SIMULIA

3DEXPERIENCE

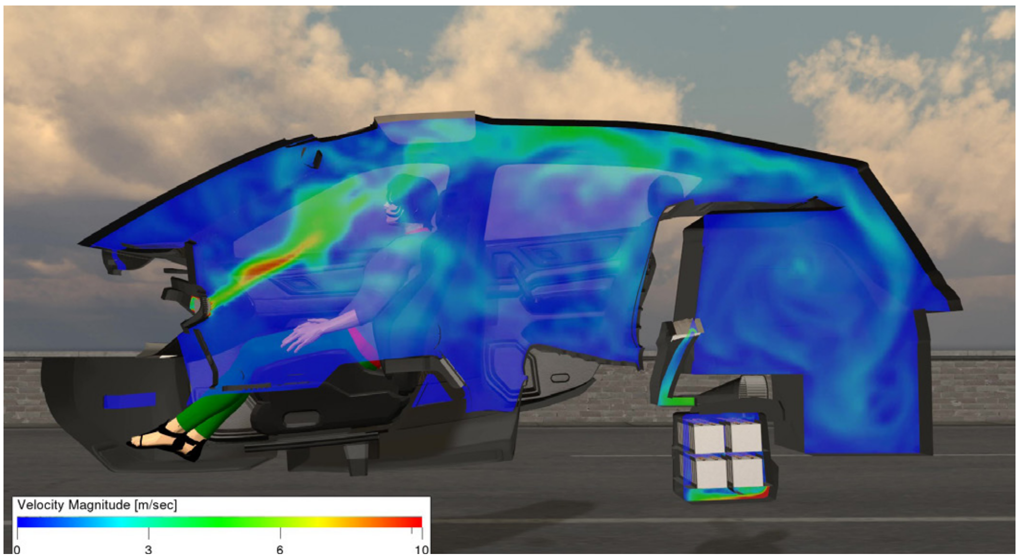
CABIN DESIGN AND BATTERY COOLING

Inceptra

DASSAULT SYSTEMES

IMPROVE YOUR ELECTRIC VEHICLE (EV) DRIVING RANGE WITHOUT COMPROMISING PASSENGER COMFORT

Electric vehicle designers constantly face a trade-off between passenger comfort, EV range, and battery cost. In fact, in extreme weather conditions, ensuring passenger comfort and safety can reduce the range by 40% or more. Even in more reasonable climates, EVs consume 15% more energy per mile because of hot or cold weather conditions. We found this trade-off can be dramatically reduced by an integrated design and verification process, to effectively provide a comfortable environment for the passengers, maintain acceptable temperatures for onboard electronics, and to keep the battery temperature within a peak efficiency range. This process enables you to select materials, window treatments, operating strategies, and localized heating and cooling, that will ensure the desired passenger experience can be achieved while satisfying regulatory requirements, maximizing range and achieving target battery life. A high fidelity transient and 3D simulation model, combined with vehicle level systems integration, is the key to success. **Design, evaluate, and iterate on cabin and battery cooling design with confidence, allowing your car to outrun the competition**.



Insight on cooling power required to provide thermal comfort & maintain battery temperature

A DELIGHTFUL PASSENGER EXPERIENCE IS THE RESULT OF EXCELLENT ENGINEERING

Consumer expectations are increasing when it comes to cabin comfort. Amenities that were considered superfluous or optional a decade ago are now a differentiator that can symbolize a brand. The climate system of the cabin, and the thermal and acoustic comfort it provides, defines today an essential part of the cabin experience. Holistic solutions for the design of the Heating, Ventilation and Air Conditioning (HVAC) system ensure an effective integration of this component, focusing on passenger comfort and range simultaneously.

Dassault Systèmes provides a complete solution from design to verification, from cabin cooling/heating simulation to passenger sensation.

- Accurately predict thermal sensation and comfort, and their impact on battery range, during steady, initial transient and full transient conditions with our best-in class SIMULIA solver, incorporating state of the art human comfort modelling.
- Verify thermal management of battery and electronic components even under extreme weather conditions, and optimize battery placement or material selection. Save energy and increase battery range using SIMULIA tools.
- Capture the dynamic behavior of HVAC system components and of a 3D cabin with occupants, and predict target temperature, time to comfort, and battery range with 1D-3D integrated simulation.

