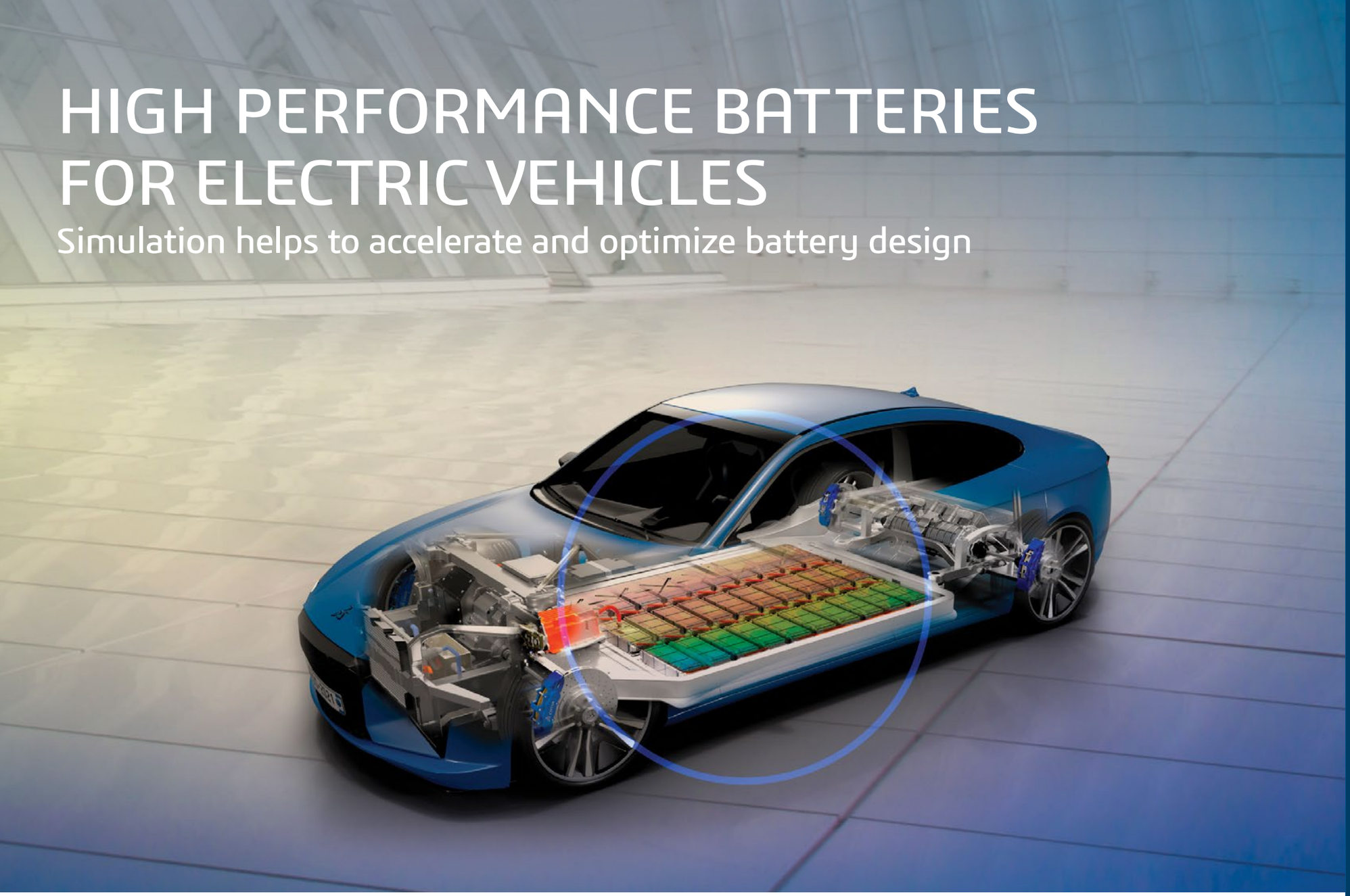
HIGH PERFORMANCE BATTERIES FOR ELECTRIC VEHICLES

