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Electric vehicles (EVs): sharing a common language for a sustainable future

A key to successfully engineering ground-breaking EVs is to enable collaboration between car body in white (BIW) and battery teams that accelerates innovation by means of working across common software platforms to efficiently share ideas, solutions, and data

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Executive summary

The pressure for action to address the climate crisis has led to a boom in demand for electric vehicles (EVs). Many leading car brands have committed to being all-electric by 2030, or earlier. But engineering electric cars requires new skill sets and new ways of working that demand collaboration between engineering teams that, in the past, may not have typically collaborated. Collaboration is needed across the spectrum of teams involved in vehicle engineering, but especially between EV battery and body in white (BIW) teams, which is the focus of this paper.

BIW engineering teams are typically mechanical engineers with responsibilities including design of the car body that will meet performance and packaging constraints set out in the vehicle specifications. Packaging challenges include incorporating all vehicle components such as the interior, powertrain, electronics and storage space within the specified overall vehicle volume. As the typical powertrain configuration has been well established for internal combustion engine (ICE) vehicles, the methodology for packaging the ICE powertrain is also well understood, which helps reduce the need for communication between powertrain and BIW teams during the design process. This was fine for the well-established ICE vehicle engineering processes, but EVs are different. With less consensus on the approach for EV powertrain system design and much stronger interaction among thermal, electrical, structural domains in determining EV performance, many more design parameters are in flux especially those related to battery systems. As a result, there are more decisions left open – including the number, size, weight, configuration and placement of batteries, all of which can significantly impact the BIW team's design decisions related to packaging and overall vehicle performance.

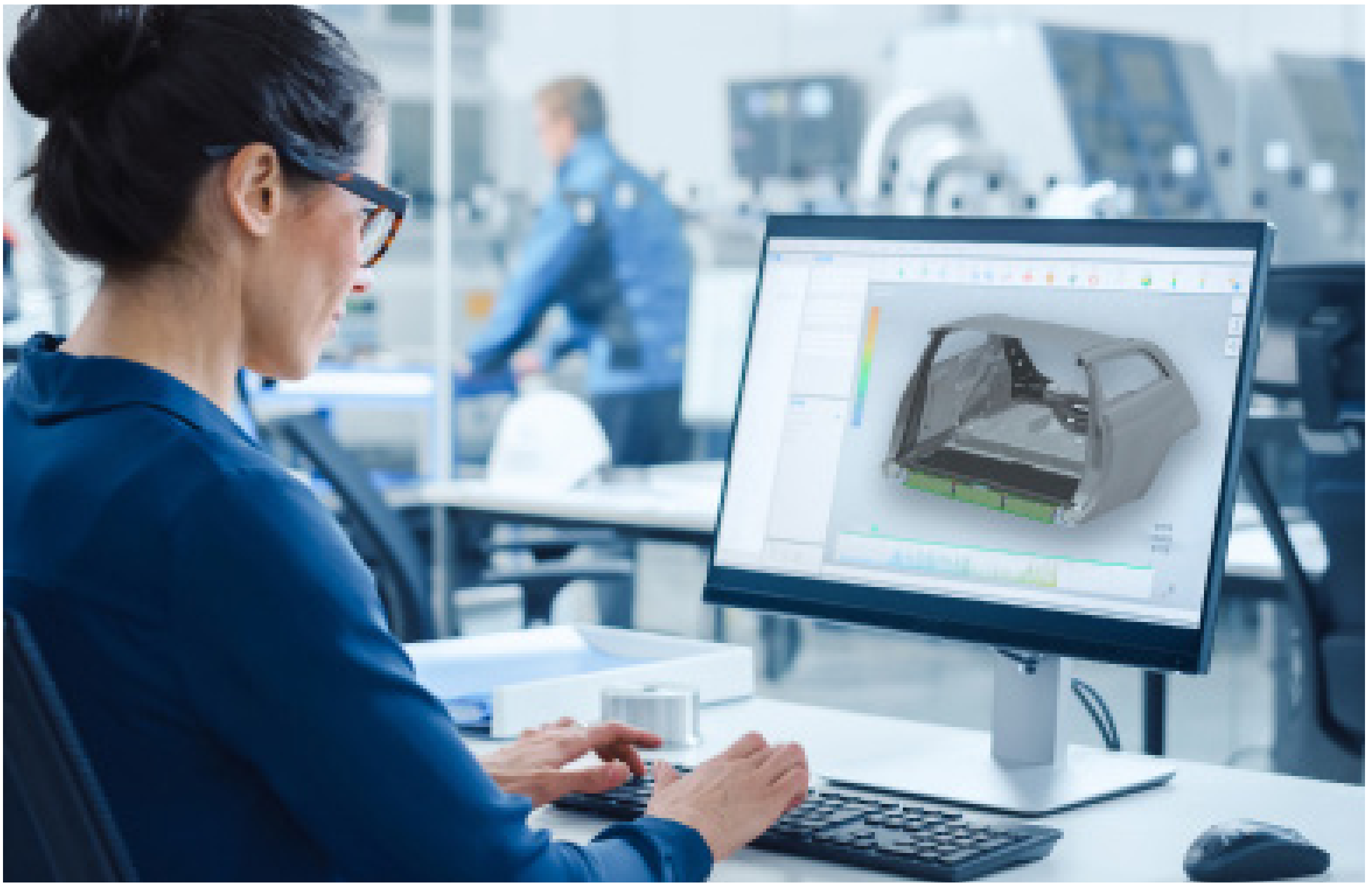
These decisions impact on and are impacted by both the battery and BIW team and require a new common knowledge base. BIW teams therefore need to think about seeking the input of a battery team, who can bring with them an understanding of battery technology, chemistry and all the data that comes with that knowledge. At the same time, the battery team needs to consider how battery pack design choices might impact body design, such as the effect choices may have on the vehicle from a weight, packaging, durability, vibration, thermal, crash and safety standpoint. Two teams, two worlds, two languages without a thorough understanding of the impact their design choices may have on the other team. It's not the ideal recipe for collaboration. But there is an answer. That is better communication, in particular the need for both teams to work together to find a common "design language" that make both feel comfortable. Failing to establish a common design language to facilitate this exchange can easily result in costly mistakes that may delay getting a new car configuration to the market.

A solution is to adopt a common engineering software platform and dataset that integrates with CAD and allows the battery and BIW teams to work seamlessly together from initial concept to detailed design, to manufacture. Facilitating collaboration on an ongoing basis helps both teams more efficiently design vehicles that meet consumer demands for EV range, safety, comfort and reduced charging time. By sharing an engineering software platform based on a common data set, they can better understand each other's design language, and collaborate to efficiently solve problems to design and build sustainable EVs.

Throughout this paper (see outline on next page) we explore each of the major stages in the EV engineering process related to design of the battery pack and its integration into the car body. We begin with an overview of relevant issues in the market that impact efficient engineering of EVs. Then for each engineering stage we consider what needs to be accomplished from an engineering standpoint and the associated design process improvements for battery, BIW and manufacturing teams to collaborate efficiently.

1. Our transportation future is electric
2. Battery pack parameter definition and battery pack layout/ structural design
3. Battery pack thermal management optimization and validation
4. Assessment of battery pack for manufacturability
5. Battery pack BIW structural integration, optimization/validation
6. EV battery pack data management for enhanced collaboration

For the sake of conciseness, in this whitepaper we are not focusing on challenges associated with Li-ion cells engineering, cell/pack manufacturing, Gigafactory operation and full design of the body in white (BIW). These topics are to be covered in separate whitepapers.