- Include localized thermal regulation solutions to reduce HVAC energy consumption. Achieve better occupant comfort through the use of microclimate systems such as heated or ventilated seats and radiant panels. SIMULIA solvers can accurately model and predict the energy savings and occupant comfort of these solutions.
- Account for real-world weather conditions or occupant diversity during overall cabin design, without the need to physically build the prototype. Digitally investigate all scenarios without having to transport the team and equipment to test in different climate conditions.
- Experience the new design of the cabin through state-of-the-art realistic rendering and virtual reality; understand physical phenomenon impacting performance, and verify cabin ergonomics and usability.

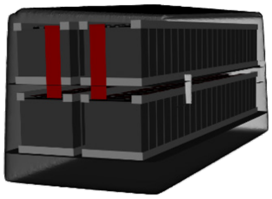
Cooldown prediction of flow & temperature distribution inside a cabin with multiple humans

BATTERY THERMAL MANAGEMENT

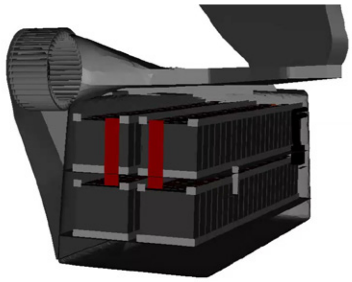
Battery thermal management is critical to ensure an extended driving range and long-term battery durability. While higher temperatures allow the battery to deliver power more efficiently, exposure to high temperatures for long periods of time can cause it to degrade prematurely. Robust control of the battery temperature is required in order to keep the battery within the range of temperatures at which it can run efficiently without impacting durability.

The Dassault Systèmes complete solution for battery design:

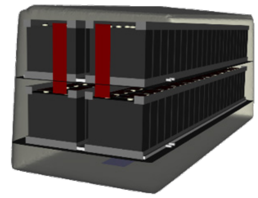
- Simulates multiple physics important to the correct functioning of the battery, from electrochemical reaction and thermo-electrical behavior, to thermal structural analysis. These solutions also tackle drop and penetration resistance, battery swelling, overall safety, and thermal management.
- Covers different levels of system complexity, from cell model, to module and cooling plates model. These solutions are able to include battery cells, connectors, cables, relays, controller electronics and cooling devices with different levels of granularity.
- Provides whole vehicle simulation capabilities, that model battery, electrified powertrain, driver and controller designs
- Predicts cooling performance under different cooling methods, including forced air cooling, cooling fins, liquid cooling plates and cooling blades
- Offers processes and modeling toolkits that are suitable for different time scales, from load cycles involving only minutes of service, to hours of driving, or even years of real driving and charging duties. These toolkits provide you with an accurate end-of-life performance prediction.
- Contains a full-suite of design workflows addressing battery issues, from a component level to system level. Verification processes can be integrated to verify the design throughout the development and at different levels of system complexity, enabling you to quickly iterate and optimize your product in a full digital environment.