Simulation helps to accelerate and optimize battery design



DASSAULT SYSTEMES

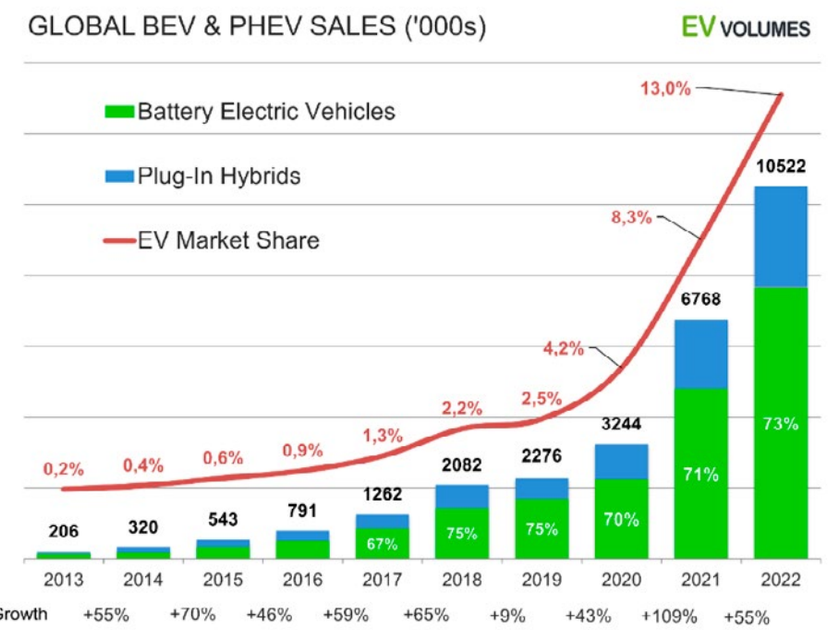
HIGH PERFORMANCE BATTERIES FOR ELECTRIC VEHICLES

The rapid adoption of electric vehicles relies heavily on the battery technology. Batteries still make up 30% of the electric vehicle cost. The big goal is to reach cost parity between Electric Vehicles (EV) and Internal Combustion Engine (ICE) vehicles within a couple of years. With the EURO-7 requirements, prices for electric and conventional vehicles are expected to become similar for the small car segment (1).

In order to achieve the needed battery technology, many long-term battery physical tests are required to gather information on battery life and performance. Hence, traditional ways of developing vehicle propulsion systems and the power source will not be able to keep pace with the rapid adoption of EV's.

This e-book talks about how Dassault Systèmes solutions for electro-chemical, electrical, thermal and structural battery simulation can help to shorten the time-to-market and realize the cost reductions that everyone aims for.

The trend towards vehicle electrification is accelerating due to high energy costs and the pressure to reduce emissions. As the battery system is the single most costly component in the electric vehicle, it is important to **design a high performing, long lasting and safe battery** that is not only affordable, but will also enable the mass adoption of electric vehicles at scale. However, it is not a low risk engineering task. Most existing vehicle manufacturers and battery system suppliers only have limited experience working on a complex EV battery system, and a lot of the knowledge and development processes expertise learned from conventional powertrain vehicles does not apply to the development of battery-driven electric vehicles.



Rapid EV market growth.
https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1013L1O.pdf

(1) According to Thomas Schäfer, VW CEO, the Euro-7-standard will cause the price of small ICE (internal combustion engine) cars to rise close to the price of today's electric cars. Source: https://ecomento.de/2023/01/27/vw-markenchef-thomas-schaefer-euro-7-norm-macht-verbrenner-so-teuer-wie-e-autos/

DESIGN AND ENGINEERING CHALLENGES OF AN EV BATTERY SYSTEM

Designing an electric vehicle battery system is challenging at the vehicle system, battery module, and battery cell levels. Beyond the battery technology itself, engineers must manage to:

- Balance driving **range**, **cost** and **performance**
- Meet **durability** and **efficiency** targets
- Keep the battery system **affordable**

Safety adds yet another layer of complexity in the battery design's optimization.

Another challenge EV manufacturers are facing is due to the proliferation of models to cater to different market segments, as no prior generation of vehicles can be used as a reference. In addition, the high pressure from the marketplace means that the **development timeline is heavily compressed** and the engineering process itself needs to be adaptive to handle the material and supply chain uncertainties.

