proActive

The official industry newsletter of Lotus Engineering

Issue 1
March / April 2004

The hydrogen promise of Mazda's rotary engine

UK: GM strays from its common architecture strategy

Welcome

Welcome to the first issue of proActive, Lotus Engineering's unique take on the customer newsletter. This publication is designed to offer you benefit right from the start, and to that end we are making the commitment of ensuring what you read will add value to your day-to-day activity.

Of course, there will be information on the latest exciting developments at Lotus, but more so it is our objective that this publication becomes part of your ongoing intelligence network for the automotive industry.

We've got an exciting issue to start - focusing on niche vehicles and the challenges of development, production and profitability. Subsequent issues will cover other interesting topics such as the latest in vehicle design and powertrain development.

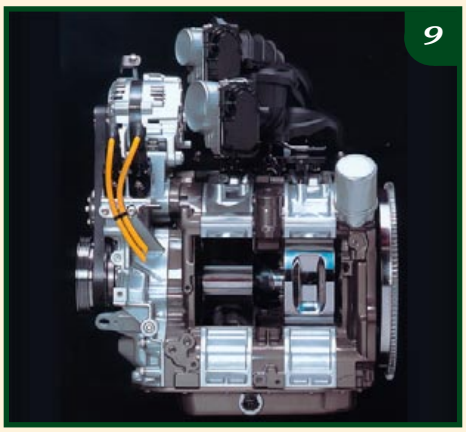
'Platform Sharing' has almost become an unsavoury term in the eyes of the consumer. Those who've bought at the bottom of the brand chain are happy. But recent analysis of the 2003 European sales figures shows that it's the premium brands that are experiencing the most customer sales growth and it's these purchasers that are most vocal in their disapproving of common elements.

Furthermore the explosion in niche variants is nothing short of startling. Automotive News Europe was moved to revise its recent market analysis report to include 20 segments instead of the previous 11. If you factor in the developments in cross-over vehicles in North America then 20 might not be enough!

So, how does an OEM resolve the ongoing needs of the consumer with those of the shareholder, and the capacity of the engineering department?

It is against this background that we report current thinking. I hope you'll enjoy the read.

Simon Wood, *Director - Lotus Engineering*



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UK: Denso most profitable major supplier in 2003

Delphi held on as the world's largest automotive supplier in 2003, but Denso was the most profitable among major Tier 1 companies and Bosch was the fastest growing.

Most managed to report sales slightly above expectations. Bosch was second in automotive sales to Delphi, and second in pre-tax profits to Denso. Bosch was helped by effects of currency translation since the rankings are in US dollars. Here is a look at the major suppliers' pre-tax results.

Denso

The Japanese supplier was the most profitable in terms of total pre-tax profits in 2003. Denso's pre-tax margin was 7.1% on sales of $US18.8 billion in the year to March 31st 2003.

Denso expects strong growth in the year to March 31. The company predicts sales of 2.440 trillion yen, equivalent to $22.8 billion at the year-end's exchange rate of 107 yen to the dollar.

Delphi

Sales came in stronger than expected in the final quarter of 2003. SupplierBusiness.com estimates that automotive sales for the year were $27.5 billion.

The better than expected result includes a $200 million currency exchange improvement.

The supplier's total revenue for commercial vehicles & new markets was approximately $1.3 billion, nearly 60% above 2002.

Delphi reported *"strong growth trends out of China"*, but *"weaker production schedules than anticipated among some North American customers"* due to year-end inventory positions.

Pre-tax income fell 40% to $471 million for 2003. But exceptional charges for restructuring pushed Delphi into an overall pre-tax loss.

Delphi expects sales of $7.2-7.4 billion in the first quarter of 2004, slightly higher than the $7.182 billion reported in the first quarter of 2003.

Bosch

Automotive sales in 2003 were 1% up in euro terms, despite being negatively affected by the strength of the euro. At constant exchange rates, growth would have been 8%.

Bosch's sales in China rose 20% in 2003 in euro terms.

The German supplier made good progress towards its target of a 7% pre-tax return, says CEO Franz Fehrenbach, with automotive technology showing improved performance.

Bosch does not specify profitability by sector, but the company said pre-tax profits were just under 5% of sales in 2003.

Traditionally, margins at Bosch's automotive technology division have been below the group average, so SupplierBusiness.com estimates that pre-tax income for the sector was about $1 billion in 2003.

Bosch expects the automotive technology sector to show *"a marked upswing"* in 2004, as global automotive industry growth reaches 4%, compared with 2003.

Visteon

The former Ford components division reported sales of $17.7 billion in 2003 - a drop of 4.2%. Pre-tax special charges of $749 million combined with operating losses to produce a total pre-tax loss of $1.15 billion - underlining the challenge faced by the company.

However the outlook on the sales side is a little better for 2004. Visteon expects sales to be between $4.8 billion and $4.9 billion in the first quarter. The US supplier reported sales of $4.7 billion in the first quarter of 2003.

Johnson Controls and Lear

The US interiors supplier was the third most profitable in pre-tax profits after Denso and Bosch in 2003. The results shown for Johnson Controls are for the 2003 financial year, which ended September 30th.

Johnson Controls expects margins to be roughly stable in its 2004 financial year, based on an improved European interiors' performance.

Lear Corp. sales finished at $15.75 billion, up 9% over the year before. Lear expects sales to grow to around $16.2 billion in 2004.

Source: SupplierBusiness.com

Top Award for Lotus Elise

The new Lotus Elise 111R is awarded Best Sportscar 2004 by Britain's leading monthly car magazine, BBC Top Gear.

This award adds to the already stocked trophy cabinet for the Elise, bringing the total number of awards to over 50 since the cars debut in 1995.

The Elise 111R, the latest addition to the Elise family, has a 1.8 litre VVTL-i engine (Variable Valve Timing & Lift intelligent) producing a maximum power output of 192PS (189hp, 141kw). Performance figures are of a supercar with a 0-60mph sprint of 4.9 seconds (0-100km/h in 5.2 seconds) before reaching a maximum speed of 150mph (241km/h).

Key to this phenominal performance is the Elise 111R's light weight of just 860kg making the British built sportscar not just one of the lightest sportscars on the market but one of the lightest cars on sale of any type! Coupled with a very strong and stiff aluminium chassis the Elise 111R continues to set standards by which all other sportscars are judged.

