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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**

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- **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**

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- **From a Lotus perspective, it is peculiar that Tesla actually started its propositions on a Lotus basis with the 2008 Roadster**

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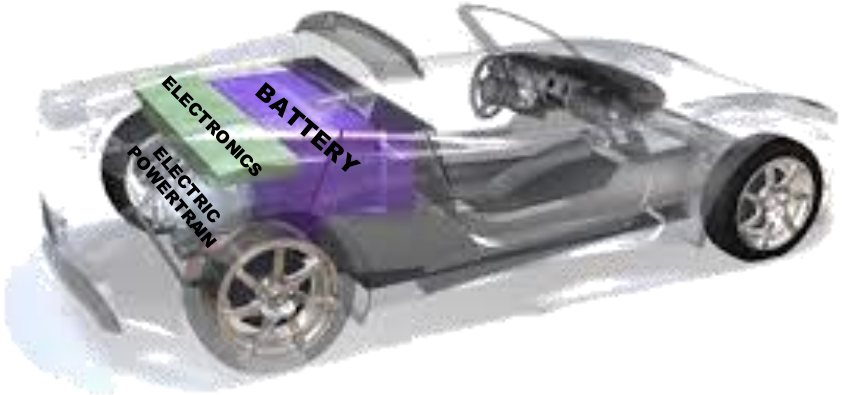
- **The Tesla Roadster was essentially the installation of Tesla electrification systems on a specifically developed Lotus Elise, a RWD architecture**



- **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**

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- **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**

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- 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

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- **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**

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- **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**

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- **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?**

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- **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**

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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**

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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

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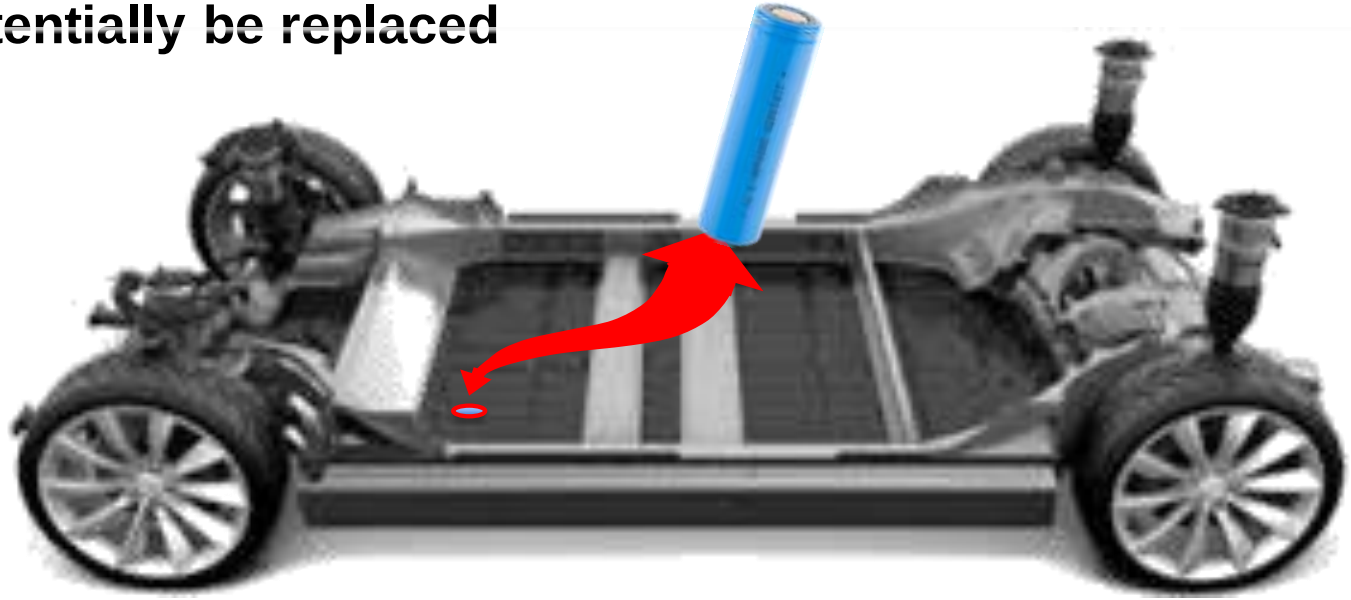
- **Cells as flashlight batteries; module or cell replacement – vision for more sustainable battery durability**
- **Taking this to an extreme, a single defective cell alone could potentially be replaced**