DIGITAL CONTINUITY ENABLES COMMON MODEL BUILD AND DESIGN UPDATES

The 3DEXPERIENCE® platform empowers the collaboration between designers, analysts, program managers and all other relevant parties to participate in the same environment and work with a **common data model**. This enables a clear **traceability** and facilitates creating a **battery passport**.

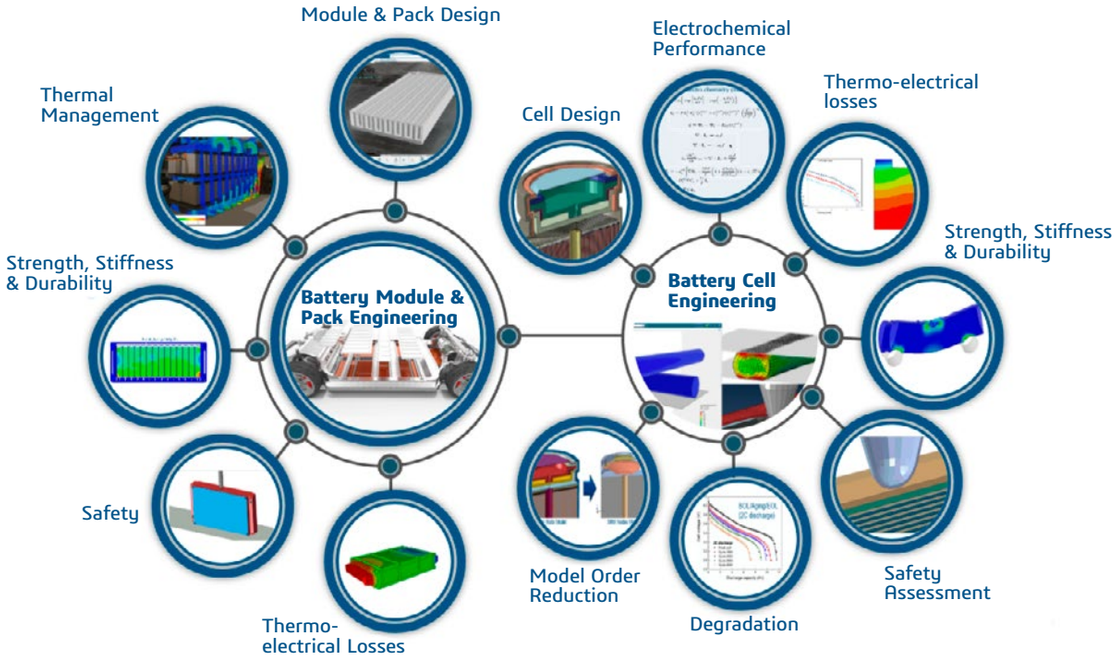
SPEED UP, CONTROL COST, DELIVER HIGH QUALITY WITH THE 3DEXPERIENCE PLATFORM

A model-based approach, using the **3D**EXPERIENCE platform capabilities, allows for seamless updates in order to meet changes in the requirements and to minimize errors. The real-time high-quality data gained enables simultaneous engineering in multiple departments. Furthermore, the platform helps to democratize the EV battery development process so that every stakeholder can contribute their expertise more easily, which results in a better, faster and more robust engineered product.

