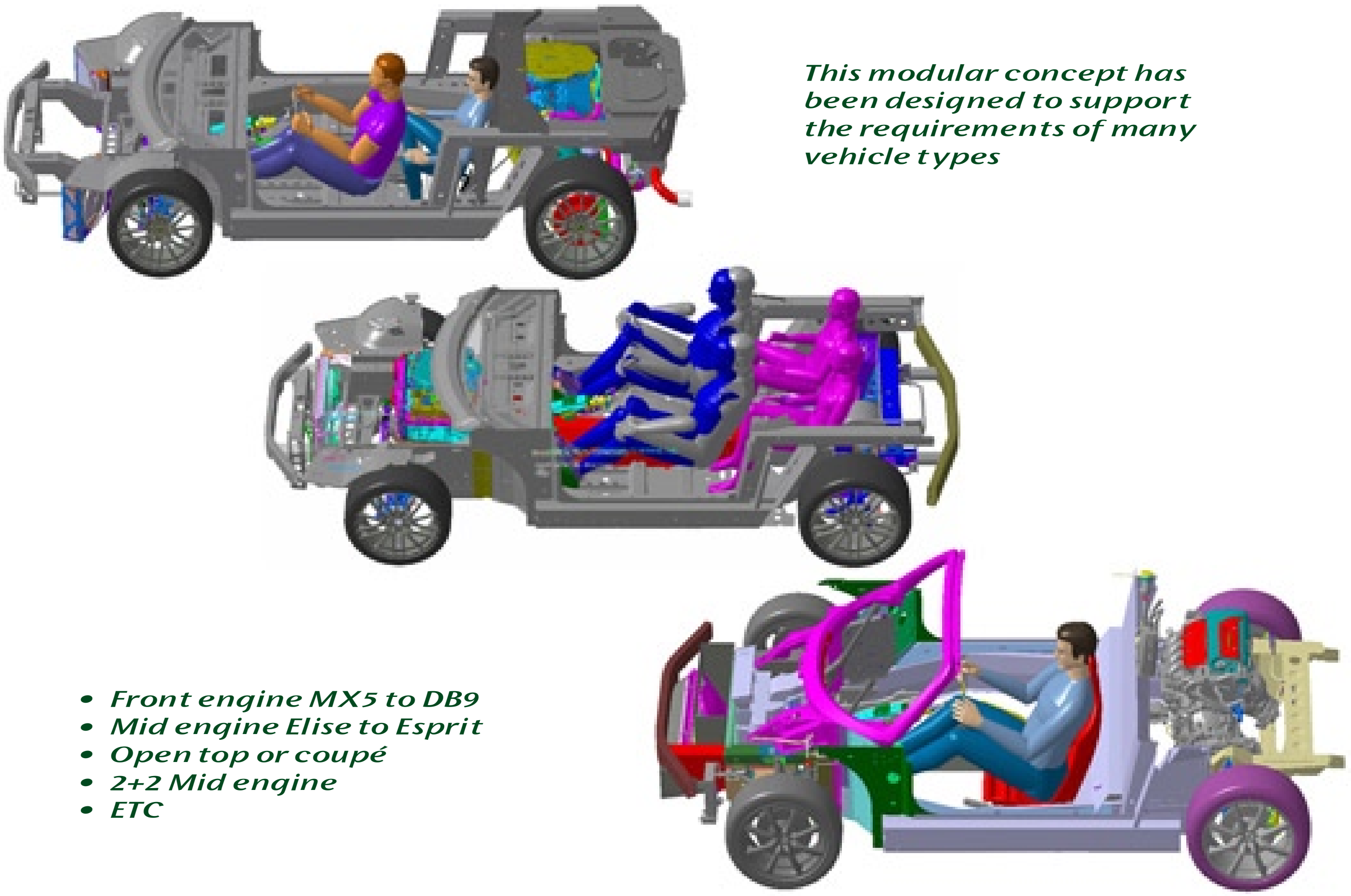
The centre section houses occupants up to 98th percentile, which is about 6ft 5ins tall, extremely impressive for a supercar. The turquoise curved surface at the front provides stiff support to the bottom edge of the windscreen, and a mounting for the windscreen wipers. Front to rear pipework runs down the central tunnel, and an access hole in the rear-bulkhead facilitates service at the front of the rear mounted engine. The A and B pillars, at the front and rear of the door apertures provide stiff mounting points for the door hinges and latches. The rear luggage compartment is integral, adding to the global vehicle torsional stiffness.

At the rear, the separate steel rear subframe with detachable bumper facilitates crash repair as at the front. During vehicle assembly, the engine transaxle and rear suspension and exhaust system are all assembled to the rear subframe before this completed module is offered up to the aluminium centre section.

When assembled, these elements constitute the structure of an open top variant, should it be required, with a torsional stiffness of around 14,000 Nm/degree, which is aimed to provide a similar structural feel to the smaller, lighter Elise. With the addition of the upper body of a conventional metal roofed version, then this stiffness more than doubles to 31,000 Nm/degree.

The innovative, intelligent design of the new structure will lead to a truly exciting Esprit replacement. But the real beauty is the low-volume VVA capability of this structure to be adapted to accommodate the requirements of alternative sports car layouts, as demonstrated in Figure 7. Exactly how Lotus or its clients exploit this, we will see over the next few years, but the potential for some truly exciting vehicles is here.

Source: Richard Rackham, Lotus Engineering



This modular concept has been designed to support the requirements of many vehicle types

- Front engine MX5 to DB9
- Mid engine Elise to Esprit
- Open top or coupé
- 2+2 Mid engine
- ETC

Figure 7

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