Our transportation future is electric

Whether you love cars with a passion or view them merely as a necessity, it is difficult to live without cars. This is why the personal mobility part of the global response to the climate crisis, and the subsequent drive for Net Zero, has been to seek out cleaner cars, not to legislate against them. After over 100 years of cars powered by fossil fuels and internal combustion engines (ICE), the industry is looking to clean sustainable electricity for the solution. Several major car makers, including Audi, Ford and Volvo, have committed to going all-electric no later than 2030. An analysis of market activities by Siemens Digital Industries Software suggests that 2020s will be the decade of electrification. With more than 480 companies in the world currently working to develop electric cars or electric light duty trucks, **BNEF has forecasted** by the end of the decade 58% of busses (up from 33% in 2020), 28% of cars and light commercial vehicles (up from 2.7% and 2% in 2020) and 40% of two-wheelers (up from 30% in 2020), will be electric by 2030.

In its latest report into the electric car market, **Electric Vehicles: Setting a course for 2030**, consulting firm Deloitte confirms that by the end of the decade electric vehicles (EVs) will account for close to one-third of all car and light vehicle sales, globally. This international picture hides significant regional variation, with China expected to be almost half electric by 2030 and some European countries (Norway and the Netherlands) already close to or over 50% market share for EVs.

But there remain concerns, for consumers and car makers alike. Deloitte's report shows that while easing slightly in some countries, concerns remain about the range of EVs, often combined with concerns about time to recharge and availability of adequate charging infrastructure to create "range anxiety". This is in addition to concerns about the price of EVs and safety of battery technology, particularly in the event of a crash.

Time for EV engineering to evolve

The current challenge for auto OEMs is how to maintain modern standards of comfort and safety – and to convince drivers they have achieved this – while either re-engineering existing vehicles or starting from scratch on a completely new design. Re-engineering a current ICE car into an EV may initially seem a less costly design approach, however, EV developments over the last 10 years have shown that a purpose built EV platform is more efficient and offers more freedom to innovate than **converting an ICE platform to electric**. In either case, to deliver desired range as well as in-cabin comfort and amenities, a need arises for more and more batteries, which add weight and create packaging issues. In addition, incorporating a large battery pack into a car body adds challenges as engineers address issues related to handling, noise/vibration/ harshness (NVH) and cabin thermal comfort.

Having established norms over years of doing things a certain way with ICE vehicles, this represents a huge transformational challenge for the automotive industry. Old organizational patterns and structures may not be well suited to meet new engineering challenges posed by EVs.

For example, since they have decades of experience and best practices on which to draw, engineers on an ICE powertrain team can design the powertrain with minimal collaboration with the car body team. But when developing new EVs, design challenges are exacerbated in this relatively young industry that lacks the design heritage and experience of ICE cars. Many of the companies pursuing EV market opportunity, even well-established car firms, are developing an understanding for the scale of this challenge, yet many are still in the process of learning what they don't know. Making this learning process as efficient as possible is an important step towards engineering EVs that satisfy market needs.

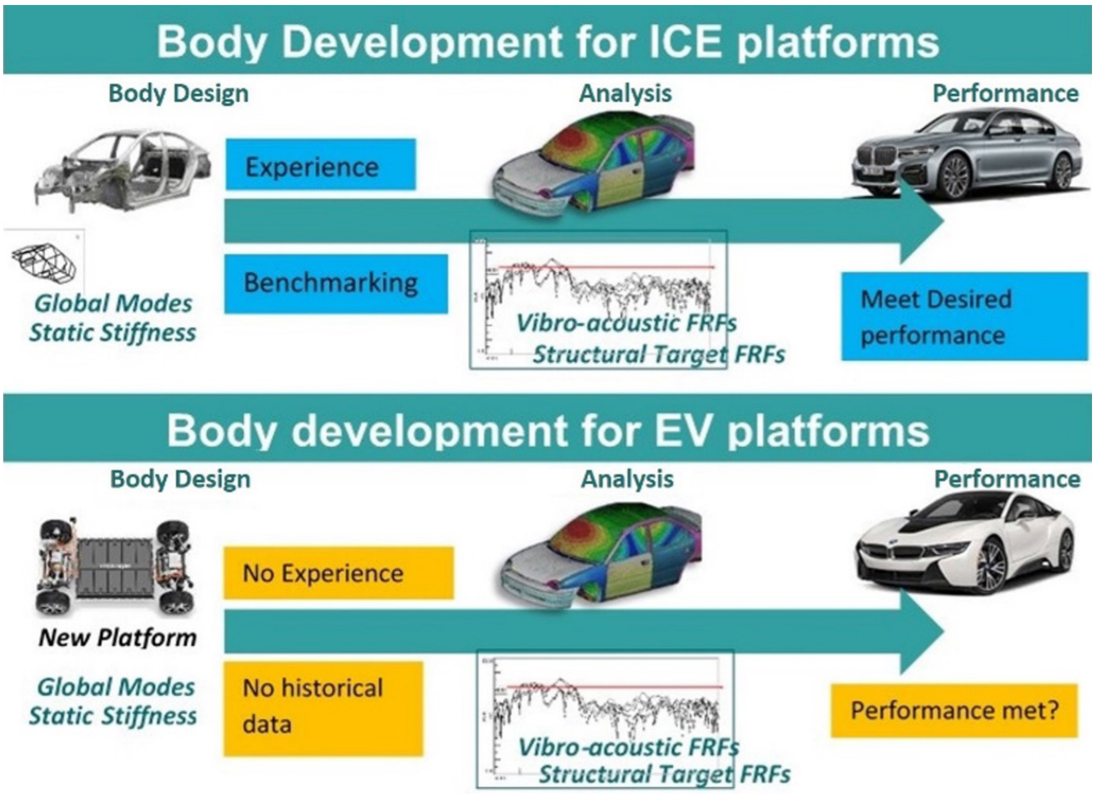


Figure 1: Comparison of body development for ICE and EV platforms.

Engineering EVs to satisfy consumer needs

Year zero for EVs as a mainstream ICE replacement is considered by many to be 2008 – the year that saw launches for Tesla's first Roadster, the Chevy Volt and the Nissan Leaf. The EV industry is therefore only 13 years on its journey into the mainstream. And while EVs have come a long way very quickly, there are still challenges to overcome. In 2008, one of the central technical challenges was low energy density and the high cost of Li-ion batteries. Through various material technology breakthroughs and manufacturing efficiency gains since 2010, **Li-ion battery costs have come down by 87%** and **energy density has tripled**. Many automakers now offer electric vehicles with over a 200-mile range and some even over 400 miles, compared to 100 miles 10 years ago at the same price point. The relative ease of getting large battery packs into EVs (60kWh or more), however, creates a new set of challenges. While the cost, weight and volume of batteries used in EVs today remain far from ideal, improved batteries systems that are cheaper, bigger and more powerful means that the major concerns today are less whether EVs are feasible but rather if they can satisfy consumer needs as well as ICE cars. Satisfying these concerns presents a new, more complex series of design trade-offs to EV battery and body engineering teams.