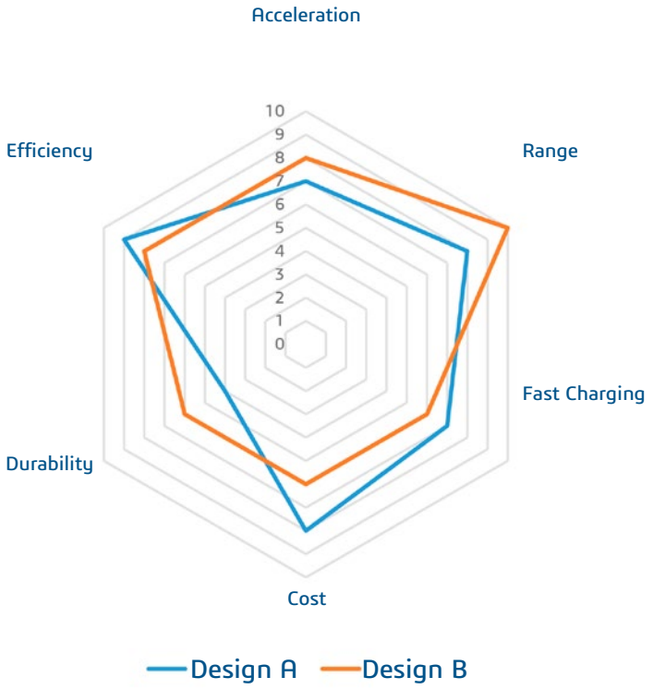
BUILD, VALIDATE AND DEPLOY A VIRTUAL TWIN FOR INNOVATIVE BATTERY DEVELOPMENT

A virtual twin and advanced digital analysis technology can help to compensate for the lack of a prior product history and process experience by creating a digital product performance history with accurate prediction. With advanced multi-physics, multi-scale analysis, EV manufacturers and battery system suppliers are able to create a virtual twin to design and try out their new battery system and design alternatives in a full digital environment. Quick design evaluations and iterations foster a faster time-to-market with a more robust and reliable solution.

With Dassault Systèmes solutions, engineers are empowered to quickly **evaluate the EV battery performance**, and to **understand the trade-off between acceleration, range, battery longevity, efficiency and cost, while continuing to ensure safety**. It enables manufacturers to optimize the design and make informed design decisions in a shorter time. A swift design and evaluation process helps manufacturers keep up with the pace, while remaining capable of handling uncertainties like supply chain, material and technology changes.



Dassault Systèmes Battery Cell and Battery Module and Pack development solutions.



Trade-Off Studies Design A and Design B

BUILDING EV VEHICLE-LEVEL BATTERY SYSTEMS FROM A BLANK SHEET?

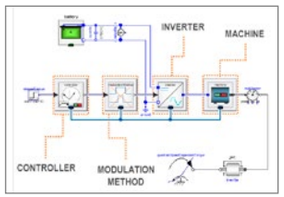
The performance and behavior of the battery have a significant impact on the usability of the entire electric vehicle and hence on user satisfaction and acceptance. Driving range and charging time are two crucial criteria that need to be optimized during the battery development process, along with aging behavior, performance over a wide temperature range and consistent power output with repeated peak loads, to name just a few.

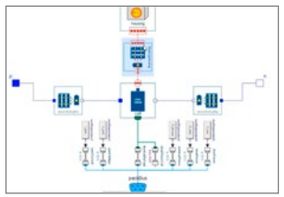
In order to be able to implement and optimize these requirements as comprehensively and precisely as possible, DYMOLA (Dynamic Modeling Language) System Behavior offers **high-performance simulation solvers and extensive model libraries**. The libraries cover not only the behavior at the battery cell, module and pack level, but also offer predefined model templates for electric machines, inverters, transmissions, cooling systems and air conditioning systems, as well as for all other essential parts of electric vehicles.

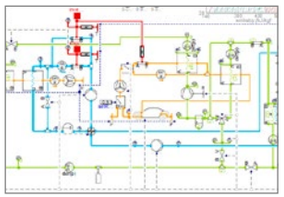
EV manufacturers and battery suppliers can use the DYMOLA System Behavior models offered by Dassault Systèmes to optimize the performance and the usable energy of batteries under a wide variety of boundary conditions and use cases. DYMOLA System Behavior can be used throughout the entire development cycle and **predefined simulation models of all relevant vehicle components and systems are provided**.

The industry-proven solution supports engineers in:

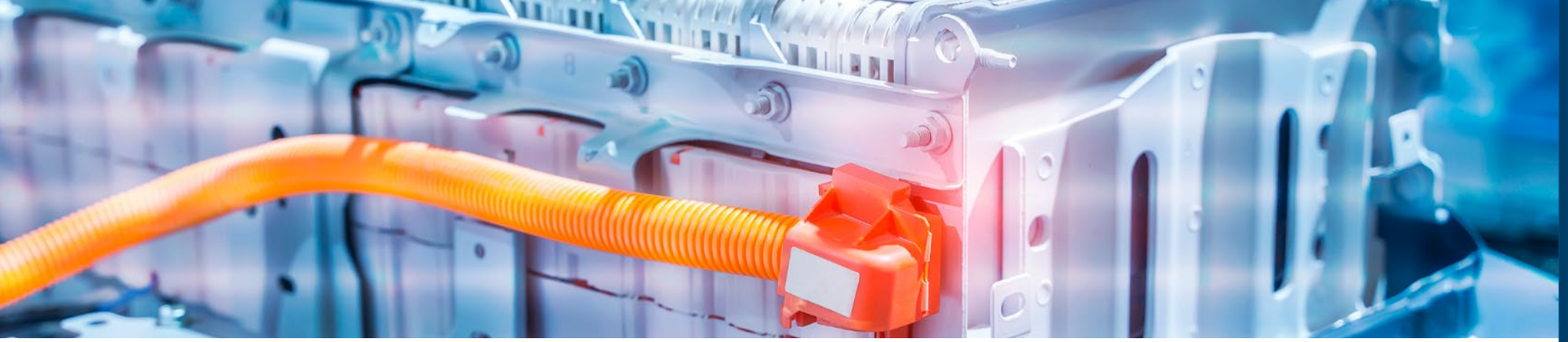
- **Benchmarking of battery cells**
- **Energetic dimensioning of the batteries, electric drive systems and entire vehicle architectures**
- **Design of the battery cooling system and its optimal connection to vehicle air conditioning systems**
- **Integration of the battery into the electric powertrain and the vehicle**
- **Evaluation and optimization of the battery aging behavior**
- **Development of control unit functions such as the battery management system (BMS) and vehicle operating strategies**.







Using the DYMOLA System Behavior models, engineers can perform component and system-level trade-off studies as well as optimization studies to scale component size, optimize Electronic Control Unit (ECU) functions, and make architectural trade-off decisions to generate the design that meets requirements without overdesign.



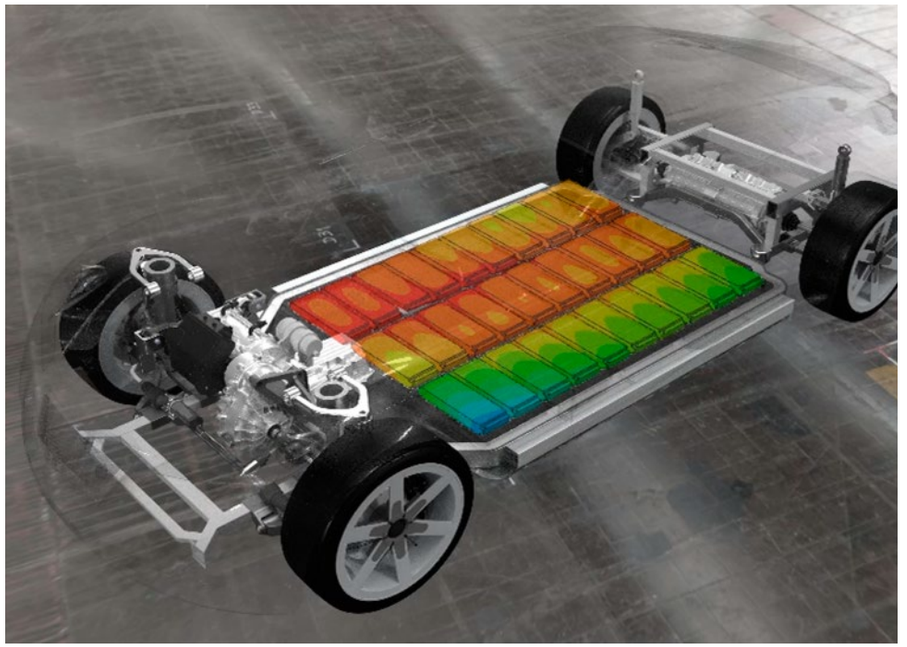
BATTERY MODULE AND PACK ENGINEERING— OPTIMIZE TO ACCELERATE ELECTRIC VEHICLE ADOPTION

COOLING AND AGING

Maintaining the right temperature is key to ensuring a safe, efficient and long-lasting battery. A battery operating in an elevated temperature will pose a safety issue and degrade more rapidly. Similarly, operating the battery in low temperatures will cause efficiency loss and a reduction in its lifespan.