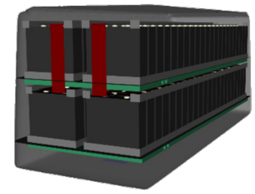
Sealed Battery Pack



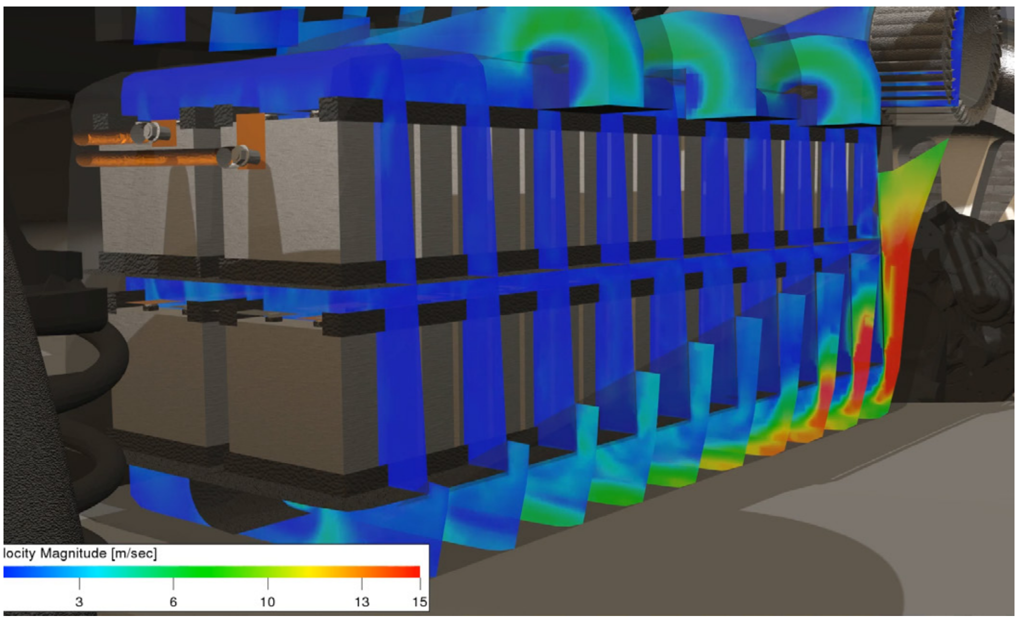
Air-cooled Battery Pack

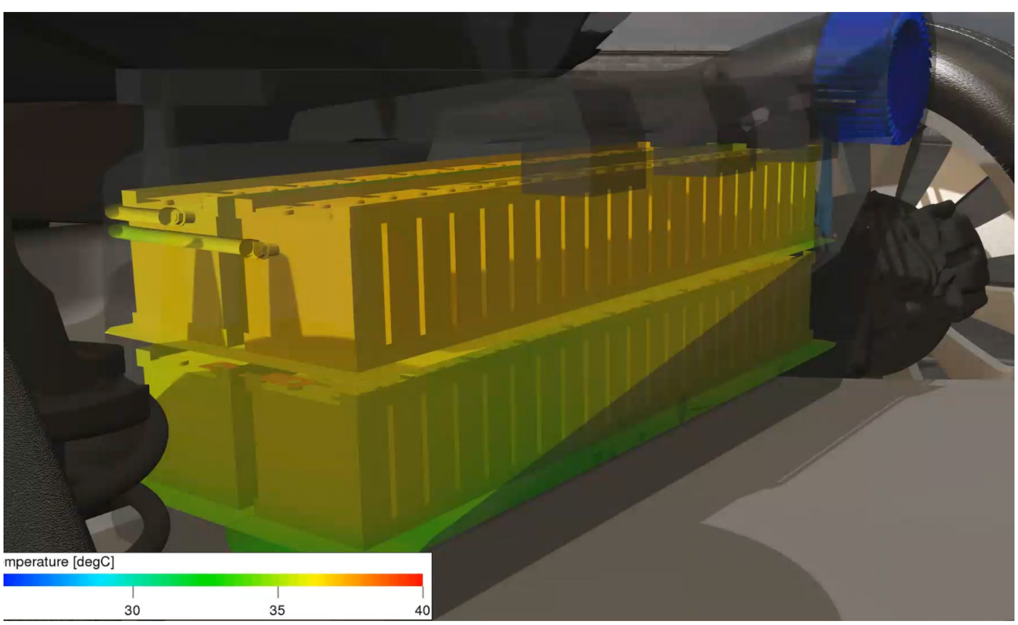


Liquid-cooled Battery Pack



Refrigerant-cooled Battery Pack





Thermal management of batteries under different cooling methods

COMBINED CABIN AND BATTERY COOLING

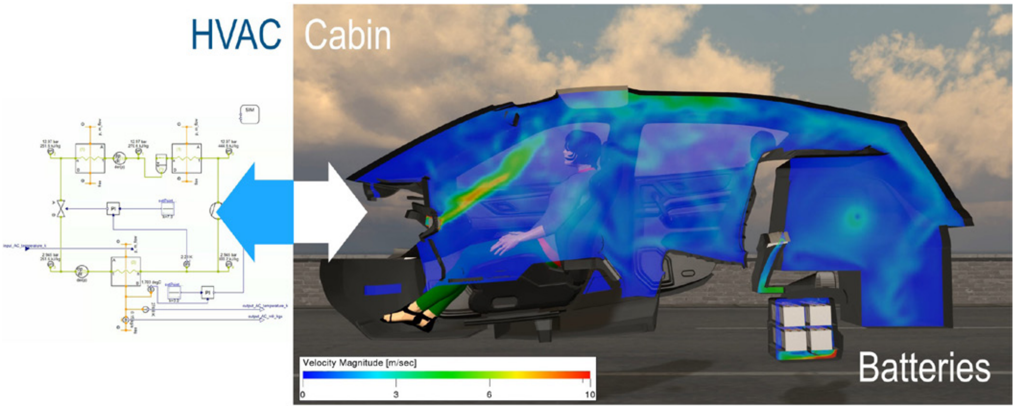
Complex system interactions make vehicle design a challenging task. For example, a design altering the cabin temperature and occupant comfort will impact the HVAC system, battery cooling and vehicle overall efficiency. Conversely, the battery temperature itself will impact the powertrain efficiency, HVAC system performance and vehicle cabin temperature. The systems must therefore be designed and optimized through a holistic approach, considering both component performance as well as the overall system performance. However, such an integrated design is not an easy process; Dassault Systèmes develops toolkits that enable an easy integration between models in different subsystems with different physics, so that engineers can focus on optimizing overall vehicle performance. An integrated design and verification solution allows users to optimize the overall system performance beyond what can be achieved through individual sub-system improvements.

- Support of the Functional Mock-up Interface (FMI) standard allows easy integration of different models from multiple solvers, and provides flexibility in integrating Dymola system modeling.
- Co-simulation capabilities involving 3D CFD (Computational Fluid Dynamics) and FEA (Finite Element Analysis) thermal models, provide high fidelity predictions of passenger thermal sensation and battery temperature distribution. Further integration with Dymola system behavior models enables the prediction of real-world driving scenarios for all systems in the vehicle.
- Integrated simulation allows engineers to optimize cabin comfort with digital calibration, as the realistic interaction between battery and thermal systems is fully captured.