The EV battery team, primarily consists of electrochemistry experts, electrical and software engineers. The car body or body in white (BIW) engineering team is responsible for body design and consists primarily of mechanical engineers. Although these teams should work together closely to deliver a successful EV, they don't always perceive a need or understand how closely intertwined their roles have become. Even if they are aware of the need to collaborate, many simply don't have access to a common set of tools, where data, new ideas and information – not to mention the implications of design decisions – can be shared.

A simple review of consumer concerns about EVs can help explain some of these trade-offs that require a new way of working. For the battery team, a solution to a problem like range anxiety may be to simply increase range through more batteries, but this presents design challenges to a BIW team as more batteries require more space and add weight. The BIW team would like to reduce the number and size of batteries to make it easier to package the batteries with other systems and to meet structural and crash safety constraints.

Battery safety also is a primary concern for consumers and EV designs must protect both passengers and batteries during a crash, especially avoiding battery damage that can lead to fire. Keeping batteries safe especially in a side impact collision, can be more challenging than keeping passengers safe due to the limited amount of space available especially when the battery pack is located under the floor of the passenger compartment. The BIW team needs space around the battery pack to protect it with an appropriate crash or crumple zone. The required side impact crash structure might require a wider rocker or sill, which reduces the remaining space available to package the battery pack within the vehicle. Even the shape of battery pack itself may be influenced by frontal, side and rear crash load paths since body structure must be placed along crash load paths. This is not an easy packaging task and it creates pressure on the battery team to reduce battery pack volume.

These safety concerns and/or increasing the size and power output of the battery pack to satisfy consumer needs, present design challenges to the BIW team since the battery pack adds significant size and weight relative to other body components. In the end, collaboration between battery and BIW engineering teams, whether driven by careful organizational management or through the sharing of tools, systems and data – or most likely a combination of both – must come to the fore. Otherwise, the conflict in goals between these two teams will be exacerbated because traditional ICE vehicle engineering organizations are not optimized to handle the tight collaboration needed for EV engineering.

Finding the common ground

Before 2008, not many car makers employed numerous battery experts or engineers. It is also worth considering that EV battery and BIW teams have different skills and capabilities. Battery engineers are experts in electrochemistry, electrical, thermal, and embedded software algorithms. BIW designers' expertise lies in car body structural design and assembly, system packaging, NVH, structural and crash analysis.

As a result, a lack of common or overlapping expertise in these teams can cause design process inefficiency and lead to errors. Without close collaboration it is possible for a change on one team to occur without considering the impact or significance for the other team. This is not completely new territory for car makers and many organizations are already working to try and address these differences in many ways:

- Battery pack design is owned by the EV powertrain team, but BIW identifies interfaces and load cases and sends requirements to the EV powertrain team.
- Cross fertilization of personnel by putting BIW experts on the battery team, and vice versa.
- Putting former BIW team managers in charge of the battery or powertrain team (and vice versa).
- Relying on subcontractors for entire battery pack design (but this doesn't necessarily solve problems, it merely outsources them and makes communication even more difficult).

Each of these measures is a response to try and improve communication to facilitate improved collaboration and integration of EV engineering teams.

What's increasingly obvious as the EVs become mainstream, is that enhanced collaboration between battery and BIW engineering teams is a major issue for engineering organizations and necessary for efficient EV design. What also becomes clear is that engineering design solutions are required to facilitate this cooperation by efficiently streamlining data sharing and decision-making between teams. This can best be accomplished by working on a common platform via a coherent digital thread that allows for easy sharing of analysis and data on shared systems and tools that include traditional design-oriented tools such as CAD.

For example, a typical trade-off is how vehicle performance is impacted when incorporating the battery pack into the car body. Depending on where the batteries are located or stacked can impact location of the vehicle center of gravity. This in turn impacts vehicle dynamics and handling, which is central to defining driving experience. Or another example, as the battery team chases range by increasing the number of batteries, weight is added that can have an adverse effect on noise, vibration and harness (NVH) as well as overall vehicle stiffness and handling.

It quickly becomes obvious that the battery team working in isolation and adding batteries, or the BIW developing a chassis with limited space for the battery pack, can impede the engineering process. While the design and build process is always iterative, simply going back and forth between conflicting options isn't an efficient use of time, especially with the drive to reduce time to market.

Throughout this paper, we explore the collaboration required at each of the major design stages for effective engineering of a battery pack into an EV car body. The paper also describes issues faced when engineering the battery pack into an EV body structure and how to establish a more collaborative engineering process. An integrated four-stage workflow is proposed that enables teams to make trade-offs at each stage in order to create a fluid process that guides engineering teams toward their goals, while limiting the chance of unforeseen surprises during battery pack to body integration.

The four-stage workflow:

1. **Parameter definition and battery pack layout/structural design**
2. **Thermal management optimization and validation**
3. **Assessment of battery pack for manufacturability**
4. **Battery pack BIW structural integration, optimization/validation**

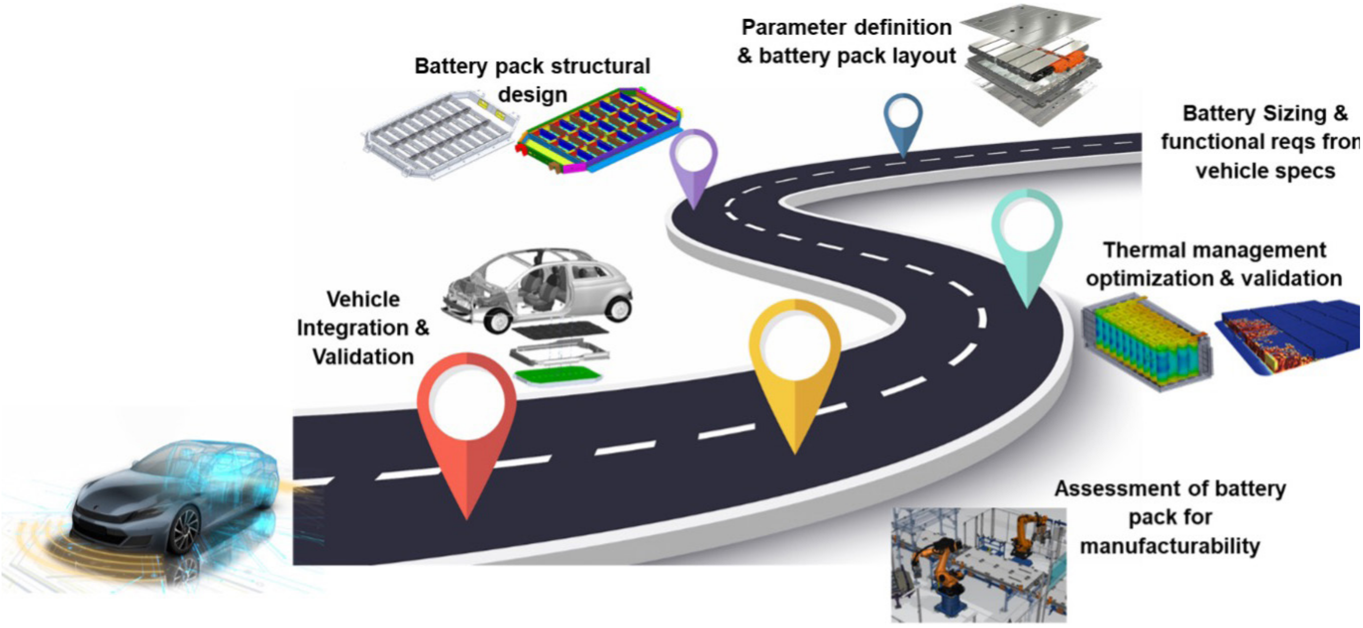


Figure 2: Engineering process for battery pack and body in white (BIW) integration.