Ansar Ali, General Manager for Lotus Cars UK, is overjoyed with the award: *"Coming hot on the heels of the world debut of the new Lotus Exige at the Geneva Motorshow, I am delighted that the Elise 111R has won this award from such a renowned magazine. I would therefore like to thank everyone who has made the Elise such a success, from the engineering and manufacturing teams at our headquarters in Hethel, Norfolk and our Sales and Marketing teams and dealers around the world"*.

BBC Top Gear magazines Nik Berg sums up the reason for the Elise 111R winning the Best Sportscar Award 2004 *"The Lotus Elise 111R is quite simply the best Elise - and probably the best Lotus - ever"*.

GERMANY: EU regulations could add €5,000 per car

A delegation of top-level motor industry executives has warned European Commissioners that a complex regulation threatens their competitiveness as global players.

EU regulations taking effect over the next decade threaten to add more than €5,000 to the cost of every European car, states a leaked planning document from ACEA, the association of European carmakers, according to Automotive News Europe.

Volkswagen CEO Bernd Pischetsrieder, the incoming ACEA president, led the delegation to Brussels which included Renault CEO Louis Schweitzer, Fiat group CEO Giuseppe Morchio, Ford president Nick Scheele, CEO Leif Johansson of truckmaker AB Volvo and Ivan Hodac, ACEA secretary general.

They met with Commission president Romano Prodi, Vice President Loyola De Palacio (transport), and EU Commissioners Erkki Liikanen (enterprise) and Phillippe Busquin (research).

The delegation argued at the meeting that *"dense, complex and often conflicting"* EU regulations hamper the motor industry. They also said conflicts between the rules of the EU and various national governments create unnecessary administrative costs.

One manufacturer representative says complex regulations waste effort and resources. *"We end up spending a lot of money that could go into productive R&D,"* he said.

Manufacturers frequently don't get enough lead-time to comply with regulations.

"We understand the need and the benefits [of regulations]," he said. *"The question is: is there a more coherent way?"*

ACEA director of communications Alfredo Fillipone described the meeting as *"an interesting exchange of views."*

For the motor industry to better compete, Pischetsrieder called for:

- an integrated assessment of new regulations and policies
- a plan to improve the industry's competitiveness
- regular consultation
- a high-level working group focusing on the motor industry.

Source: just-auto.com

BELGIUM: EU and carmakers fail to agree on CO_2 emissions objectives

The European Commission has signalled it is sticking to an ambitious programme to cut vehicle CO_2 emissions, blocking overtures by the motor industry to reduce long-term objectives.

In a document published February 11, the commission reaffirmed its objective to reduce per-car CO_2 emissions to an average of *"120 grams per kilometre by 2005, and by 2010 at the latest,"* Automotive News Europe said.

Carmakers are unlikely to meet the 120g/km target by 2005, but *"it remains realistic to meet the objective by 2010 if the necessary measures are taken and all efforts are made,"* the commission said in a report to the EU council of ministers and parliament.

Beneath the bland language, carmakers and the EU are locked in a tug-of-war over how much and how quickly carbon-dioxide emissions will be reduced. It is a struggle fought with diplomatic politeness, but the stakes are high.

European carmakers are positioning themselves to ask to slow the long-term pace of CO_2 reductions. EU regulators are responding that they want to speed CO_2 cuts.

So far, the CO_2 reduction goals are voluntary. In separate agreements, ACEA, the European carmakers association, and Japanese and Korean carmakers pledged to cut emissions to 140g/km by 2008 (2009 for the Asian brands) and 120g/km by 2012 (2013 for Asian brands). But the EU can legislate stiffer rules if it is dissatisfied.

Last October, Renault chairman Louis Schweitzer, then ACEA chairman, told Automotive News Europe that 120g/km by 2012 was an *"unreasonable"* target.

Carmakers argue that consumers shun low fuel consumption vehicles and that the investment required to bring CO_2 emissions to the 120g/km level is prohibitive.

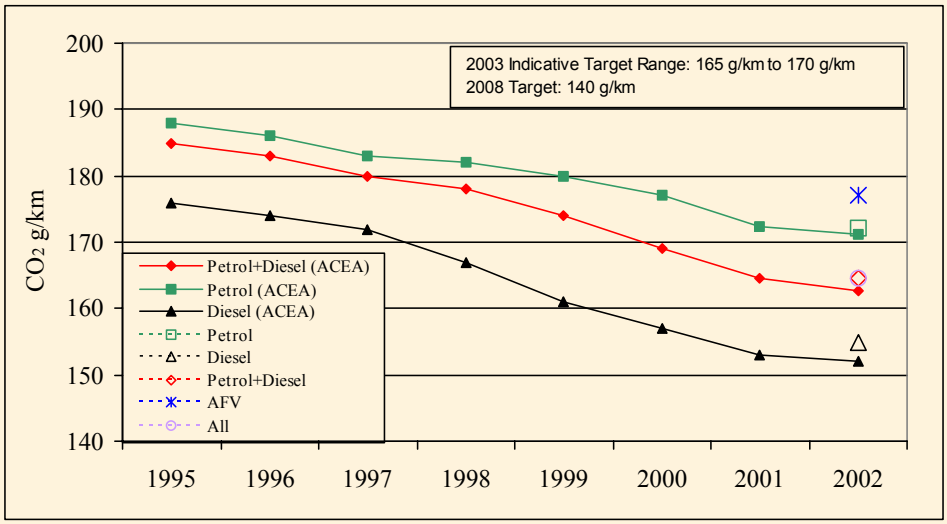
ACEA carmakers publicly say they can only meet their commitment to 140g/km by 2008.

But European carmakers may be ready for a compromise. EU sources say ACEA suggested in a preliminary note to the EU in December that cutting CO_2 emissions by 5% between 2008 and 2012 might be possible. This would mean a CO_2 emission average of 133g/km.

ACEA spokesman Alfredo Filippone denied the group made any such suggestion.

EU figures show the CO_2 reduction since 1995 has been slightly less than suggested by carmakers - 10.8% instead of 12.1% claimed by ACEA.

According to an EU official, who declined to be named, ACEA is being less transparent with its CO_2 figures than JAMA



EU Trends of ACEA members' fleet in average specific emissions of CO_2, based on ACEA data[9]. For 2002 the official EU data are added. 2001 and 2002 data are corrected by 0.7 % for cycle change adjustment.

GENEVA SHOW: Fiat and General Motors to share large car platform

Fiat will use the platform of partner General Motors to build a new large car, Fiat Auto chief executive Herbert Demel said on Tuesday, according to Reuters.

"Last week Fiat and GM signed an agreement according to which Fiat will use the GM Epsilon platform to derive the new upper-medium car," Demel told a news conference at the Geneva car show.