Early design validation can also be conducted in a realistic environment. Digital testing of the vehicle cabin under real world driving cycles and weather conditions for example, involving long transient cooldown and heat-up scenarios, can be achieved at the early design stage. The fast-turnaround and high level of confidence in the simulation means fewer late stage issues, and lower delays in time-to-market.

An example of a combined cabin and battery cooling simulation is shown below. The model consists of a fully-detailed cabin with air-cooled battery and HVAC system. The cooling design allows the cold air from the air conditioning vent to cool the passenger first, before being directed towards the battery pack compartment and finally released to the exterior. Depending on the location of the battery or other electronic components inside the cabin, varying amounts of cooling power may be required to maintain the battery temperature and provide thermal comfort, as excessive power consumption leads to decreased range.

Correct allocation of energy, by integrating the HVAC system model in the simulation, avoids sacrificing performance. During a braking event, for example, a regenerative breaking is activated to recover part of the dynamic energy and charge the battery. The regeneration usually only recovers part of the energy as it is limited by the battery charging rate. With this integrated vehicle design in mind, part of the regenerative breaking energy can be used to drive the compressor and precool the cabin and the battery. With integrated system optimization in mind, redistributing energy was shown to bring a 3% reduction in cooling power consumption. Similarly, zonal heating or cooling with microclimate systems can be used within the integrated cabin and HVAC model to further save energy, by providing local thermal comfort quickly, whilst reducing HVAC power and demands. This holistic digital simulation provides insight on how much HVAC or heater power is needed to achieve high battery range without compromising thermal comfort of the aesthetics of the vehicle. The Dassault Systèmes toolkit allows engineers to easily perform integrated system optimization even in such complicated modeling scenarios.



