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Automotive ECAD-MCAD co-design leads to first-pass success

Executive summary

Automotive electro-mechanical complexity is straining traditional separated electrical and mechanical design methodologies. ECAD-MCAD co-design can boost productivity and ensure design accuracy by replacing cumbersome means of collaboration between the electrical and mechanical domains. Until now, they had to integrate through email, spreadsheets, and XML files. With modern CAD tools, designers are able to synchronize their data more efficiently and collaborate more effectively on critical design items between domains, thereby ensuring that the design intent is properly implemented.

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The challenge: first-past success

Achieving first-pass success is the goal of every automotive design team, both electrical and mechanical. The hope is to minimize or even eliminate costly design iterations. Reducing the number of design iterations reduces product development cost and, more importantly, helps ensure that the product launch goal is achieved.

In the automotive industry, first-pass success is more challenging than ever because of the increasing electromechanical complexity and density of modern vehicles. Most modern cars run their critical systems, such as the throttle and braking systems, electronically through computers and sensors. Most cars can also be equipped with an array of cabin amenities like infotainment systems, air conditioning, and heated seats. For high-end luxury cars the case is more extreme. According to Car and Driver (2016) the Bentley Bentayga contains greater than 100 million lines of software, 90 computers and control modules, and a wiring harness that weighs about 110 pounds.

This paper discusses how an efficient ECAD-MCAD codesign process helps design teams eliminate costly electromechanical issues during vehicle development and increase the probability of achieving first-pass success.
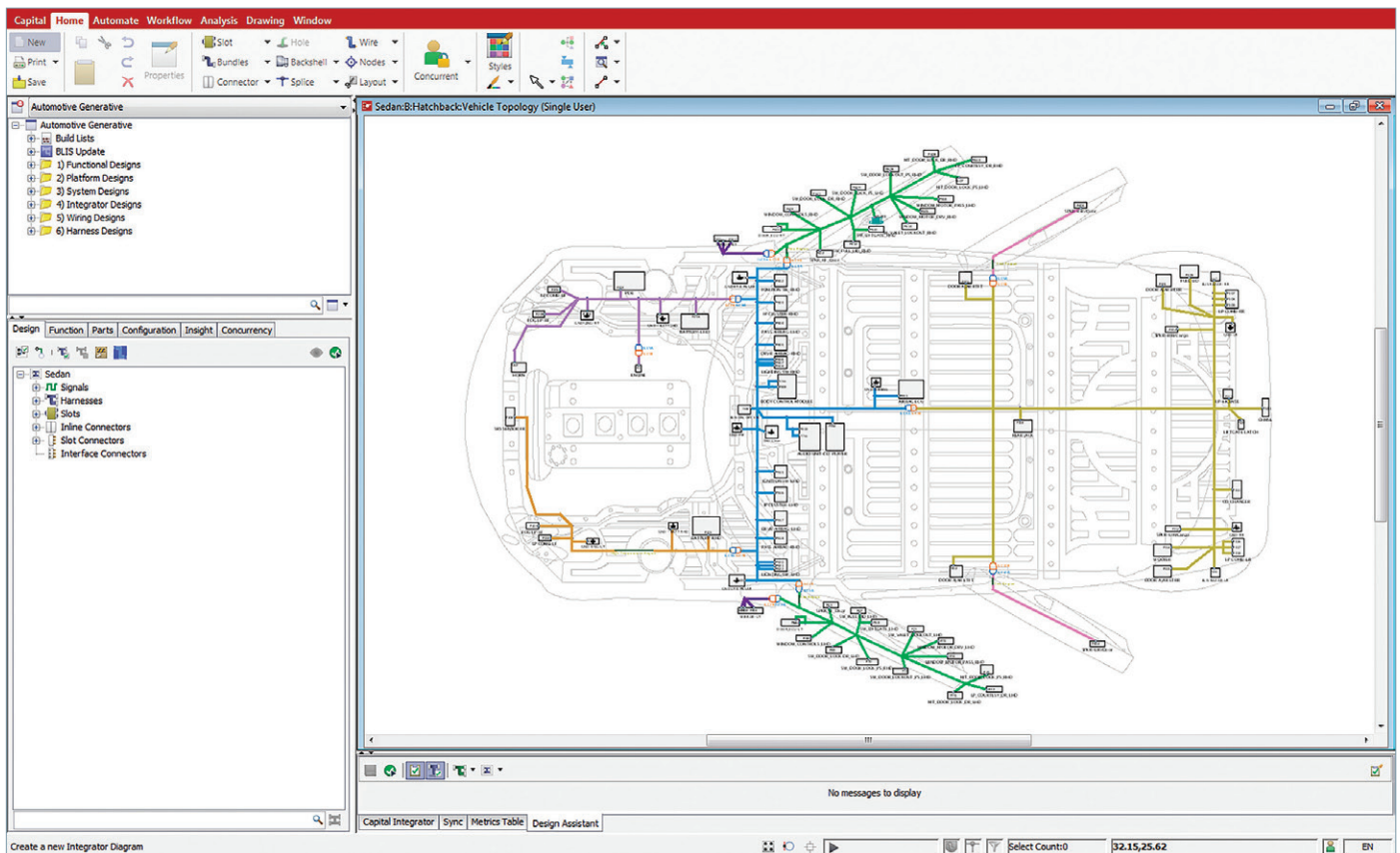