The deal would *"significantly reduce engineering costs and investments,"* he said, according to the report - the new large car is due for launch in 2005.

Fiat's last major car platform-sharing project was for the Croma, a range of large hatchbacks launched in the late 1980s, which shared its platform with Alfa Romeo's 164, Lancia's Thema and Saab's 9000 model lines. All four were in production for about a decade.

Fiat Auto already has a tie-up with GM in its Fiat Powertrain engine joint development operation and also shares the development costs and production facilities for a large minivan line and two commercial van lines with partners Lancia, Peugeot and Citroen.

Source: just-auto.com

USA: Americans rediscover V8 horsepower

Environmentally friendly cars may be trendy but powerful V8 engines are becoming more popular as Americans renew their love affair with horsepower, according to an Associated Press (AP) report.

Citing Ward's Automotive Reports, AP said that carmakers installed eight-cylinder engines in 29.1% of passenger vehicles built in North America for the US market last year, the highest rate since 1985 - the rate has risen every year since 2000.

In the same four-year stretch, smaller four-cylinder engines fell from nearly 27% to 25.3%, AP noted.

Associated Press said analysts and industry executives give a variety of reasons for the rise in V8s: strong demand for trucks and sport utility vehicles, relatively inexpensive petrol prices [though they are increasing again] and technology that is leading to improved fuel efficiency, even in bigger engines.

Consumer incentives also have allowed many people to *"buy-up,"* using cash rebates or low interest rates to help them nab a vehicle with a larger, more expensive engine, the report noted, adding that some simply want more muscle under the bonnet.

Aided by aggressive TV advertising, DaimlerChrysler's 345-horsepower 'Hemi' V8 has emerged as the standard-bearer for beefy engines, AP said, adding that the engine gets its name from the hemispherical shape of its combustion chamber, allowing it to produce more power and achieve greater fuel economy.

Lee Weinman, a Ford dealer in Chicago, told Associated Press the fact that major automakers are beefing up engines at the same time they are spending billions on hybrid vehicles and fuel-cell technology speaks to the increasingly diverse tastes of American drivers.

For example, Nissan, which made its name in the domestic market selling small, fuel-efficient cars, recently launched the full-size Titan pickup with a hefty V8 engine to challenge models from the Detroit-based Big Three carmakers. Nissan also added a bigger engine and more horsepower to its latest Altima sedan, AP said.

But Associated Press noted that, while many consumers are choosing bigger engines, more also are opting for more ecologically friendly petrol-electric hybrid vehicles. For now, the only hybrids available in the United States are small cars made by Honda and Toyota, yet sales have risen from about 20,000 in 2001 to 47,000 last year, according to JD Power and Associates affiliate Power Information Network.

Motor Trend magazine, which often splashes the latest hot rods on its cover, even named Toyota's hybrid Prius its 2004 Car of the Year, AP said.

"There definitely seems to be a trend of buyers looking for more power, but a successful manufacturer pretty much has to have a wide offering to remain viable," Weinman told Associated Press.

Daniel Becker, director of the global warming and energy project for the Sierra Club, told the news agency that another trend in the US car industry is also telling - the continued expansion and sales gains of foreign carmakers, particularly Toyota and Honda.

AP noted that the Sierra Club and other environmental groups have been critical of Detroit carmakers in recent years for focusing more on large SUVs and pickups than on hybrid and other *"green"* technology.

"There will always be a market for the gas-guzzling powerhouse, but the American manufacturer seems to be willing to lose market share as Toyota and Honda bring in better technology," Becker told Associated Press.

UK: GM strays from its common architecture strategy

General Motors' top executives make much of the importance of leveraging *"vehicle architectures"* across the corporation's vast global product range.

Plans to derive a small Cadillac from the Epilson-based Saab 9-3 are the latest example.

So why did GM choose to develop an all-new architecture for the Pontiac Solstice sports car? Indeed, the lack of discipline leads to doubts about the company's commitment to cost reduction.
Yet one wonders if GM's Bob Lutz-led product planners are finally beginning to see the light - that the extra margins earned by successful products far exceed savings from platform sharing.

The Chevrolet Cobalt and Pontiac G6, launched at LA and Detroit respectively, show how GM is implementing its global architecture strategy across its brands. But there are concerns that GM has drifted from this strategy.

The Cobalt is built on the Delta architecture, which also includes the Saturn Ion. But the Pontiac Solstice, in the same size category, required a completely new architecture, called Kappa.

General Motors has reacted quickly to critical acclaim for the Solstice concept shown two years ago. But it could not capture the key qualities of the car using the Delta underpinnings. As a result GM is now seeking other uses for Kappa. The Saturn Curve and Pontiac Nomad concepts shown at the Detroit auto show are two possibilities.

No compromise approach

"To get the Solstice right they obviously decided they had to stray off the platform," says Michael Robinet, a US car market expert with industry analysts CSM Worldwide. *"Basing it on Delta could have been easier but GM is taking a no compromise approach."*

GM has already had problems extending the use of Delta to Europe since forming the GM-Fiat alliance. The next generation Astra will use the joint GM/Fiat C-platform. The new 2004 Astra is basically a heavy update of the older GM3000 platform.

The Chevrolet Corvette, a key brand builder, also retains its own platform, the C6. Low ground clearance sports models seem to require their own platform at GM, in contrast with Volkswagen, which bases the highly successful Audi TT on the Golf platform.

The Pontiac G6 does stick with the architecture strategy, sharing the high volume Epsilon platform with the Opel Vectra/Signum, Saab 9-3 and Chevrolet Malibu.

Epsilon disappointments

GM is looking for annual volume of 200,000 units from the G6, but other models on this platform have so far had a disappointing reception. Sales of the Vectra/Signum have not reached predicted volumes and the Malibu has similar problems.

"The interior is not where it needs to be," said Robinet.

Adding variety to its product line-up is critical to GM's global competitiveness. While it is not necessarily delivering these new models very efficiently at the moment, increased commonality is a goal of the company.

But with so many brands GM has the most complex task of all OEMs in this area. It will take many more years to deliver the right combination of commonality and product excitement.

Manufacturing processes is a complicating factor. Processes for a low volume vehicle are different from a high volume model. That can justify a different architecture.

When GM decided to develop the Kappa architecture it could instead have modified the Delta platform, said one GM executive. But engineers saw the opportunity to develop other low volume models, such as the Nomad and Curve, off the new platform.