Parameter definition and battery pack layout/structural design

Definition of basic battery parameters

The starting point for the design of an EV is usually a list of desired performance metrics that are used to get an initial estimate as to the battery pack volume, weight and configuration. EV performance requirements include typical vehicle performance goals, such as top speed and acceleration, but also specific EV requirements, such as range and battery charge time. These requirements are the criteria that ultimately determine the required battery pack size measured in kilowatt hours (kWh). Relevant vehicle specifications from marketing teams (in turn driven by consumer demands), are given to the battery and BIW teams and include items such as:

- Target drive range
- Top speed and acceleration
- Target price
- Regen effectiveness
- Auxiliary power demand
- Motor and inverter efficiency
- Max voltage and current
- Drag coefficient
- Vehicle mass
- Vehicle envelope and sizing

These parameters are fundamental in shaping the initial estimate for volume and weight of the battery pack and are used by the battery team to determine pack performance, packaging and cost trade-offs.

In making these decisions, the battery team considers everything from battery chemistry to total number of cells. Cooling system configuration must also be considered, such as type (water or air) or placement of coolant flow (through and around versus underneath or over cells). The aforementioned parameters can impact overall battery pack height or width, which later can cause issues in packaging the battery pack in the vehicle. The battery team also evaluates the cost impact of these parameters in order to help maintain the vehicle target price. The final result of this battery team design step is to select the cell type as well as number of cells per module and number of modules in the battery pack.

In parallel, the BIW team will take vehicle requirements into consideration for initial car body design exploration. The BIW team considers how to package all proposed systems (both mechanical and electrical) into the vehicle to meet the requirements, both in terms of packaging and performance. The battery pack obviously performs a key powertrain function, but due to its location and size it must also contribute to structural integrity by helping provide car body strength, stiffness and durability. This is of particular concern with regards to crash and safety considerations. While locating the battery pack under the vehicle floor is a common practice, it does make it vulnerable to side impact crashes. Being able to protect the pack sufficiently in this regard is a major packaging concern for the BIW team as additional space may be needed around the battery pack for crumple zones.

The BIW team also considers the integration of passenger in-cabin amenities, because an increasingly complex set of amenities not only drives power demand, but it also adds to packaging challenges. When the pack is placed under the floor of the car, it is essential that passenger comfort be considered – most notably from a thermal and acoustic comfort perspective. How hot will the batteries run? What impact will that have on those in the cabin? How noisy will it be, and will there be excessive vibration?

Having considered all these factors, the key outcome from the BIW team is an allowable battery volume that will be presented to the battery team. This volume in combination with the battery team's initial battery parameter definition of type/number of cells and layout becomes the starting point for the battery team to begin exploring battery layout options.

Exploring battery pack layout options

The BIW team and EV battery team have to work together to explore battery pack layout options. The goal of this collaboration is to maximize the number of cells in a given volume without sacrificing thermal and structural integrity of the pack. The teams need to collaborate to ensure that the specified cell count required for power output and thermal performance can be packaged within the target volume provided by the BIW team.

The EV battery team begins detailed design of the initial pack configuration and baseline cooling layout. This considers very detailed information on the cells, including chemistry and performance as received from the cell supplier, as well as the other previously defined parameters. The battery cells are then combined into modules (a grouping of cells). The modules in turn are laid out to fit within the pack volume provided by the BIW team. At this stage of the design process, areas within the battery pack may need to be reserved for components that are needed for the cooling system or electronic components. As this is a complex set of parameters, a final design is only achieved by trying several alternative design options.

Although most companies recognize the need for collaboration during this process, execution can be challenging. For instance, the BIW team defines initial battery pack CAD geometry for coolant channels and a structural layout. To determine thermal and structural performance of this design, detailed meshing for CFD and CAE analysis is needed first for analysis. Each time there is a change in the design and related CAD geometry, this process is repeated. The ability to execute thermal and structural simulation in the native CAD environment with automated meshing, and without the need to simplify or clean geometry, facilitates design exploration as well as team collaboration.

Keeping your cool

The cooling system layout can have a significant impact on battery performance, safety and overall packaging. In addition, the cooling system design can also impact how easy it will be to package the pack into the target volume provided by the BIW team. The most effective way to undertake this design effort is by leveraging a CAD-embedded CFD simulation for the battery pack. This allows engineers to conduct design trade-offs related to battery thermal management in an automated way, since CAD-based design changes are easily accounted for in CFD analysis without the need to clean geometry or spend time addressing meshing issues. Such a CAD-embedded battery CFD framework must also allow battery engineers to easily import the cell chemistry/performance data needed for cell technology-specific pack layout exploration. Overall, this helps improve the efficiency of both battery and BIW teams.

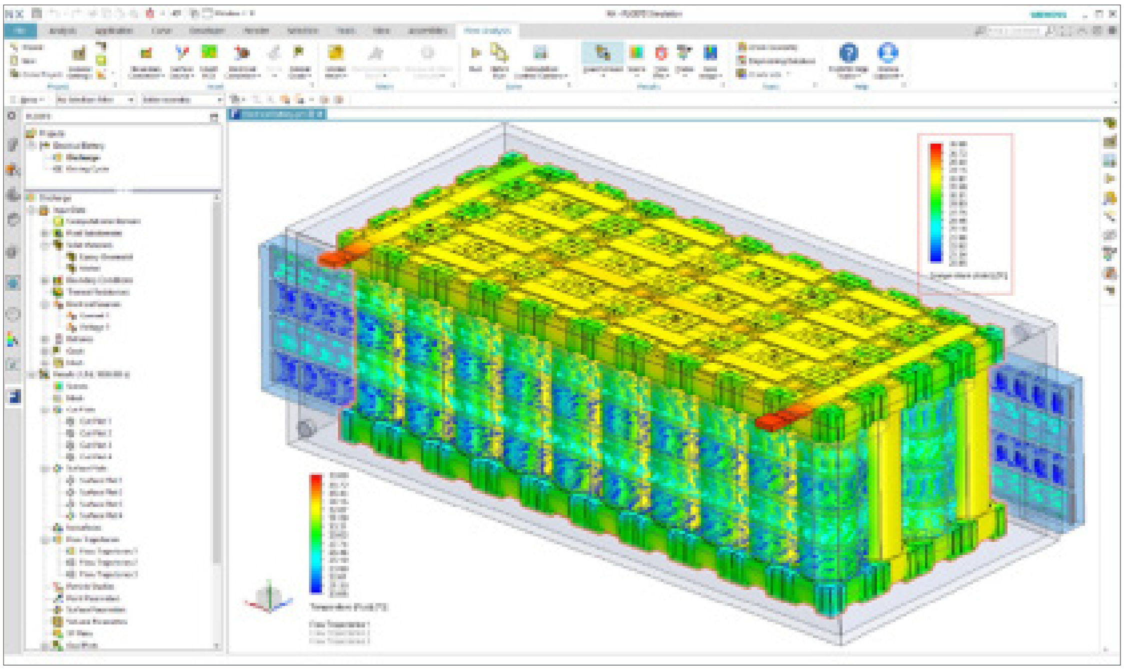


Figure 3: CAD-embedded CFD for battery pack allow BIW and battery teams to efficiently collaborate to explore packaging options that can maximize the number of cells in given volume, without sacrificing thermal integrity.