Figure 1: Automotive electrical systems complexity is increasing as customers demand more electronic features.

ECAD-MCAD co-design

This is easier said than done. The potential impediments to ECAD-MCAD collaboration are numerous. First and foremost is the traditional separation that has existed between the electrical and mechanical disciplines. Electrical and mechanical engineers typically work with completely different tool sets and have completely different vocabularies. Many times they even reside in different physical locations.
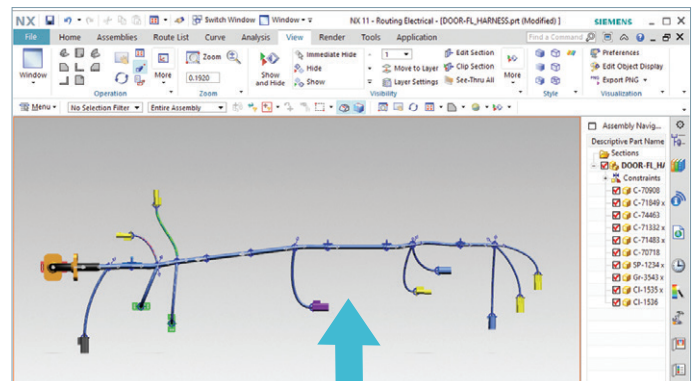
Furthermore, mechanical and electrical CAD systems have different ways of presenting the structure of the same object. In an MCAD system, a computer module might be represented in a physical bill of materials such as the screws, casing, circuit board, and connectors. However, an ECAD representation of the same module displays a functional or schematic view that transcends the physical structure of the object. Certain electrical functions might be mapped to several different circuit boards and connectors, making it impractical to associate a single function to a single physical part.

Because of these impediments, previous efforts to collaborate have met with limited success. Earlier ECADMCAD collaboration tools used everything from sticky notes, and email, to Excel® spreadsheets. These approaches fell far short for obvious reasons. As a result, many automotive product development teams resorted to internally developed software and processes for collaboration that had to be tested and verified with each new release of the underlying ECAD and MCAD tool suites. These locally developed software and processes were costly to maintain and required dedicated in-house support.

The development of the XML file format helped resolve some of these challenges. XML is a platform-agnostic format for storing data, meaning that it can be read by many different types of programs, machines, even humans. For electrical and mechanical designers, this meant that data stored in XML could be transferred directly between their respective design environments, bridging the gap that had traditionally existed between the electrical and mechanical domains (figure 2).

Because of its versatility, many companies have devised their own XML schema to enable interoperability between various software products. Siemens Digital

Industries Software, for example, developed PLMXML as a means of communicating between their product lifecycle software, such as NX, and other applications that have adopted the format, like the Capital electrical system and wiring harness designer.
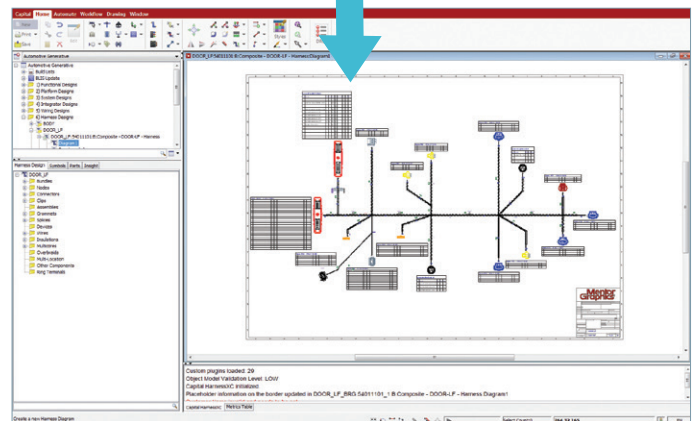

Figure 2: XML helped connect the traditionally separated ECAD and MCAD domains.