GM was the first carmaker to use a comprehensive platform strategy. Forty years ago it was rebadging the same cars across its American brands. But over time the strategy resulted in a series of uninteresting products - one of the reasons Japanese carmakers made such huge inroads into GM's US market share in the 1970s and 1980s.

One of the ingredients of successful companies such as BMW is a willingness to ignore the parts bin if the concept demands it.

Taking risks with a small sport car may be the wrong way for GM to start. It certainly is contrary to plan. But engineers may have slipped this one past the 'beancounters'.

Pontiac G6

Source: SupplierBusiness.com

UK: Shell predicts future fleet fuels will be improved rather than newly developed

Improving existing fuels rather than developing new ones will probably power the fleet vehicles of the future, delegates to the Fleet News Europe Conference 2004 were told.

Giving a view of fuels in 2020, Shell International's European fleet manager, Ann Cormack, said cleaner diesel was likely to be the preferred option for companies, especially with those that frequently have vehicles operating in cities.

She said LPG and CNG would continue to be niche fuels and biofuel was also increasingly on the agenda but its CO2 impact depended on how it was produced.

She said: *"The challenge for fleets is how to choose which fuels to use. There are three main concerns which we share with our customers: cost – fuel can be the majority of cost depending on vehicle portfolio; availability – the network and infrastructure need to be in place and sustainability, we don't want to put our effort into something that will run out after 25 years."*

She said improvement to existing fuels was the preferred solution as the technology was available, it would meet government and EU environmental requirements, the existing infrastructure was sufficient and there would be a minimal cost increase.

Cormack said hydrogen has the potential to be the ultimate fuel - but significant technology and infrastructure hurdles have to be overcome. She added that, as a result, it would be some time before fuel cells became a reality.

Source: just-auto.com

Drivers – Start your engines: A legend is reborn

After an absence from the market place for 2 years, Lotus is reintroducing the Lotus Exige - a car that at the time revolutionised the hardcore sportscoupé market despite being on sale for just over 18 months.

The first generation Exige was introduced to the world in early 2000 as a pure race car for the road. Born out of the successful Lotus Sport Elise racecar, which was campaigned throughout Europe with such success in 2000 and 2001, the Exige was hand built in low numbers for a few markets around the world.

The second generation Exige, unveiled as a world debut at the Geneva Motorshow in 2004, takes the same racecar-for-the-road philosophy and applies it to the driver of today.

With phenomenal performance and handling, powered by an advanced 1.8 litre VVTL-i (Variable Valve Timing with Lift - intelligent) engine producing a maximum power output of 141 kw and 181 Nm of torque, the Exige sprints to 100 km/h in 5.2 seconds and 160 km/h in 13.2 seconds before reaching a certified top speed of 237 km/h.

Key to this phenomenal performance and handling is the total aerodynamic package (which gives 41.2 kg of downforce at 160 km/h - 19.3 kg: front and 21.9 kg: rear) and light weight, the latter made possible through innovative engineering and clever design; indeed the Exige weighs in at 875 kg - unladen with no options - giving a power to weight ratio of 161 kw/t.

For more details on the new Lotus Exige please click here.

The hydrogen promise of Mazda's rotary engine

By Jesse Crosse

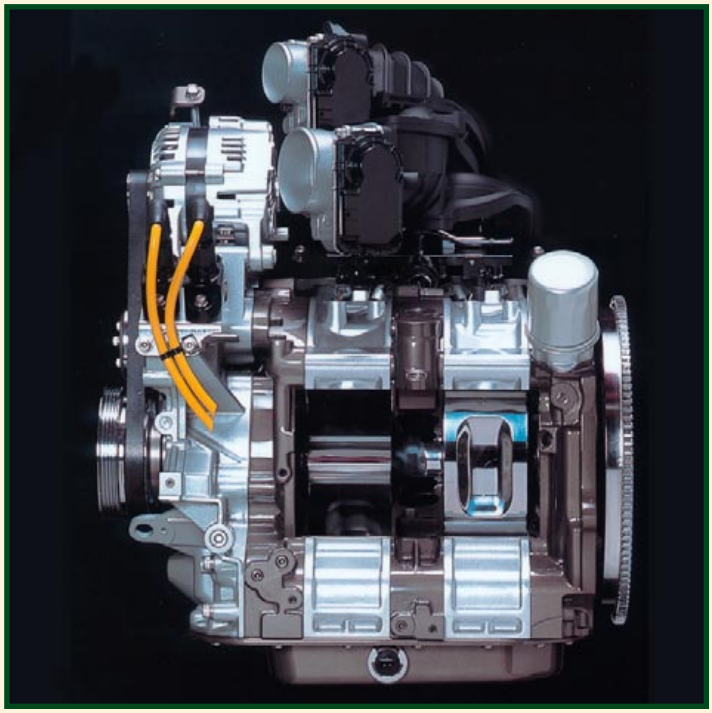
Eighty-five years on from the night when Dr Felix Wankel allegedly dreamed of piloting his own car powered by an engine that was half turbine and half reciprocating, the rotary engine has conspicuously failed to evolve as quickly or successfully as its piston-equipped counterparts. But the rotary engine has inherent attributes that could make it eminently suitable for running on hydrogen. Mazda is seriously looking into it.

After a brief flirtation by NSU/Wankel in the 1960s with the NSU Ro80, only Mazda was prepared to battle on against the increasingly insurmountable odds of wear, high consumption and emissions that came with the territory. The last serious commercial foray with the RX7 in the 1980s was eventually defeated on the last two counts, but in 1995, Mazda resurrected its rotary concept with the Renesis engine. In 2003 the Rotary made a commercial return to niche markets in the new Mazda RX8 with emissions, wear and consumption problems apparently under control once and for all. And now, as the automotive industry moves into its third Millennium, Mazda's persistence could be about to pay off. Because by all accounts it seems the rotary engine has inherent attributes that make it eminently suitable for running on hydrogen.

Despite Ford's own activities in the field of hydrogen-propulsion, such as the alliance with DaimlerChrysler and Ballard and its own fuel cell and H2ICE programmes, Mazda has been able to pursue its own hydrogen ambition. Senior research engineer on the Hydrogen RE project, Masanori Misumi, emphasises how serious Mazda is about its alternative fuel programmes. *"Since 1990"*, he says, *"we have put more priority on hydrogen energy, conducting considerable research on hydrogen projects including hydrogen storage systems."* Early attempts at developing a hydrogen rotary engine were fairly rudimentary, explains Misumi, because there were no bespoke hydrogen injectors available. *"In 1991, the hydrogen was metered by a needle valve upstream from the engine, then a poppet valve in the engine itself let the hydrogen in, but fuel metering was poor."*

The rapid growth of compressed natural gas (CNG) engines for commercial use during the last decade spawned the development of electronically controlled gas injectors and were exactly what the hydrogen men had been waiting for. At last, it became possible to meter the ingestion of gas into the engine accurately. In the case of the rotary engine, the conversion was relatively simple compared to a reciprocating ICE. *"We put the injector in the top of the cylinder and we are proud of the fact that no other modifications were necessary - just the integration of this injector,"* recalls Misumi.