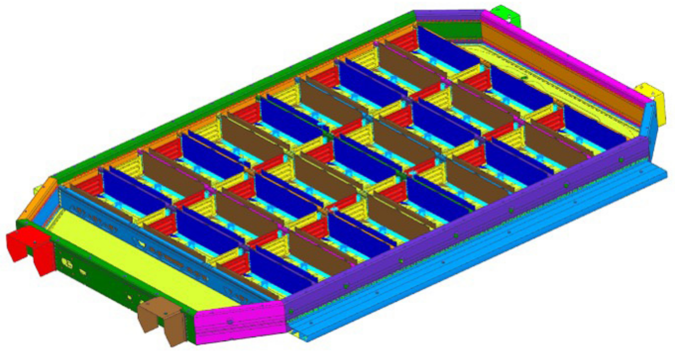
The outcome from this step is a finished individual cell/module layout with the number of modules needed, all fitting within volume provided by the BIW team.

Structural design of battery pack

In parallel to the battery team system design effort, the BIW team are designing the structural components of the battery pack. The battery pack structure must arrange and fit all the components inside the battery pack. The battery pack structure must also be designed to help meet the overall vehicle structural and crash-worthiness goals. This typically requires the development of an internal support structure in addition to the outer battery pack support frame. With the required battery system details in terms of module dimensions, weight and quantity – as well as information on other areas that need to be reserved for components such as electronics – evaluation of structural design alternatives for the battery pack structure can now begin.

Frame and internal support structure components, such as cross beams, must be designed in such a way to properly arrange and fit battery components within the desired battery pack volume. The number and positioning of cross beams must also ensure that the battery pack satisfies pack and vehicle stiffness requirements. At this stage, optimization studies can be done to assess multiple design alternatives, testing out varying numbers of cross beams and longitudinal columns for battery module arrangement.

Considerations throughout this analysis must also keep overall weight in check. If the battery pack weight is over target, engineers may need to find opportunities to reduce weight through redesign of the battery pack enclosure. This may involve switching certain components to lighter materials. For example, one could substitute composite material for aluminum to maintain stiffness while achieving a significant weight reduction. Composite design simulation tools can be used to assess manufacturability and fiber orientation to make sure the composite components are manufacturable and meet structural requirements.



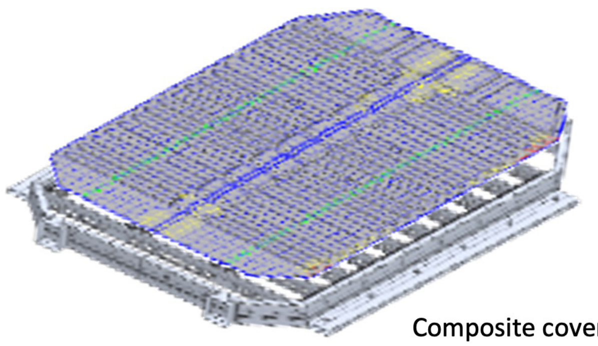


Figure 4: Structural engineering and lightweighting of the battery pack go hand in hand.

The final output from this stage of the process is a detailed battery pack layout with the total number of cells required within the specified battery pack volume needed to achieve thermal and structural performance, as well as overall vehicle performance.

Battery pack thermal management optimization and validation

Battery energy and thermal management system design

Now that the mechanical aspects of the battery pack have been defined, it is time to verify whether the battery pack meets all the thermal and energy requirements. The final goal of this stage is for the battery team to release a final pack design. A verified design will then be sent to the BIW team to integrate into the car body in a way that meets the overall vehicle structural, NVH and weight targets. For the battery team, this stage includes the following steps:

- Pack thermal management optimization.
- Battery pack thermal runaway analysis to ensure a graceful failure.
- Validation of battery energy and thermal performance against vehicle requirements.
- Battery management system (BMS) embedded software development and validation.

Thermal management optimization is conducted to ensure cell-to-cell temperature variation, to maintain maximum temperature within specification and to verify that the battery pack meets all thermal and energy requirements. Engineers use CFD simulation solutions to optimize thermal management strategies, ensuring it meets requirements for critical operation scenarios. During this optimization stage, design iteration may occur with the BIW team.

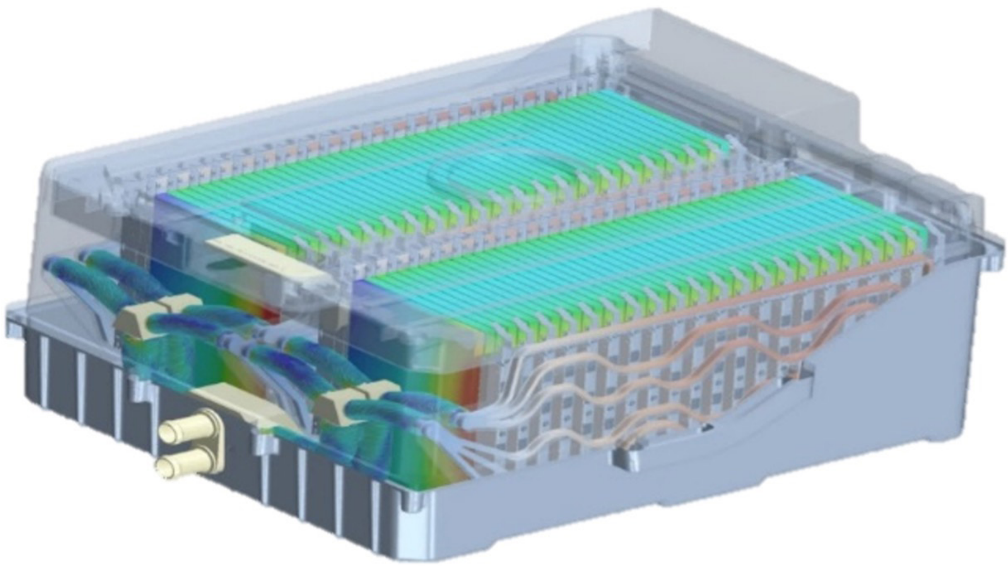


Figure 5. Battery pack coupled electrical-thermal simulation with automated optimization capabilities are critical to ensure optimal thermal management.

A key design metric is ensuring the pack does not get in a thermal runaway event. The design must ensure a “graceful failure” to avoid fire in case one or more cells fail. At the pack level, additional safety considerations must be met. For instance, how to limit large numbers of cells facing temperature spikes in case one cell in a pack undergoes a thermal runaway event. Or, how to slow down the spread of battery pack gases venting to the cabin while passengers exit a car.