The Battery Module and Pack Thermal Analysis enables engineers to properly evaluate the battery thermal management system, select the right cooling architecture, and optimize the detail design of the battery heating and cooling. With this workflow, **engineers can predict the battery thermal performance, improve the battery thermal design, and optimize the battery for better power output, longer driving range, and faster charging speed under real-world driving and charging scenarios**.

Combined with the battery management system engineering and aging analysis, it can further predict the battery capacity reduction and power fade under different usage conditions, and further optimize the battery performance and durability through battery and cooling control.



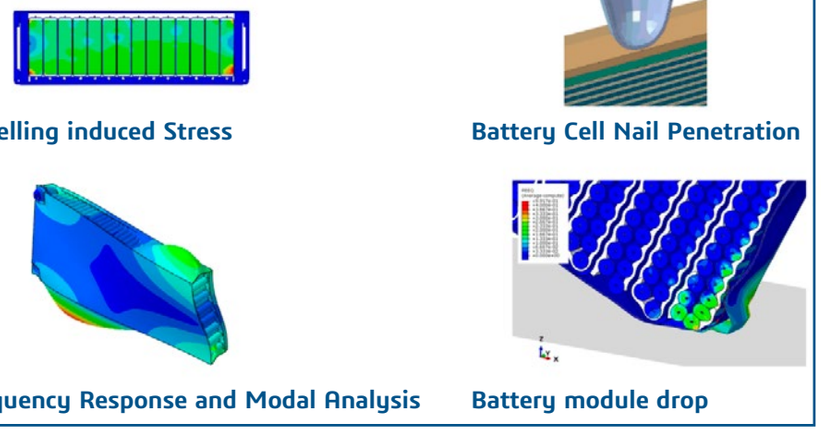
Module temperature distribution during cooling.

BATTERY MODULE AND PACK ENGINEERING— OPTIMIZE TO ACCELERATE ELECTRIC VEHICLE ADOPTION

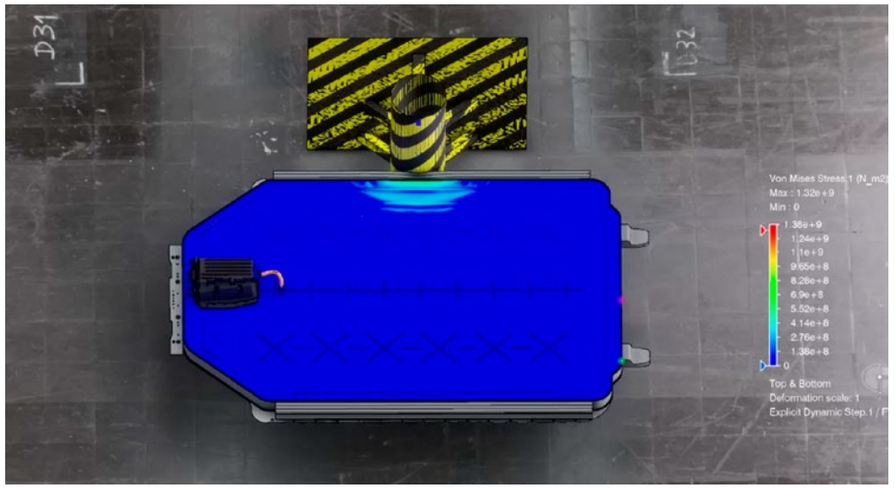
DURABILITY AND SAFETY

It is important to secure the longevity of the battery over the period of ownership, with minimal degradation in performance. The Battery Strength, Stiffness and Durability analysis ensures the structural integration of the battery pack. It makes sure it can tolerate extreme driving and charging scenarios, by **predicting battery system structural integrity and durability considering mechanical load, thermal load, and stress caused by battery swelling during charging and discharging**.

In the unlikely event of battery damage, a **Battery Safety Analysis** ensures a well-designed thermal and ventilation system to prevent or slow down the propagation of battery failures. It turns a potential catastrophic event into a manageable battery decomposition and can eliminate the threat to the vehicle occupants and first responders.