The physical dimensions of the rotary means that unlike a reciprocating engine there's plenty of room and the RE has two hydrogen injectors delivering gaseous fuel to its combustion chamber. Using two helps to overcome the fact that hydrogen has a lower volumetric energy density than gasoline and so a much greater volume of the gas must be injected. Once injected though, there's more time for the hydrogen to be thoroughly mixed with air because the rotary engine's output shaft turns through 270 degrees in one intake cycle compared to 180 degrees for a reciprocating engine. Mixing not only occurs over a longer period, but the vigorous intake flow ensures a more uniform mixture of hydrogen and air, something that's essential for satisfactory hydrogen combustion. The Renesis is also unique in being able to run as a dual-fuel hydrogen-gasoline engine, an important feature because packaging is at a premium in the RX8 and its small hydrogen tank only gives a gaseous range of 50-60km.



But when it comes to hydrogen combustion, the rotary enjoys a much more fundamental advantage and as Misumi points out, *"its intake and combustion strokes are completely separate"*. In each cylinder of a reciprocating engine, induction, compression, power and exhaust events all take place in the same physical space, the type of stroke that is occurring being controlled by inlet and exhaust valves, the fuel injection system and the ignition timing. When the new charge is inducted, it arrives into a hot environment and unless the mixture is set lean backfiring can occur. This contributes to the fact, says Misumi, that *"output of a normally aspirated hydrogen reciprocating engine is 30 percent to 40 percent of a gasoline equivalent."* Early versions of the rotary ran close to the same 'stoichiometric' chemically correct mixture setting as a conventional gasoline engine and used a conventional three-way catalytic converter. This was made possible by the cooler environment of the separate inlet chamber into which the fuel is being induced.

The lower temperatures also mean injectors can be fitted with rubber seals to prevent hydrogen leakage. Consequently, its output was much higher than usual for a hydrogen ICE, the rotary reaching almost 90 percent of the power it would produce running on gasoline. However, to achieve lower NOx emissions it was necessary to settle for a halfway house. Stochiometric mixture is also known as 'Lambda 1'. The Mazda engineers found that with a leaner mixture of Lambda 1.8, NOx levels fell close to zero at 2ppm but the trade-off was a drop in power from 210PS to 110PS.

To compensate, the next generation will have both a turbocharger and hybrid drive. The turbocharger will draw on technology being developed for diesel engines, its turbine electrically-assisted at lower engine speeds (from 1,000rpm) when exhaust gasses that normally drive it are flowing more slowly. A 10kw mild hybrid drive motor in line with the engine's crankshaft will provide 10kW (13.6PS) of additional power. The target, says Misumi, is to achieve the same output as a gasoline equivalent, the cost ending up at the equivalent or slightly less than a full hybrid system. A 144-volt battery provides electrical storage and powers the stop-start system which kills the engine whenever the car comes to a halt to reduce consumption and emissions, then starts it again when the driver presses the accelerator. The electric hybrid motor draws power from the battery during low speed acceleration to boost engine power. Then, when the driver lifts the accelerator pedal, the motor becomes a generator, the force required to drive it helping to slow the car and the electricity produced being used to charge the battery in a process called 'regenerative braking.'

The use of compressed hydrogen gas is becoming a more popular alternative than cryogenic storage of liquid hydrogen because refuelling is a safer, more simple process not unlike filling a car with LPG. In contrast, the problems associated with members of the public handling liquid gas delivered at -253 degrees Centigrade are greater and may only be possible using robotic filling rigs. Liquefied gas also has the disadvantage that it evaporates or 'boils off' over time as the storage flasks inevitably warm up. The downside of compressed gas is unease over the storage pressures (despite full US and European safety certification) and the fact that at 350bar (5,000psi) the energy density by volume is lower than that of gasoline, restricting range. In common with Ford fuel cell vehicles the RX8 stores its gas in a Dynetek, alloy-lined composite tank at 350bar (5,000psi). A number of manufacturers are working on similar high pressure hydrogen storage devices drawing on experience gained in the more conventional use of CNG (compressed natural gas). 700bar tanks are under development and the energy they store at the higher pressure is claimed to be much closer to that of gasoline occupying the same volume.

Mazda is no beginner in the field of hydrogen propulsion. It developed the HR-X , a hydrogen engine study, in 1991, the HR-X2 rotary together with a hydrogen powered MX5 roadster followed in 1993 and the rotary-powered Capella Cargo in 1995. In 1997 it showed its Demio fuel cell car for the first time, with the Premacy FC-EV following in 2001 and the latest idea, the RX-8 Hydrogen RE breaking cover at the Tokyo Show last October. During the course of these projects Mazda explored various means of storing hydrogen. The Premacy FCEV carried an on-board methanol reformer and became the first of its type to be both publicly tested and government approved in Japan. In 1995, the Capella carried a metal hydride hydrogen storage device where the gas is literally absorbed into the material and then released on demand. Misumi says energy density using this approach was good and bettered that of liquid gas. But the weight penalty, some 400kg, has so far proved insurmountable. Hydrides are also slow to fill. Substantial heat is generated during the filling and release of hydrogen and they are costly.

Other companies are seriously pursuing the development of hydrogen ICE vehicles, notably Ford, which is using the global I4, 2-litre reciprocating engine as a basis in conjunction with Lysholm screw-type superchargers. BMW, having publicly eschewed an expensive fuel cell propulsion programme that in any case would not sit comfortably with a brand that occupies the prestige performance end of the market, also has an active hydrogen programme including both V12 7-Series Cars and the MINI. Overall, the outcome for hydrogen combustion engines looks promising and if they ever proliferate, will contribute to solving the biggest problem which is not the development of clean, hydrogen-consuming propulsion technology, but developing a hydrogen economy to support them.

How to have your cake and eat it

By Anthony Lewis

The automotive cake used to be easy to slice. Five or six slices of varying sizes and most were able to feed reasonably well.