Battery pack safety testing, though critical, doesn't offer insights on why a design may fail. Pack safety simulations are a powerful addition to the design process because they complement testing by offering insights on where limitations are and how to improve a design to address any operational issues. During cell development, even though significant simulation and testing occurs at the pack level, safety simulations become even more important because undertaking large battery pack safety testing can be challenging. Safety simulations that account for chemical reactions, transient temperature spread and the details of pack layout geometry are necessary. In the end, significant simulation and testing is needed during this step to ensure safe operation. In addition, it is critical to assess the impact of any pack geometric changes to satisfy thermal performance on vehicle integration and packaging.

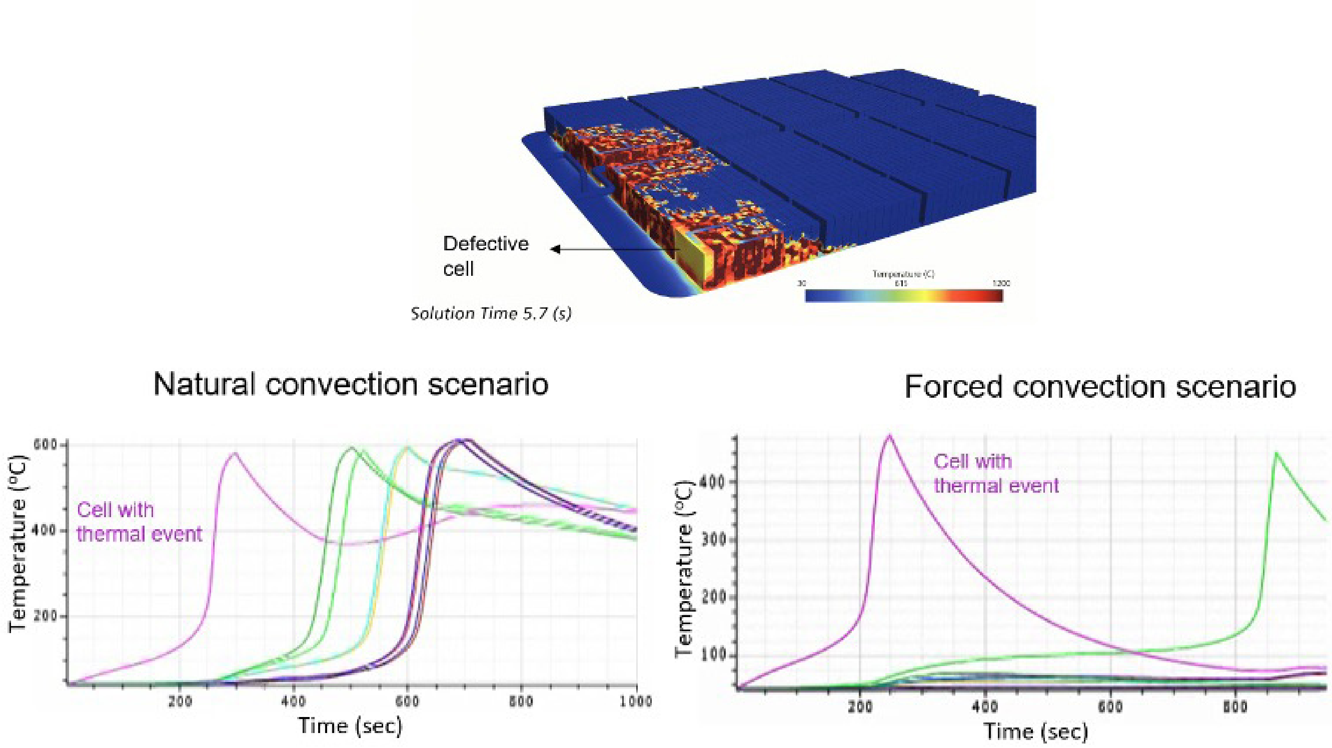


Figure 6: Battery pack thermal runaway simulations are critical for identification of design limitations and complementary to safety testing and validating that designs meet safety standards.

Battery energy and thermal management validation

Once the thermal management of the battery pack has been optimized, and before fixing or "freezing" the battery pack design, the EV battery team will work with systems engineers to validate the electrical and thermal performance of the battery pack within the complete vehicle system. For this, a digital continuity and integrated workflow between detailed three-dimensional (3D) battery pack design analysis and one dimensional (1D) vehicle system analysis is used. Central to the success at this stage is bringing battery-specific rich analysis to system simulation without slowing down computation. A massive speed up is achieved through the extraction of reduced order models (ROM) and integrating it into a system simulation. This integrated 1D-3D workflow allows engineers to validate drive range for a complete drive cycle with realistic power demand, including demands from cabin cooling and other auxiliary power. Engineers can also reliably estimate change in range at different ambient temperatures.

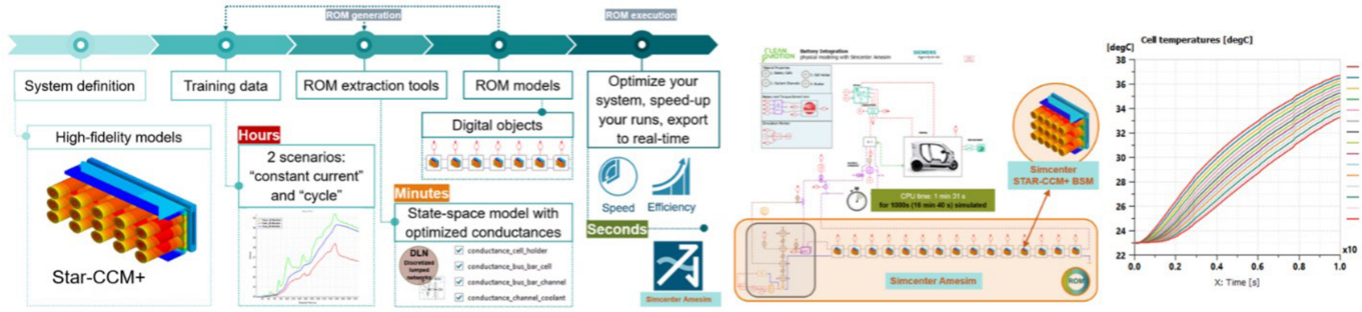


Figure 7: Significant speed up in validation of battery pack thermal and energy management for real-world driving conditions is achieved through seamlessly connecting detailed battery pack model with vehicle system simulation.

BMS algorithm and embedded software development and validation

The battery management system (BMS) is the brain of a battery pack and can be developed as the pack mechanical and electrical system design occurs. As shown in Figure 7, there are four key elements for BMS algorithm and software engineering:

1. Software requirement management and process orchestration for development and validation.
2. To ensure performance, accurate algorithms to estimate state of charge, state of health, remaining drive range, as well as algorithms for cell balancing and thermal management are developed. These algorithms need to account for cell chemistry and performance. 1D electrical thermal model of battery pack, as discussed above, is essential for algorithm development.
3. Algorithms then need to be transformed into embedded software. Poorly architected software introduces errors that cause recall and liability risks. Once the software architecture is designed, embedded software integration needs to ensure **AUTOSAR** implementations, generating real time executables (RTEs) and cyber security.
4. Extensive testing of BMS is critical. Engineers are increasingly relying on Software-in-the-loop (SiL) and Hardware-in-the-loop (HiL) testing to validate BMS software before release.

Of course, as BMS performance is dependent on the nature of battery pack mechanical layout and systems, the ability to update any BMS simulation with a new model that reflects any battery pack layout design changes is beneficial to overall design efficiency. The final output of this section of the process is a verified, final, signed-off battery pack design.