Verify the battery structure design against normal operation and abusive conditions.



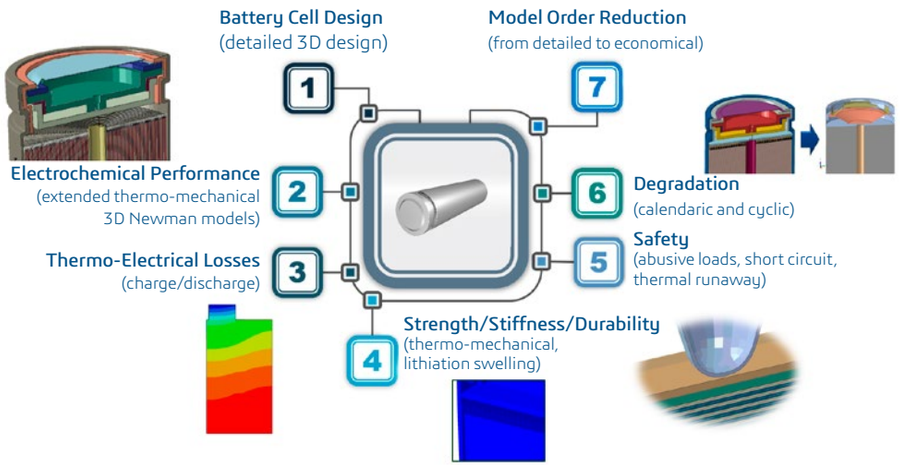
Battery Pack side pole impact simulation.

BATTERY CELL ENGINEERING—THE FOUNDATION FOR A HIGH PERFORMING BATTERY SYSTEM

Engineering the battery cell properly is one of the most important tasks. **The cell design decision fundamentally impacts the battery system performance, efficiency, and cost**. SIMULIA's Battery Cell Engineering workflows offer a complete multi-physics/multi-scale simulation solution from 3D battery cell detailed design to model order reduction. Engineers can evaluate a given design of a battery cell based on its electrochemical performance, thermo-electrical losses, strength/stiffness/durability, safety, or degradation, with model order reduction available for higher-level engineering analysis.

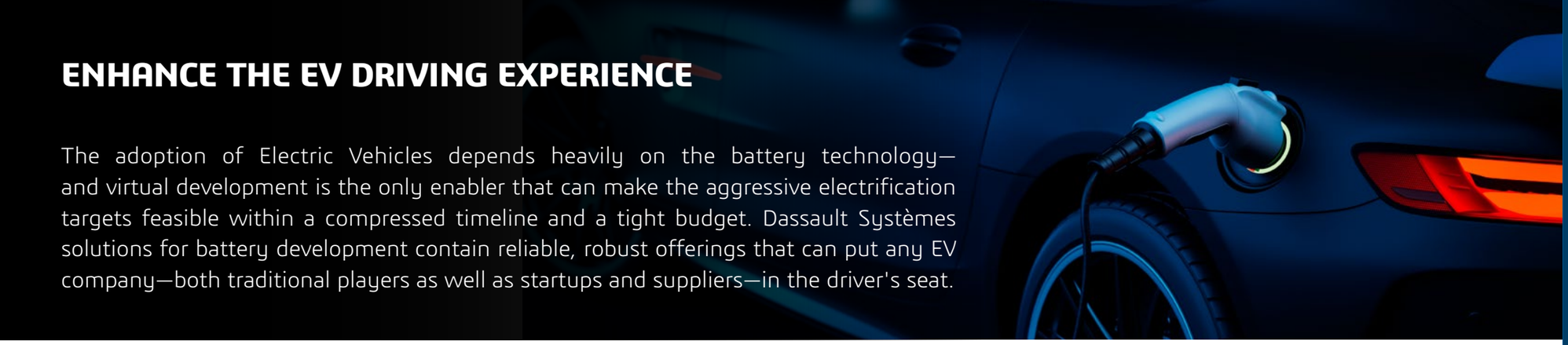
A unique advancement in multi-physics and multi-scale simulation technology enables the analysis of the coupled behavior of thermo-electrochemistry with swelling of the batteries. This type of coupled simulation has the potential to ensure battery safety, optimize performance and improve fast charging capabilities and driving range for EVs.