Today that cake is divided into so many slices that some must be trying to survive off crumbs. Or, put it another way, niches within niches.

Depending on how you define your model line-up, there are now as many as 20 different segments, or slices, that need to be taken seriously.

As an easy example, look at BMW. The company had three core models (five if you include estate or wagon versions) and now has seven.

The European market consisted of around ten segments, depending on how you wanted to define it. Today that could easily be 20 or so. This splintering has been spurred by the growth of niche vehicles - a growth that shows no signs of diminishing.

According to figures from JATO Dynamics, car makers sold 428,000 more specialist, or niche vehicles last year in Europe, a 16.8 per cent increase to almost three million units, while there was a decline of 656,000 *"traditional"* cars such as hatchbacks, saloons and estates, representing a 5.5 per cent slide.

Within that blossoming niche market, small people carriers like the Vauxhall/Opel Meriva and Ford Fusion, showed the biggest growth, up 69.6 per cent while what might loosely be described as *"coupés and roadsters"* also saw significant growth, up 21.4 per cent.

No prizes for guessing that the Peugeot 206CC is the leader here, accounting for one-in-three of all segment sales - a segment that also includes Mazda MX-5, Toyota MR2 and Ford StreetKa.

Elsewhere among the layers of this particular mix, the van-derived cars have gone all posh and become *"multispace"* vehicles - and sales increased 5.1 per cent last year, led by the Renault Kangoo and Citroën Berlingo.

From just these few examples, a picture emerges of a rapidly, even radically, shifting market. It is also worth noting that one of the biggest casualties of this shift has been the traditional large car sector from volume brands, down by 20 per cent in 2003.

Also down, by 22 per cent, was the city car section - Ford Ka, Renault Twingo, VW Lupo et al - but that was probably more to do with lack of new models in 2003 than anything else; Fiat Panda made a late entry in 2003, but that was about it.

So, why and how has this happened? There are several strands worth exploring.

The first is that the speed of car makers to go from design to production has increased greatly, aided by the advances in CAD-CAM design technology. Where design freeze to job 1 was typically 30-36 months, it is now more in the order of 20-24 months; some car makers are suggesting that could be reduced to 18 months quite soon.

But since it all starts at the design stage, what is the designer's point of view? Jaguar's Ian Callum believes that crossover vehicles are the next niche.

"We are already seeing them in concept form, particularly in the United States, and this trend will inevitably make it across to Europe. They are designed to bridge the gap between sports utility vehicle and estate car. In the United States auto makers are also looking at a substitute for minivans, which have lost much of their glamour or appeal.

"Most manufactures are covering the spectrum from A segment vehicle to full-size sport utilities. Companies like Mercedes-Benz and Volkswagen are even moving into the super luxury car market (with Maybach and Phaeton).

"I think that what we are likely to see beyond crossovers in the future are more sports cars - even Volkswagen is understood to be looking at doing a sports car to stretch the brand still further," said Callum.

As for Jaguar itself, *"I would like to do an SUV, but we are not in a position to do one. We are not a big player, we are only producing*

Peugeot 206CC

"At PAG we have to be careful not to cannibalise sales from each other. If Jaguar were to do an SUV, what impact would that have on Land Rover, for example?

"Now that we have an estate car (X-Type) a crossover vehicle of some sort could be a possibility, but we would have to address a number of problems, particularly off-road performance because there is a ride-height issue.

"I would rather wait and see where the cross-over trend ends up to fully understand it before we make any decisions at Jaguar."

That cautious approach is a luxury that Jaguar can afford while volume car makers can't.

Their cause has been helped enormously by advances in more flexible manufacturing systems, a point highlighted in a recent report from CSM Worldwide. *"In an increasingly competitive environment, OEMs continue to be pressured to find new offerings based on highly flexible platform architectures,"* said CSM.

It is predicting growth in *"tall B-segment programs"*, which we have already identified as *"small people carriers"* like the Fiat Idea or Renault's upcoming J77, as an example of this trend.

"You need to be a little bit of everything to survive"

CSM is also predicting that Europe's C-segment - or lower medium - will grow by one million units to 6.2million between now and 2009, and the A Segment, or city car, by 0.7million to 1.7 million units, spurred by new arrivals, and reversing last year's trend.

Ian Callum's brother, Moray, design chief at Mazda Motor Corporation in Japan, gives a different twist to the idea of niches. Now that the Mazda brand has been revitalised with what Moray describes as *"a succession of good launches since the Mazda6 in 2002"*, the company would start going into different segments.

"We need to expand the range and some products will be geographically specific. There is obviously the potential in North America for non-car vehicles, 4x4s and SUVs, but with limited resources we need to do things differently. The RX-8 is a typical example - it's a sports car but it's practical.

"We are not going to be pigeon-holed by segments. In North America we might be seen as a Japanese import company up against Nissan, Toyota and Honda, but in Japan we are equally popular among race car enthusiasts as pick-up truck fans."

"You need to be a little bit of everything to survive."

It is that sentiment that takes us to perhaps the most fundamental reason for the inevitable growth in niche vehicles. In a 2003 report, the EC's Futman Project (Future of Manufacturing in Europe 2015-2020 - the Challenge for Sustainable Development) suggested that *"flexibility and customisation were the new techno-organisational concepts in the automotive industry."*

"Ten years ago, the Japanese model 'lean production' was the portfolio for organising manufacturing processes. Today it is obvious that there is more to being competitive although many elements of the lean production concept have become standard means of organisation."

"Today flexibility and the ability to customise products are gaining importance. One of the major problems in this respect is how to handle increasing complexity and how to ensure integration while maintaining economies of scale and keeping capital lockup in manufacturing equipment under control," said the report.

And it came up with this intriguing *"blue sky"* vision from an un-named European car maker as a vision for manufacturing cars in 2020: *"Small scale factories producing 5-10,000 cars a year. The space frame and other basic parts would come from suppliers closer to the assembly factories. In the factories, components chosen by the customer are added."*

That is, surely, the ultimate in niche models.

One of the other nuggets from the Futman project was there is now major awareness of the arguments over whether it is best to build-operate-own or pay-on-production. This is because increasing flexibility is not only looked for with respect to product variants but with respect to the volume or capacity of production, too. But the report points out that there are too few examples to be conclusive.

Modularisation - or *"construction kits"* - and how platforms are used works at different levels of the supply chain, with respect to the product as well as the manufacturing equipment.

But there does seem to be different approaches among OEMs in Europe and in Japan on how to balance the reduction of complexity on the one hand and the integration of the different modules and systems into one working car on the other hand.