NX and Capital integration through PLMXML allows for the ECAD and MCAD designs to be periodically synchronized, ensuring design compatibility while allowing the designers to operate in their native environments. At a high level, the design flow between Capital and NX might look like this:

1. The ECAD designer begins by creating the wiring and connectivity layout in Capital. This layout includes key components such as wires, connectors, multi-cores, and splices. The designer then exports this wiring data to the mechanical engineer.

2. The mechanical engineer imports the PLMXML file and the electrical data is automatically linked to 3D objects in NX. The mechanical engineer can then route the wiring through the vehicle or vehicle part and then exports a file containing these incremental changes for review by the ECAD designer.

3. The ECAD designer can then import this data and perform a number of checks on the design. With 3D wire lengths from NX, the designer can perform voltage drop calculations, ensure that enough space has been reserved in the mechanical design to fit the wiring bundle. Changes can be made as needed, and a new incremental file can be sent back to the mechanical engineer.

This process enables the designers to verify the collaborative design at regular intervals, preventing spatial or electrical system violations. However, this method still requires the manual export and import of data by the designers. The ECAD and MCAD domains can be more tightly integrated to achieve greater savings in time and cost.

XML limitations

1. Linking different platforms together via XML is certainly an improvement over the old methods of transferring Excel sheets or marked-up PDF files to track changes and maintain design intent. But, because the XML data must be manually exported and imported, after one domain completes design changes, they must wait for the other designer to review and accept or reject the proposed changes. This increases down time on a project, prolonging the development process.

2. Additionally, this level of integration circumvents the barriers between ECAD and MCAD only partially. When proposing design changes, the ECAD and MCAD designers are doing so with only the knowledge of what the changes mean for their domain. Therefore, a designer working in the Capital environment could propose changes that would cause spatial or physical violations, and not know this until the mechanical engineer reviews and rejects the changes.
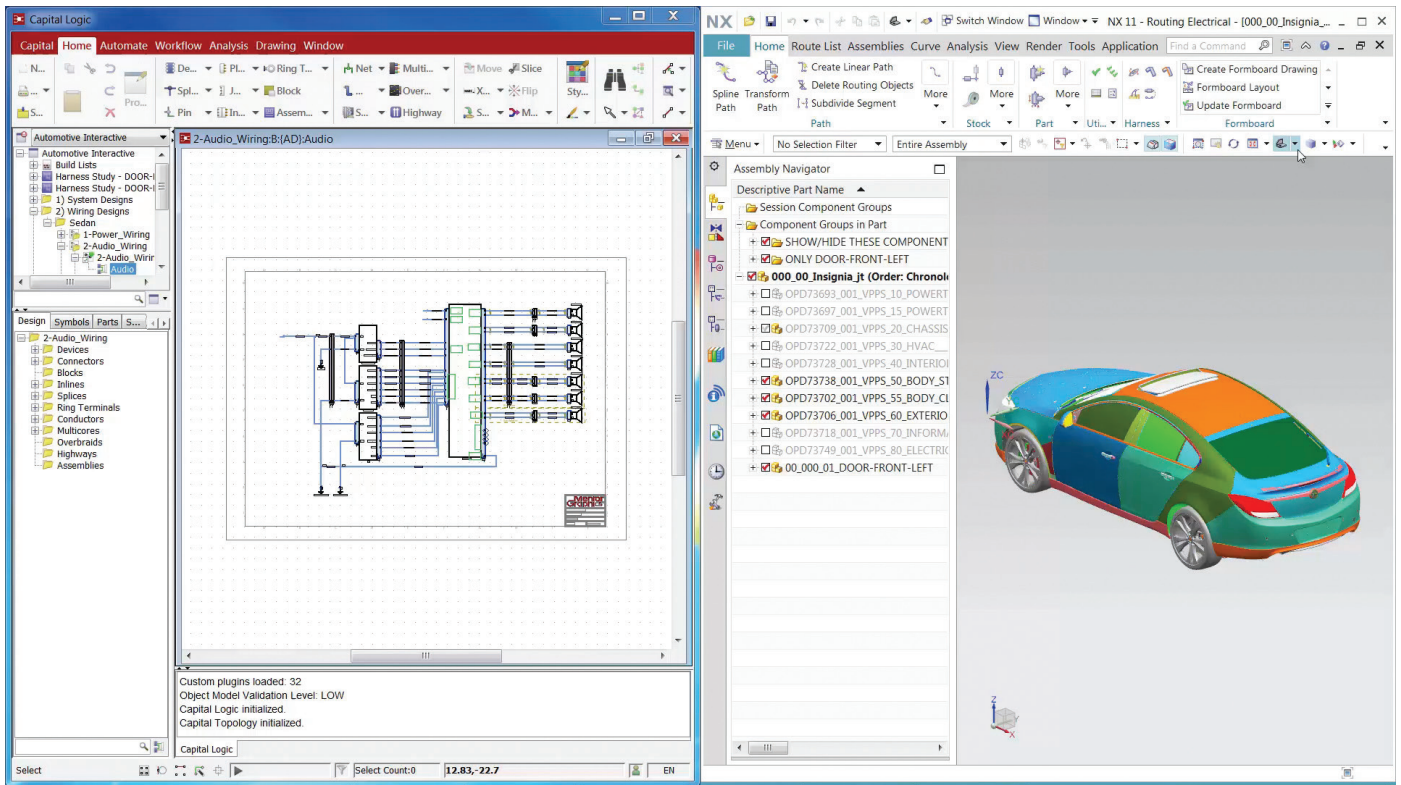
True co-design: cross-probing

