CARS

Electrification - Effects on Vehicle Architecture

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• The automotive industry is undergoing great change in these times

• Vehicle electrification is one of the key disruptive technology trends

• These innovations also change the way customers view and use vehicles
• It is now evident that the simple installation of electrical systems on legacy architectures is not the long term solution

• These considerations should guide how to approach next generation vehicle concepts

• Tesla has been leading in showing how a clean-sheet electric vehicle architecture approach leads to innovative products
From a Lotus perspective, it is peculiar that Tesla actually started its propositions on a Lotus basis with the 2008 Roadster.
The Tesla Roadster was essentially the installation of Tesla electrification systems on a specifically developed Lotus Elise, a RWD architecture.

The vehicle was developed and produced at Lotus – at the time, Lotus became the site producing the largest volume of electric vehicles.

Clearly, a first-generation, legacy-based approach.
• This approach enabled Tesla to make a specific product proposition, aimed at environmentally and technically minded sportscar customers

• On this basis, Tesla was able to market its technology and gain invaluable field experience
For its subsequent products, Tesla then evolved the Roadster technology experience to complete vehicle clean-sheet approaches.

These products not only deployed Tesla’s electrification technology differently.

They also showed the innovative product proposition potential of not being constrained by legacy products and processes.

The product architecture platform provides for flexibility in terms of battery sizing and the choice of RWD of AWD on all vehicles.
• Tesla’s lead has become a reference in terms of electric vehicle architecture

• The «battery skateboard» concept seems now the mainstream approach to clean-sheet electric vehicle offerings
• The battery of an electric vehicle has also become a means of increasing vehicle structural integrity and passive safety.

• The lowered center of gravity also increases active safety.
Other new technology trends seem to be well suited to electric vehicles:

- Tesla is demonstrating how electric vehicles benefit from connectivity for over-the-air updates
- Other propositions have adopted the notion of one-wheel, one-motor, for vehicle dynamics purposes
  - Autonomous driving is also a growing trend, again well paired to electric vehicle technology
- Will these architecture concepts become the long-term solutions?
What are the alternative approaches?

✓ Current battery technology requires considerable space, and has been leading to a «sealed box» concept

✓ The quest for increasing battery performance for range has given impulse to basic battery chemistry and physics research, therefore with long-term result expectations

✓ The push to «one-wheel, one-motor» has downplayed the contribution that driveline technology can still really provide
VISION:

1. Battery Skateboard - field experience of battery skateboard vehicles will be slower to realize
   ✓ Little or no comparison of vehicle architecture alternatives
   ✓ Development will concentrate on incremental battery function improvements – linked to cell, software, and electronics technology
Battery skateboard vehicles – additional considerations:

• «Easy» on high vehicles, on a simpler, continuous shape – consequence: vehicle weight and large frontal area

• Lower vehicle occupant packages lead to interrupted and complicated shapes
  ✓ Compromises in terms of energy, battery weight, and cost
  ✓ Only significant energy and power density increases would simplify this situation

• Sealed box, complete battery replacement is a very expensive proposition, a non-purchase factor for customers
• Cells as flashlight batteries; module or cell replacement – vision for more sustainable battery durability
• Taking this to an extreme, a single defective cell alone could potentially be replaced
Some concepts have partially gone in that direction, with multiple and replaceable independent smaller battery modules.
VISION:

2. Avoid multiple motors and transmissions at each axle

   • For AWD, axle driveline separation seems sensible – no propshaft, more space where battery is efficiently located
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   • At each axle, more than one driveline seems redundant
     ✓ Each independent motor-wheel connection involves a specific motor, inverter, and driveline
     ✓ The desire to control vehicle yaw because of the fast response of electric motors may not be necessary, given the low frequency of yaw response
• Fast electric motor response may instead be very effective as a non-dissipative traction control
• It may also be a way of identifying more, fast-transient, recuperation opportunities – even more so with AWD
• Driveline systems are fully capable of providing:
  ✓ effective yaw control on any axle
  ✓ single drivelines can more easily become multispeed
  ✓ single drivelines are also more effectively disconnectable for constant speed efficiency
• Instead of «ONE-WHEEL, ONE-MOTOR»

`«SINGLE-WHEEL HANG-ON»`
VISION:

3. Integration of new technologies on electric vehicles

3.1. Connectivity and autonomous driving – increase available range with better understanding of what energy will be required for the journey, self-learning capability and updates

- Increase available range with better understanding of what energy will be required for the journey
- Improve system functions with self-learning capability and software updates
3.2. Solid state battery cells – changes in battery thermal management

- More energy in same space and weight
- Higher working temperatures, smaller heat exchange surfaces to ambient
- Less critical in crash
- However, it still seems for the long term
3.3. Alternative complete vehicle thermal management

- Consider all vehicle thermally-relevant systems as one

- Identify synergies between systems normally treated as separate entities

- Vehicle can benefit from integrated thermal treatment of powertrain, cabin, and battery

- Stabilize even more battery temperatures with more efficient warm and cold conditioning
3.4. HVAC reconceived

- Different use of space for cabin climate
- Remove the need for dissipative cabin heating
- Heat pumps – reversible refrigeration principle
3.5. Steer by wire

- Simplify steerable axle local architecture
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- Synergies with redefined HVAC for more efficient combined space management (especially dashboard area)
- Possibly increase available battery space
VISION:

4. Increase the structural role of the battery

- Instead of contribution to chassis performance, energy carriers could become the main chassis
- Mechanical elements at axles as bolt-on modules
- Requires battery that does not need disassembly for maintenance and replacement, and less safety-critical in crashes
• Example – Evolution of Lotus rear-engined race cars

• Lotus 18 – upright driver, fuel tank above legs
• Lotus 20 – lower, reclining driver, fuel tank at the side
Lotus 25 – Turned the energy carriers into structure
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• The first Formula One monocoque chassis
Thank you for your attention

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