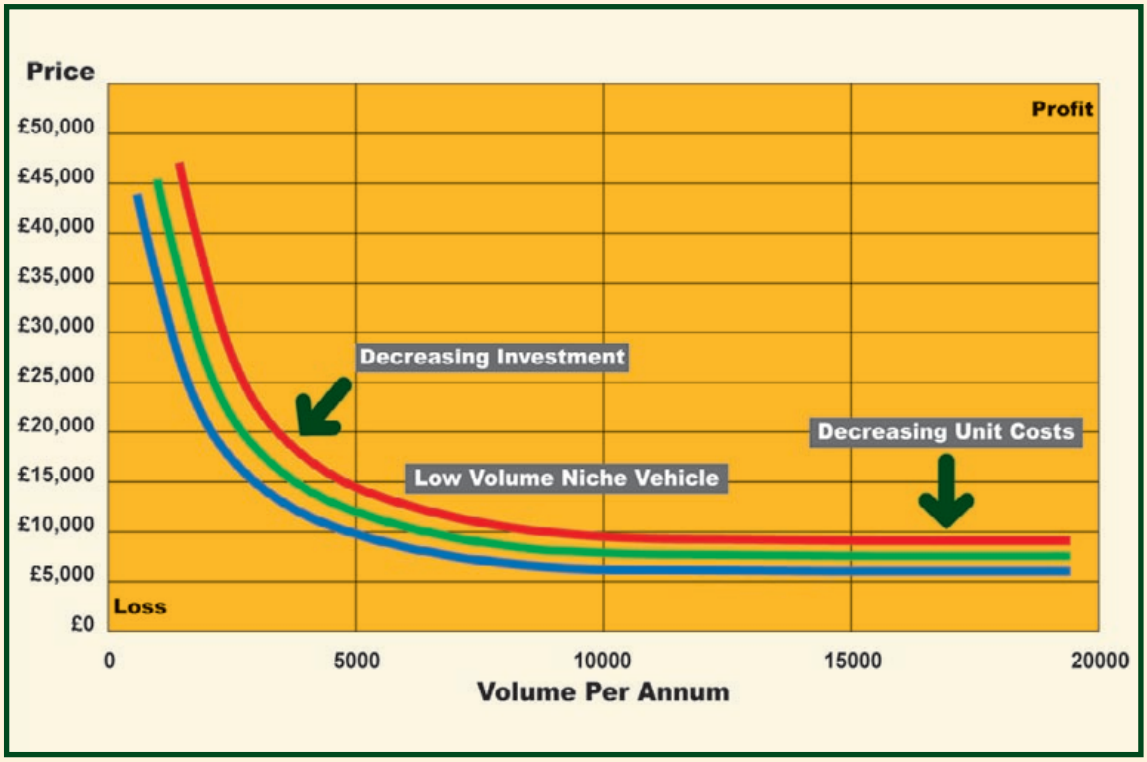
While European companies rely increasingly on networking with strong, independent suppliers, the Japanese tend to a more hierarchical system. While the first seems to have advantages with respect to innovation the second may foster the reliability of the car as a whole.

Another means of reducing complexity and making the manufacturing process reliable and flexible could be the localisation of production in possibly smaller factories close to relevant markets, an idea hinted at by Mazda's Moray Callum, and one that fits perfectly with a re-definition of niche vehicles - by type and by geographical location.

Cost Effective Niche Vehicles of the Future

The automotive market place is more competitive than ever. Customers are increasingly demanding exciting new products, but at a reasonable price. This forces OEM's down one of two routes, either differentiated exciting products or mass market lower investment products.

The marketplace for modern mainstream volume cars is a constantly evolving dynamic, and currently has very different characteristics to a decade ago. For example, there is no longer a 'family car' segment, but several sub-segments from the Meriva to the Grand Espace (MPVs), the Vitara to the Land Cruiser (SUVs), Berlingo to Vaneo (van-based derivatives). As product differentiation increases, so volume per product line decreases, and it becomes harder to generate a business case.



Meanwhile, limited product development budgets forced Lotus engineers into a lateral approach to maximise the return on the investment in new products.

Nick Sampson, programme director at Lotus Engineering explains the course of events leading to the development of a paradigm-changing technology. *"As we set about maximising the learning from the design and development of the bonded extruded aluminium Elise chassis, our OEM clients were inquiring about how to improve the business case for genuinely unique niche products. It led us down the challenging path to where we see ourselves now, on the brink of prototype build of a truly unique niche vehicle."*

After four years of conceptual development, Lotus recently announced details of the technology, which it is applying to a future family of premium Lotus sportscars and to vehicles for an undisclosed client. A novel approach and an innovative technology, it opens the door for more accessible niche vehicle development. It is real and it is happening, and Lotus Engineering refer to it as Versatile Vehicle Architecture (Lotus VVA).

The original feasibility study looked at fundamental business case parameters. A simple business model was produced identifying investment costs, unit costs of production and overheads. These 3 parameters varied between different niche products, but a definite pattern emerged as shown in figure 1.

"What we learnt may seem obvious in hindsight, but it was work that needed doing to confirm where we needed to concentrate," explains Sampson. *"Each curve shows the lifetime break-even point for a benchmark niche product. Selling at a price and volume above the line earns a profit, whilst below the line means a loss over the lifetime of the product. The break-even point for lower volume products is dominated by investment cost, and for higher volume products by unit cost."*

Sampson and his researchers then discovered the key factors Lotus' clients were struggling with. *"Legislative requirements for safety, emissions and recycleability raise the required investment costs. In parallel, increasing consumer expectations for product features and product performance exerts high pressure on unit costs."*

The conclusion reached is that to ensure profitability at low volumes (below 10,000 p.a.), both the unit cost and the investment burden must be targeted for reduction.

Vehicle platform systems

Using the results from the analytical research, the Hethel-based engineers studied the total life costs of a range of typical niche vehicles in terms of development, tooling investment and bill of materials cost. They discovered that 7 key areas account for over

65% of the life cost of a vehicle. This group of component-sets commonly defines the vehicle platform, and many could enjoy high levels of commonality across different vehicle variants.

The Vehicle Platform Structure

Initial research identified four major structural corner nodes as key elements to the approach, each joined by a series of linear structural sections and stamped or folded sheet. A very simplistic initial proposition, based on sound groundwork.

The primary thinking behind the simple structural model was derived from looking at the current solution in the Lotus Elise. The technology developed through 1994-5 was a simple, effective and low cost solution but was restricted in terms of versatility and package.