Integrated simulation to improve battery range & thermal comfort at early design stage

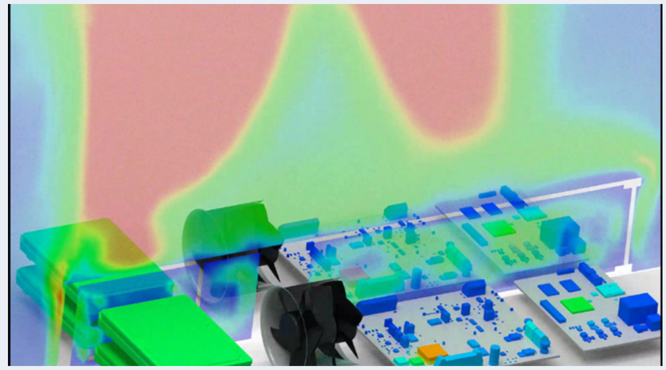
TAKEAWAY

Designing an electric vehicle is a challenge, not only because it is a new vehicle structure, but also because of the demanding expectations around system efficiency and customer experience. Dassault Systèmes provides a complete solution for electric vehicle designs, encompassing early concept stages and final verification, as well as individual component and subsystem models or full vehicle integrations. The simulation toolkits cover all the relevant physics, allowing the evaluation of all the systems and key performance indicators. Furthermore, the integrated simulation capability allows you to optimize the energy management for the full vehicle, enabling you to create a product without compromises.

Electronics Cooling

Electronic components are very sensitive to high temperatures. Failure is not acceptable, and keeping electronics cool is becoming a top priority. Poor thermal management of batteries can also lead to reduced range. Both extreme cold and overheated batteries lead to failure, causing cost and safety issues. There is a need for optimal battery cooling while minimizing energy consumption for cooling.

HVAC systems can help with electronic cooling and SIMULIA's steady and transient fluid simulation tools can predict the flow paths around electronics and find solutions to achieve comfort while keeping the electronic temperatures optimal. Furthermore, digital simulation can be used to predict battery temperature rise during hot solar soak and implement thermal insulation strategies to prevent overheating of batteries. Simulation also helps in optimizing the placement of batteries, evaluating the effect of insulation around the battery pack for example, to reduce battery exposure to solar radiation in the summer and extremely low temperatures in the winter.

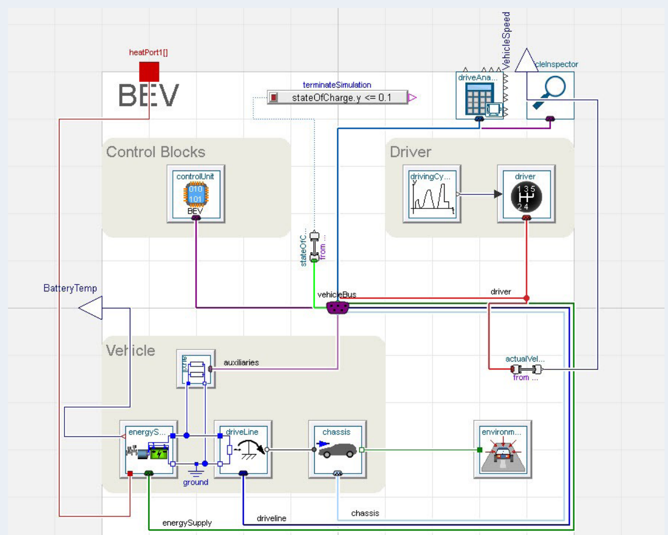


Simulation of the cooling of electric components in operation

Systems Model

An electric vehicle is a complex system and each sub-system requires different modeling expertise. Dymola reduces the apparent complexity of the system, consolidates and synthesizes the system to create high fidelity models. These provide a better understanding of the system behavior, and encourage collaborative and multidisciplinary work.

Dymola also supports symbolic equation processing which makes simulation more efficient, robust, and easy to reuse. The multi-engineering compatible libraries allow high-fidelity modeling of complex integrated systems. It supports free and commercial libraries that users can easily customize, or supplement with existing components from their in-house tools. A wide array of commercial libraries are available from Dassault Systèmes or from 3rd Party library providers to create vehicle models with ease. Available libraries include: Electrified Powertrain, Battery, Electric Power Systems, Brushless DC Drivers, Hydrogen, Engine, Powertrain, Suspension, and more.