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- **Some concepts have partially gone in that direction, with multiple and replaceable independent smaller battery modules**

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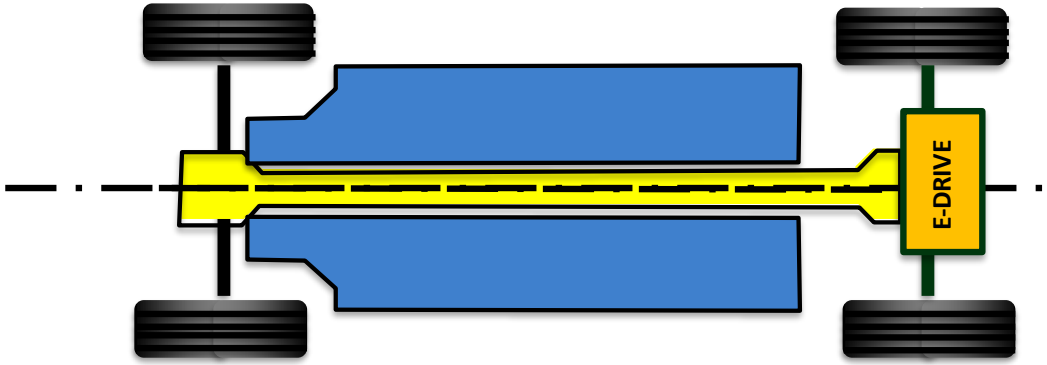
VISION:

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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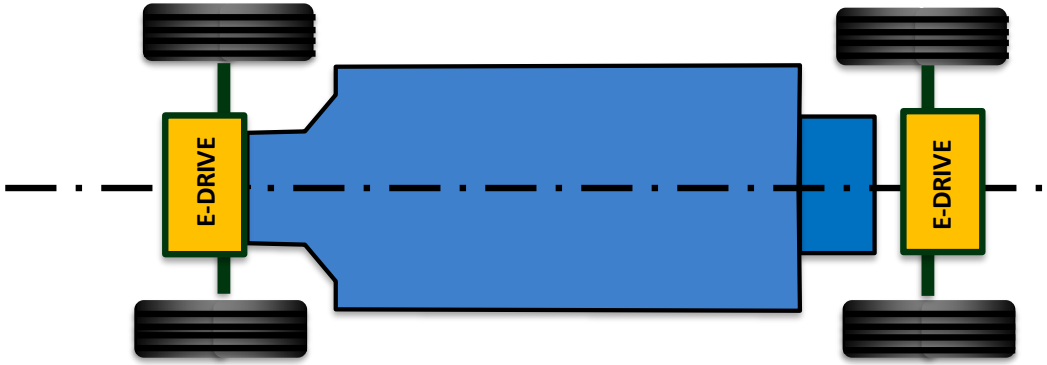

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VISION:

2. Avoid multiple motors and transmissions at each axle

- 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

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- **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**

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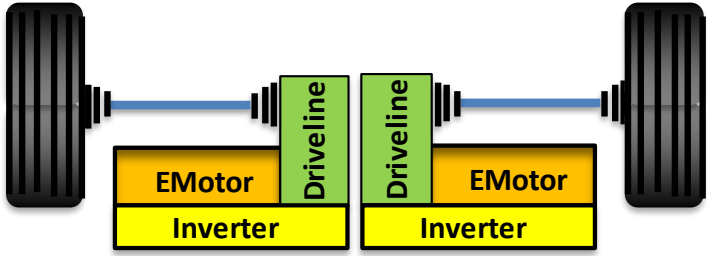
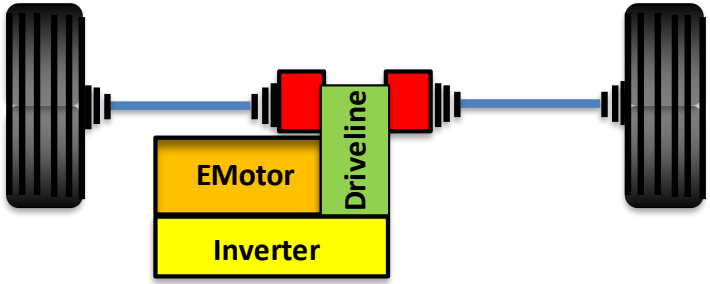
- **Instead of** **«ONE-WHEEL, ONE-MOTOR»**



«SINGLE-WHEEL HANG-ON»



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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

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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

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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