Dassault Systèmes **3D**EXPERIENCE platform enables **streamlined model-to-simulation experience**, so that designers and engineers can quickly modify the design, evaluate its new performance, and iterate to further improve the design. A unified Modeling & Simulation (MODSIM) capability is important, especially for battery engineering, as batteries' multi-physics, multi-scale nature can benefit immensely from the robust and automated workflows offered by **3D**EXPERIENCE platform.



Battery Cell Engineering Workflows.

ENHANCE THE EV DRIVING EXPERIENCE



The adoption of Electric Vehicles depends heavily on the battery technology—and virtual development is the only enabler that can make the aggressive electrification targets feasible within a compressed timeline and a tight budget. Dassault Systèmes solutions for battery development contain reliable, robust offerings that can put any EV company—both traditional players as well as startups and suppliers—in the driver's seat.

HIGH-PERFORMING BATTERIES MAKE THE DIFFERENCE!

Drive further

Integrating thermal system analysis enables engineers to optimize the EV's thermal efficiency, allowing the more efficient use of battery power and a longer driving range.

Last longer

A full vehicle thermal analysis helps to optimize the battery positioning, insulation, storage and cooling as well as allowing the battery to hold its charge longer—even in extreme climate conditions.

Safer

Safety is the top priority, and Dassault Systèmes' toolset enables prediction of battery behavior in mechanical and thermal abusive events, and ensures the design of the battery to avoid a catastrophic result.

More comfortable

Combining vehicle dynamic, drivability, and occupant-comfort analysis, engineers can design an efficient, high-performance, yet comfortable, real-world driving experience for the customer.

Charge faster

Optimizing the charging time while mitigating the impact on battery degradation—for a better EV experience.

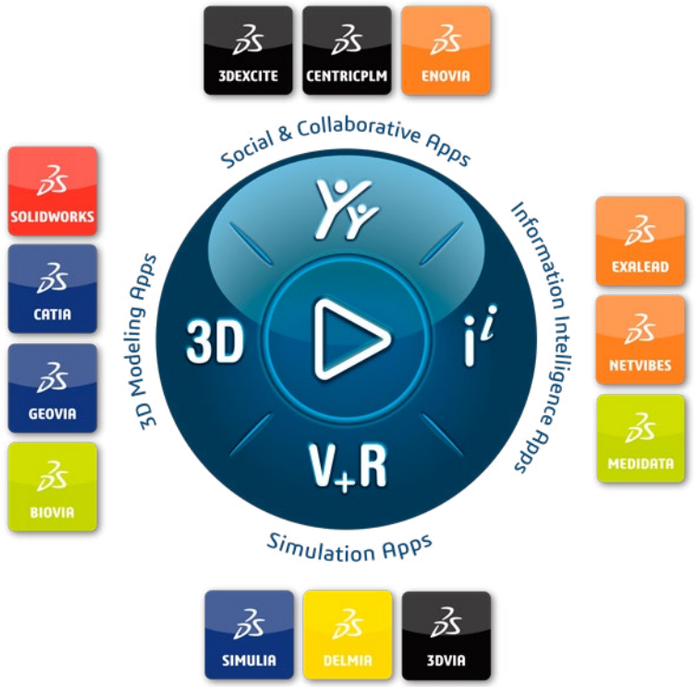
More affordable

High fidelity multi-physics analysis allows engineers to design EV batteries faster and smarter, reducing the R&D and manufacturing cost and making EVs more affordable.

Our **3D**EXPERIENCE® platform powers our brand applications, serving 11 industries, and provides a rich portfolio of industry solution experiences.

Dassault Systèmes, the **3DEXPERIENCE** Company, is a catalyst for human progress. We provide business and people with collaborative virtual environments to imagine sustainable innovations. By creating 'virtual experience twins' of the real world with our **3DEXPERIENCE** platform and applications, our customers push the boundaries of innovation, learning and production.

Dassault Systèmes' 20,000 employees are bringing value to more than 270,000 customers of all sizes, in all industries, in more than 140 countries. For more information, visit **www.3ds.com**.



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