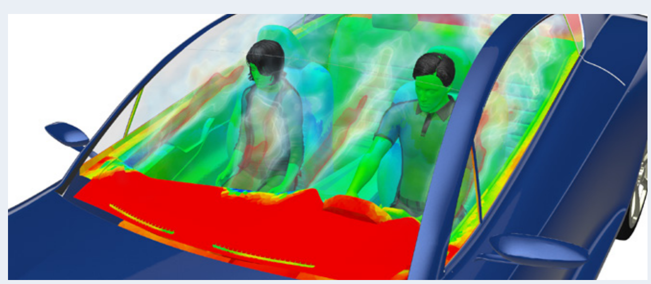


Dymola model for integrated HVAC & battery modeling

Cabin Comfort Model

Vehicle cabin comfort is a hugely influential factor when purchasing a new vehicle. A comfortable and visually appealing cabin is paramount if companies want to impress buyers. There are many challenges in designing an efficient and comfortable cabin, accounting for factors such as range anxiety, maintaining occupant thermal comfort, and ensuring acceptable electronics temperatures during extreme weather. Sizing the HVAC at the early design stage is very important to achieve the above-mentioned range and comfort without compromising the looks of the vehicle. SIMULIAs Fluid Thermal Solutions can be used to address all these challenges and help in digitally designing efficient and comfortable cabins.

SIMULIA PowerFLOW®'s quick design approach is used to achieve the optimal flow and temperature distribution from the ducts. Integrated PowerFLOW-PowerTHERM coupled simulations predict hours of transient temperature distributions with high accuracy, replicating any real word environment. Fast iterations of drive cycle simulations can be carried out in early design to get temperature trends and compare designs. With simulation, it is even possible to virtually choose materials, such as varying glass types, and assess their impact on energy conservation and comfort, without ever leaving your seat.



Long transient cabin PowerFLOW simulation for cooldown & heat-up with Microclimate

Inceptra supports engineering and manufacturing organizations with best-in-class solutions to digitally design, simulate, produce, and manage their products and processes, enabling enhanced innovation and productivity.

As the largest Platinum partner in North America, Inceptra is dedicated to Dassault Systèmes' product development software portfolio, complementary solutions, and related services, including training, implementation, integration, support, consulting, and automation services. For more information, please visit Inceptra.com.

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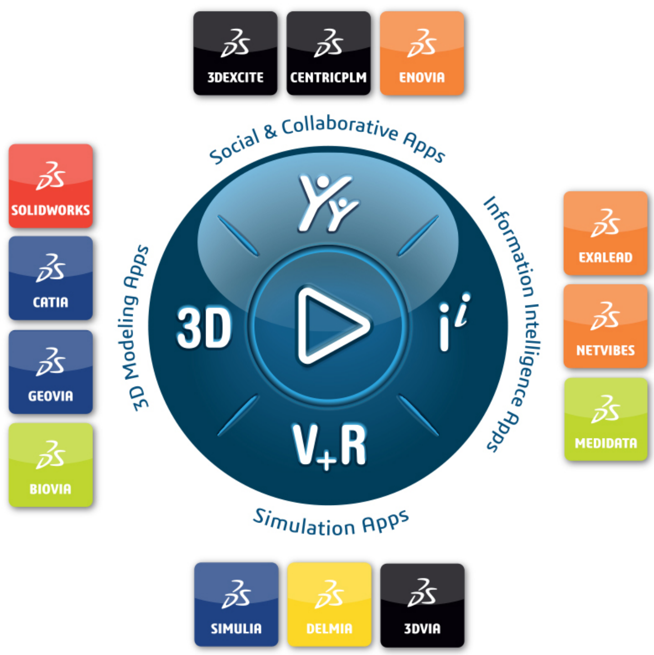

Our **3D**EXPERIENCE® platform powers our brand applications, serving 11 industries, and provides a rich portfolio of industry solution experiences.

Dassault Systèmes, the **3D**EXPERIENCE 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 **3D**EXPERIENCE 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 **3ds.com**.

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