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3.4. HVAC reconceived

- ✓ Different use of space for cabin climate
- ✓ Remove the need for dissipative cabin heating
- ✓ Heat pumps – reversible refrigeration principle

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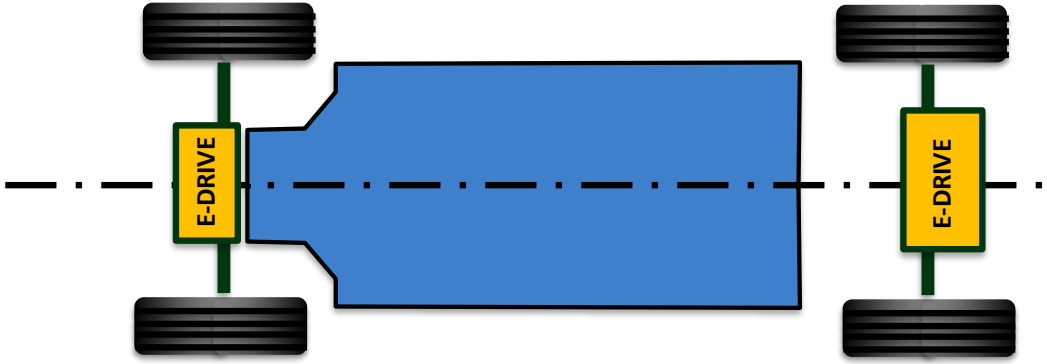
3.5. Steer by wire

✓ **Simplify steerable axle local architecture**



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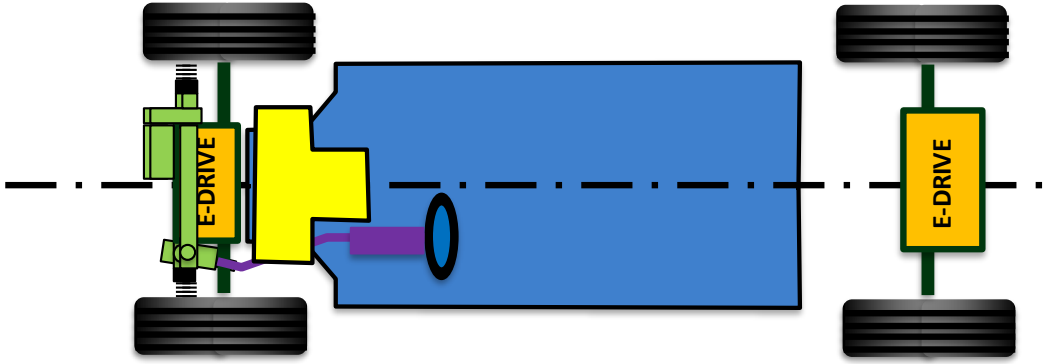
3.5. Steer by wire

- ✓ **Simplify steerable axle local architecture**
- ✓ **Synergies with redefined HVAC for more efficient combined space management (especially dashborad area)**



- ✓ **Possibly increase available battery space**

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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

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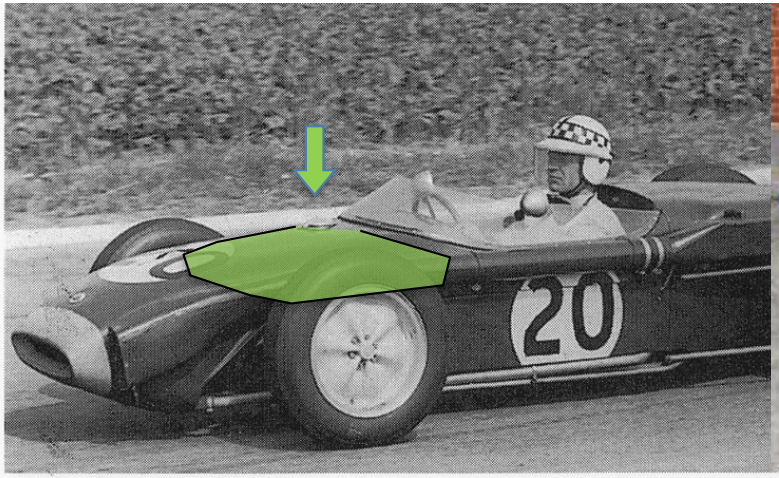
- **Example – Evolution of Lotus rear-engined race cars**

- **Lotus 18 – upright driver, fuel tank above legs**
- **Lotus 20 – lower, reclining driver, fuel tank at the side**