Assessment of battery pack for manufacturability

Throughout the design process, the manufacturability of the battery pack must be considered. It is essential to make sure that the battery pack design is such that it be manufactured easily within the framework of a company's manufacturing capabilities. There may be a temptation to leave the manufacturing related issues to the very end of the process, but leaving such considerations to the end can lead to significant delays and increases in manufacturing cost.

Software simulation frameworks built upon CAD can be used by manufacturing teams to efficiently assess a design from a manufacturing perspective early on in the design process. Important considerations include the ability of the design to be built within the company's factories while maximizing manufacturing throughput and verifying that manual and automated manufacturing steps can be carried out efficiently. Use of manufacturing simulation early in design provides an opportunity to consider design modifications that can enhance the manufacturing process.

For instance, how much of a plant should be fully automated, manual or consist of operations where people and robots collaborate? As battery pack components can be relatively heavy, this will drive up the level of automation in the assembly. At the same time, complex detailed operations may be better suited for manual assembly. In addition, to improve efficiency, processes and cycle time must be validated, while the levels must be balanced between automation and manual processes. Regardless, workplace design is defined by process validation, layout refinement and ergonomics.

For battery pack assembly where manual operations are required, simulation can be, for instance, to determine the reachability of employees of different heights to determine if they can carry out a particular task. A process simulator can be used to simulate human behaviors and develop appropriate workstations and tooling. For instance, a tilt conveyor could be used to tilt the battery pack so all connectors can be made accessible by different employee profiles during assembly. This results in a lower risk workstation design that ensures operator health and safety while improving efficiency, because it was proven at the front of the process.

Assessing the overall impact of production flow is essential to understanding production cost and environmental impact. For instance, this incudes energy simulation to understand how much energy you need in your production. With a drive to more sustainable production, a design change might be considered to reduce energy consumption. Line simulation that understands the costs of your production, resource allocation and utilization can be used to determine how much buffer you need, for the most efficient production.

In the end, simulation can be used to establish a virtual production that fits to the specification of the product and provides feedback into product design to assess what needs to be changed early in the design process in order to optimize production and save costs.

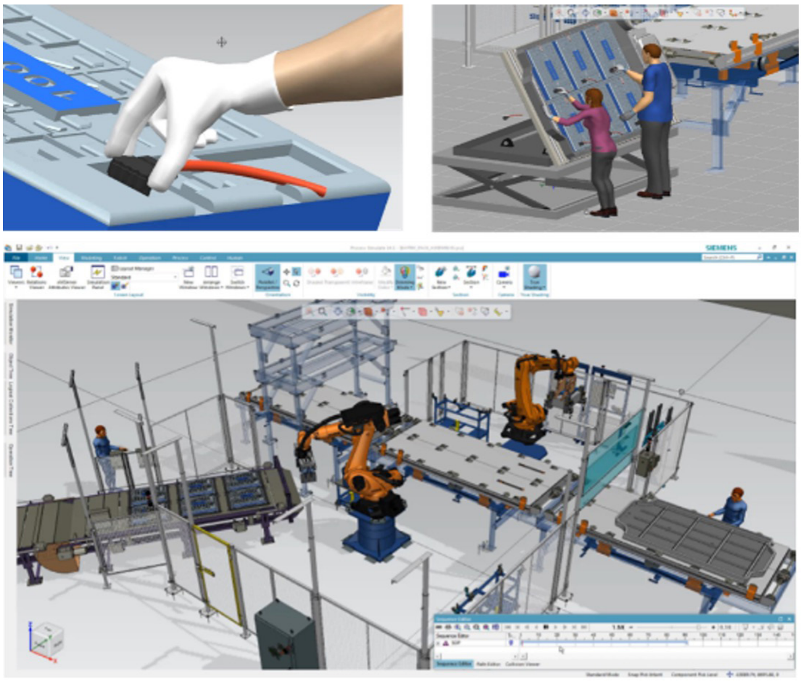


Figure 8: Digital manufacturing solutions allow battery manufacturers to plan and validate processes before floor implementation.

Battery pack BIW structural integration, optimization/validation

Once battery pack detail design is complete, structural performance and packaging of the final design within the BIW must be verified. It is important to consider that the BIW of an electric vehicle is significantly different from that of an ICE vehicle in that the battery pack is a structural part of the vehicle. The BIW of an ICE vehicle can weigh a couple of hundred kilograms, and adding a battery pack adds another couple of hundred kilograms, which makes the battery pack a significant portion of the BIW weight, potentially doubling it. This added weight changes the structural and dynamic properties of the body significantly and, in turn, impacts attributes such as crash performance, durability, driving dynamics and noise, vibration and harshness (NVH).

The position of the battery low in the vehicle is generally a good thing when it comes to driving dynamics as this lowers the center of gravity and results in a beneficial effect on roll behavior. However, the extra weight from the battery pack will require increased engineering of suspension and tires to ensure ride comfort and maintain durability performance.

From an NVH perspective, things are rather complicated. Weight can have a positive effect on NVH behavior, simply because more mass needs more force to vibrate. The consequence though is that engineers seek to lower the upper body weight to compensate for the additional weight of the battery pack. The design of the upper body is therefore of critical importance to ensure it remains stiff enough to avoid poor NVH performance.

An interesting observation here is that many OEMs have somewhat standardized vehicle platforms on which they build their different models, so the lower structure of a car is common to many models. However, many different upper body shapes for sedans, hatchbacks, MPVs, SUVs share this lower platform. As the number of models increases, combined with a lack of experience of designing bodies for electric vehicles, this presents design challenges for BIW engineering teams. Engineering solutions for use early on in the design process are being developed to help design the structure properly by utilizing standardized beam and joint concepts.

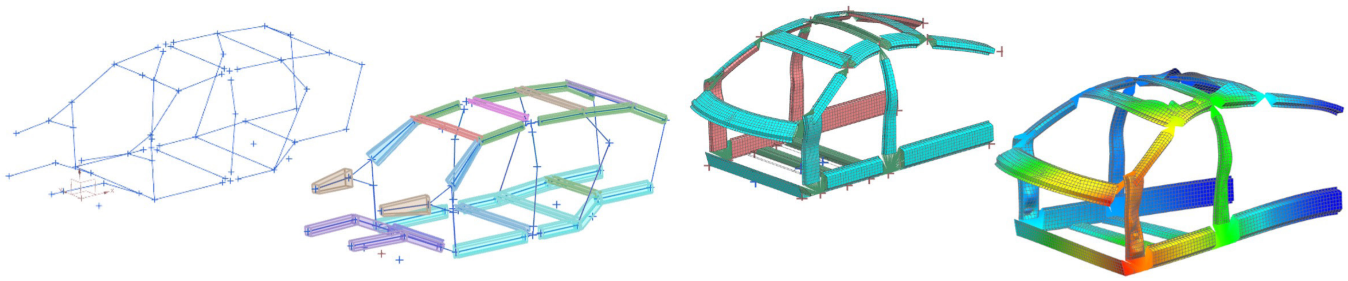


Figure 9: Engineering solutions utilizing standardized beam and joint concepts help design the body structure properly, especially if a lack of EV body design experience presents challenges.