Various alternative structural arrangements were considered and evaluated before striking the ideal, most versatile solution which incorporated a complex node at the base of the 'A post'.This philosophy was then continued for the rear corner of the structure.

In order to maximise the scope to which the versatility of the solution would be applied, three considerably different structural concepts were considered:

- Front-engine, front wheel drive, low-dominated monocoque
- Mid-engine, rear wheel drive, semi-monocoque tub
- Front-engine, rear wheel drive, semi-monocoque tub

Commonality and adaptability

Combining the results from the studies into vehicle platform systems and structural versatility, Sampson's Lotus engineers developed a solution that combined commonality and adaptability. Commonality and adaptability offers significant opportunity to share tooling and development (investment cost), and to reduce piece part costs (unit cost).

Having identified the areas for reduced cost, attention turned to the technological solutions for the structure. Three material combinations were conceived and evaluated:

- Aluminium castings, extrusions, and sheet as per the original concept
- Steel pressings and roll forms utilising latest steel material technologies
- Aluminium castings, extrusions, pressings and roll forms

In addition, body skin materials were evaluated in steel, aluminium, composites and plastics, accounting for investment and volume considerations. Furthermore, Sampson and his team studied a range of joining technologies:

- Welding: resistant spot welds; gas welding
- Mechanical fastenings: self pierce rivets
- Adhesive bonding: cold cure; hot cure
- Hybrids: riv bonding; weld bonding

First realisation of Lotus VVA

In August 2002, Lotus signed up its first client for VVA. Having conceived the range of vehicles required from the programme, this first realisation of Versatile Vehicle Architecture focussed initially on the choices available to the client. A range of materials, processes and joining technology options were discussed at length before decisions were taken and vehicle concept initiation kicked off.

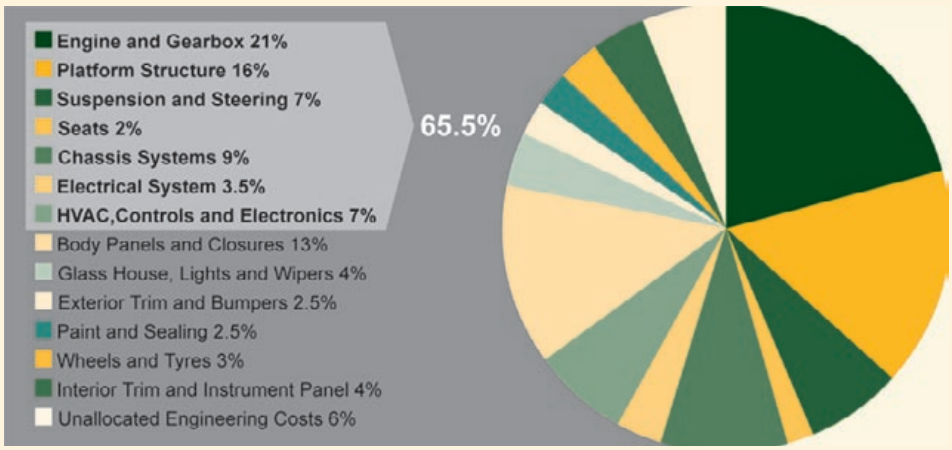


Figure 2: Typical Vehicle Cost Breakdown

> "This exciting first project will demonstrate the versatility of VVA"

Aluminium castings have been selected for the corner nodes, and the remainder of the structure is made up of a combination of aluminium pressings and extrusions. Finally, the exterior body panels are also aluminium. A hybrid solution combining self-pierce rivets and adhesive bonding has been selected for the joining technique, an area in which Lotus Engineering is able to offer considerable knowledge and experience.

The highly complex cast aluminium corner nodes provide the greatest challenge, as they account for a relatively high development and design effort. The complication arises in the design of the nodes for application to each vehicle variant, while also meeting the required crash legislation and enabling wide packaging variability between each variant.

Closing in on prototype build...

The programme is now rapidly approaching the next major stage, to produce the first prototype vehicle. The programme will support a range of cars from a low slung luxury sports car to a saloon car to compete in the executive segment. The first vehicle, however, will be a crossover vehicle combining the attributes of an SUV, MPV and sports car.

"*This exciting first project will demonstrate the versatility of VVA to achieve a range of new and unique products that differ widely in configuration, layout and package*

"Increasing consumer expectations for product features and product performance exerts high pressure on unit costs"

arrangement," explains Sampson. "*Critically, however, commonality of vehicle platform systems across the variants within the programme and adaptability of elements of the vehicle structure is realising significant investment and unit cost savings, which is key to this technology solving the issues we need to overcome.*"These recent pictures (below) show parts of the vehicle structure for one of the current programme's variants.

The adapted parts are linear in shape and require a relatively low investment for application to other variants. This allows changes to length and overhangs with minimum cost.

The overall programme costs of doing a family of vehicles based on the VVA architecture has been found to offer significant savings compared to a range of individual standalone projects.

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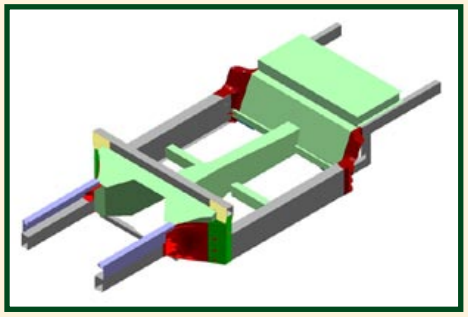

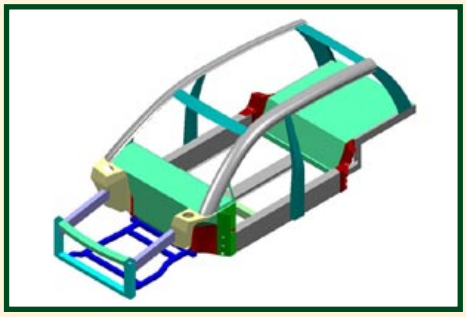

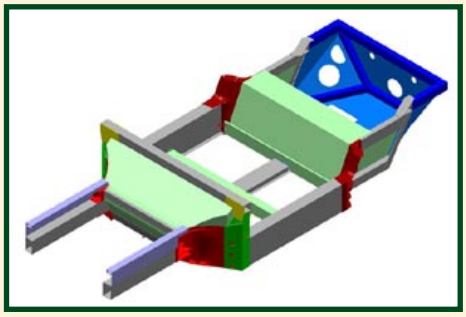

Common parts in red ; Adapted parts in blue

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