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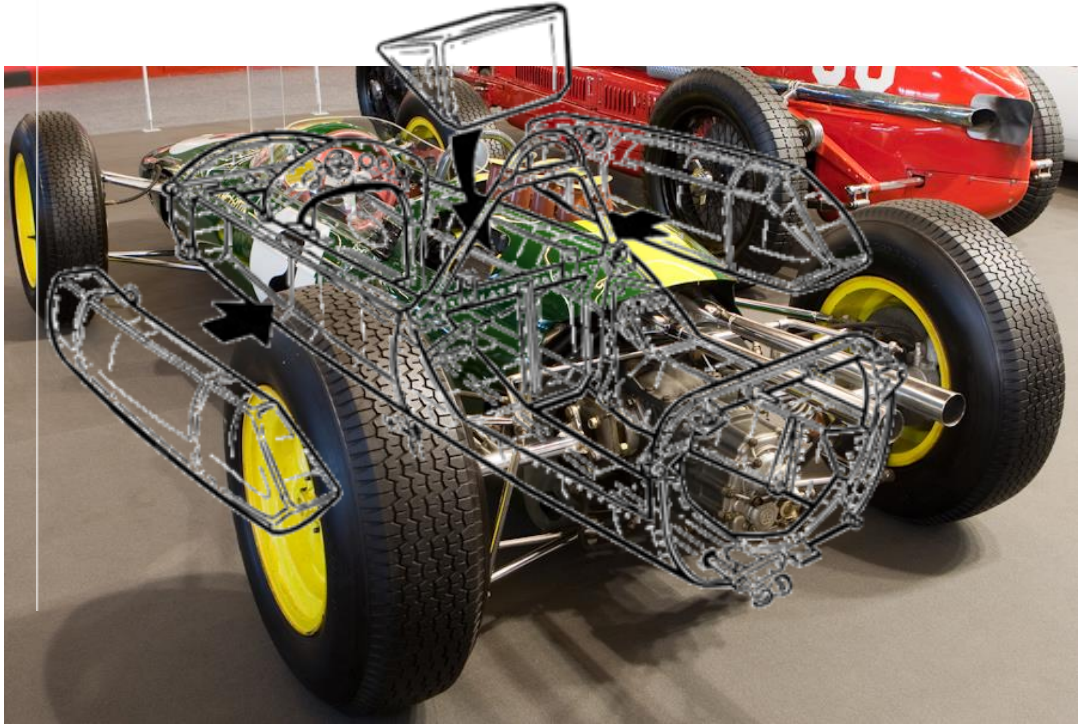
- **Lotus 25 – Turned the energy carriers into structure**



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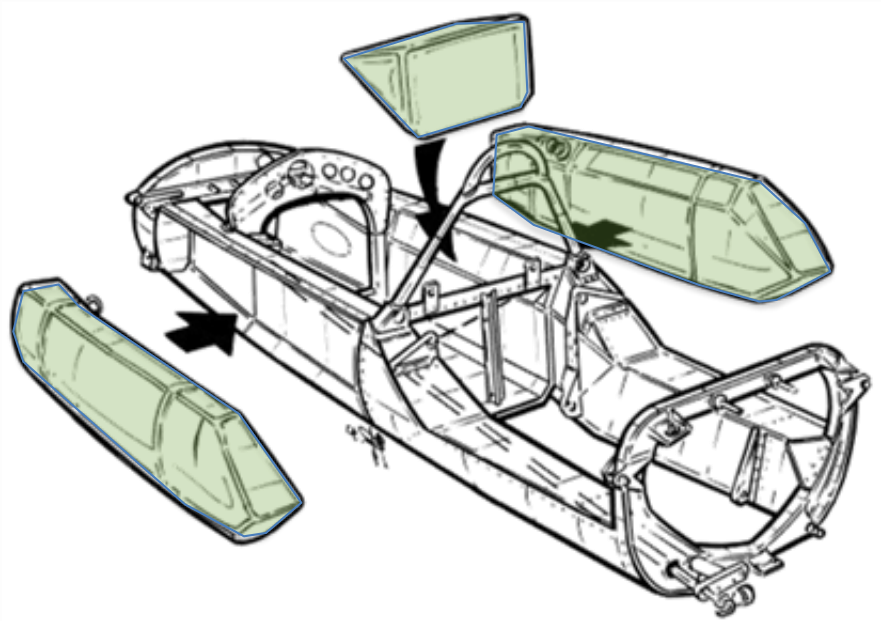

- **The first Formula One monocoque chassis**

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Thank you for your attention

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