For an ICE vehicle, basic design of the BIW is well understood. However, for an electric vehicle battery pack, integration introduces additional challenges. Integration of the battery pack into the BIW must be performed so that proper structural details ensure proper overall performance for crash (side impact, primarily), durability and NVH. This is unlike an ICE vehicle where this analysis could be performed solely on the BIW. Unique to EVs, the BIW must be designed to not only maintain occupant safety but also to protect the battery pack from intrusion or penetration. Side impact protection is especially challenging for battery pack safety as there is limited space to incorporate the crumple zone.

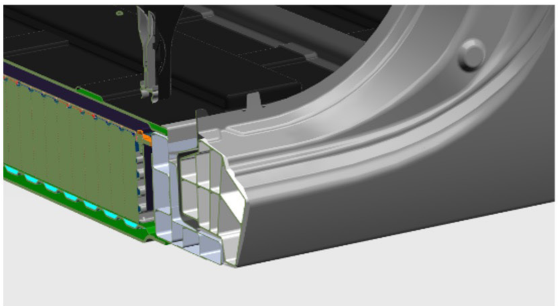
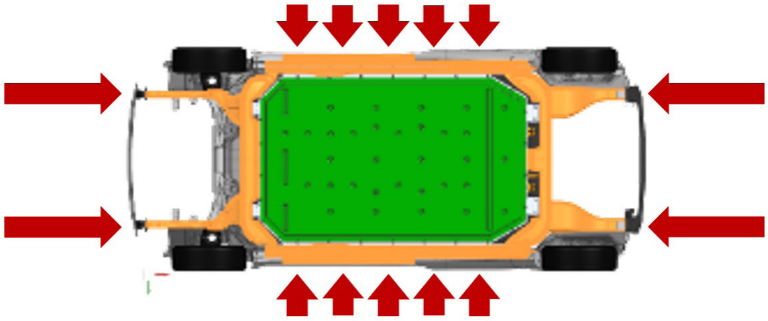



Figure 10: Integration of the battery pack into the car body requires attention to structural details to ensure overall performance for crash (primarily side impact), durability and NVH.

Since engineering of the BIW for ICE vehicles is well understood, based on many years of experience developing best practices, current engineering solutions are well suited for design. However, in order to ensure efficient integration of the battery pack within the BIW, solutions must also provide for the efficient exchange of data related to electrical and mechanical design, as well as analysis.

EV battery pack data management for enhanced collaboration

Digital transformation, or the widespread digitalization of processes, data flows, and methodologies, provides the foundation automakers need as they confront the diverse yet intertwined challenges of vehicle electrification. Such a transformation accelerates development cycles by enabling data to be captured and leveraged throughout the product lifecycle and secure collaboration between engineering teams, such as those developing battery packs and car bodies. With these capabilities, EV manufacturers are better equipped to manage the design of new platform configurations that optimize battery size and placement while concurrently integrating the battery pack within the car body.

Digitalization is a powerful facilitator of close collaboration between engineering teams, even those that have traditionally had little interaction. EV design teams can build a common vocabulary for engineers, designers and product managers, with which they can exchange information and ideas conveniently and quickly. The result is an easier and more impactful collaboration between teams. Engineering teams can incorporate new information and ideas directly into their designs without translation or interpretation. While data is presented in a way that makes sense to people of all disciplines and roles, through intuitive interfaces that support insight and decision-making, rather than cause fatigue.

As EV manufacturers connect teams with digital threads, battery design and BIW engineering should be a key target. Today's advanced digital engineering solutions can offer these teams a common platform (or vocabulary) through which they can co-develop and optimize the EV body and battery packs, taking multiple factors into account, such as battery thermal management, size, and the target size and aesthetics of the vehicle. This will help the overall program meet targets for drive range, safety, and charging time, while also producing an attractive and exciting EV for customers.

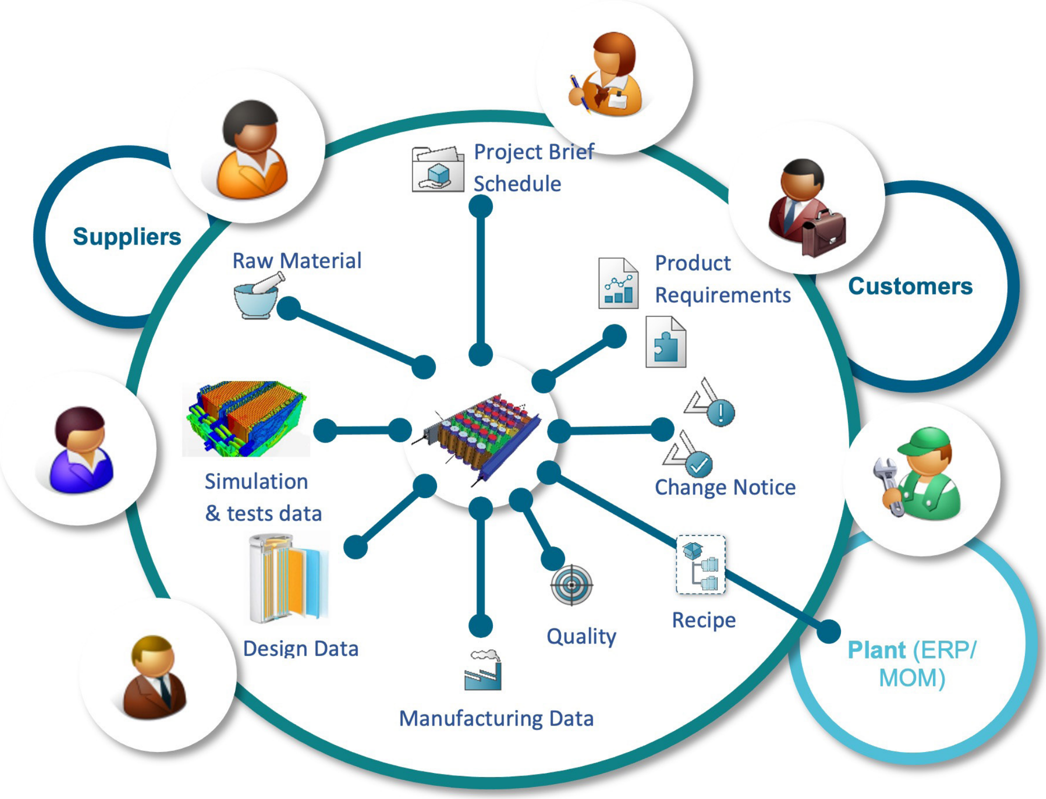


Figure 11: Modern advanced digital engineering solutions offer design teams a common platform (or vocabulary) to co-develop while integrating the battery pack and EV body.

Conclusion

The climate crisis has led to many leading car OEMs to commit to being all-electric by 2030 or earlier. However, engineering electric vehicles requires new skill sets and new ways of working that demand collaboration between engineering teams that, in the past, may not have typically collaborated.

The importance of body in white (BIW) and battery teams sharing ideas and discussing the implications of design decisions cannot be overstated. Failing to establish a common design language and software platfom can result in costly mistakes that may cause delays in getting a new vehicle to the market.

In the end, collaboration, whether driven by careful organizational management or through the sharing of tools, systems and data – or most likely a combination of both – comes to the fore. This enables potential issues to be identified early in the development cycle while the funnel for design choices is widest. The ultimate result must be a safe, comfortable vehicle that delivers on performance and retails at a good price point.

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