Figure 3: An integrated ECAD-MCAD design flow allows for real-time cross probing.

The electrical and mechanical design processes should be more connected, integrated, and collaborative than they are today. Seamless cross-probing between the two domains enables closer integration and collaboration, by enabling the design in each domain to be completed with contextual information from the other (figure 3).

A key feature of such integration is replacing the cumbersome file-based exchange of the XML method. With XML, integration depended on exporting a massive file of changes into a file system for the other engineers to retrieve and then import. Capital and NX support API level integration, where the two domains are directly connected to immediately update the design with changes or new information. Engineers no longer swap XML files but are truly integrated at the data level via a

robust mechanism. For instance, a Capital designer may publish a bill of materials for the wiring which can then be seamlessly integrated into NX.

With this integration, the electrical system and wiring harness can be designed with explicit knowledge of the wet, hot, and noisy areas of the mechanical design. Doing so allows the ECAD designer to account for the impact on the electrical performance of these areas when designing the electrical system. On the mechanical side, space reservations can be made and the severity of bends in the harness can be adjusted to account for the wiring bundles that must route through the mechanical structures. With access to this contextual information from other domains, both electrical and mechanical engineers are able to quickly reconcile incompatibilities between the ECAD and MCAD designs.

In a typical example, the mechanical engineer wants to make sure that the bundle containing all of the necessary wires will route through the allotted physical space. But, the mechanical engineer does not want to create and manage these wires in the MCAD model, as it would be too difficult and time-consuming. Instead, the electrical definition is created in Capital. The maximum allowed bundle diameter, based on various mechanical constraints, can be sent to Capital which will ensure that synthesized or routed wires in these bundles are not exceeded by automatic design rule checks. This ensures correct by construction design and avoids costly rework.

Furthermore, the addition of objects like clips, grommets and tubing to the harness design requires cross-domain collaboration. These objects are best created in the 3D MCAD environment and then merged with electrical data from the ECAD tool. Once this association is made, the fully buildable wiring harness can be automatically engineered in all of its configurations.

In the last few years the electrical & electronic content in vehicles has exploded while the space available has remained constant (figure 4). This means that more electronic content is packed into the same space, potentially leading to electro-magnetic and radio interference. Cross probing and cross visualization between environments enables designers to understand signal routing in 3D space, and thus determine optimal routing to avoid electro- magnetic and radio interference.

For example, in high-end car manufacturing, the design team may want to consolidate the instrument cluster and infotainment systems in their new vehicles Consolidating these two systems can change the location of safety critical electronic systems, thus altering the cabling length requirements and impacting signal integrity. Here cross-probing enables both the electrical and mechanical design teams to quickly determine the optimal routing for the cabling.
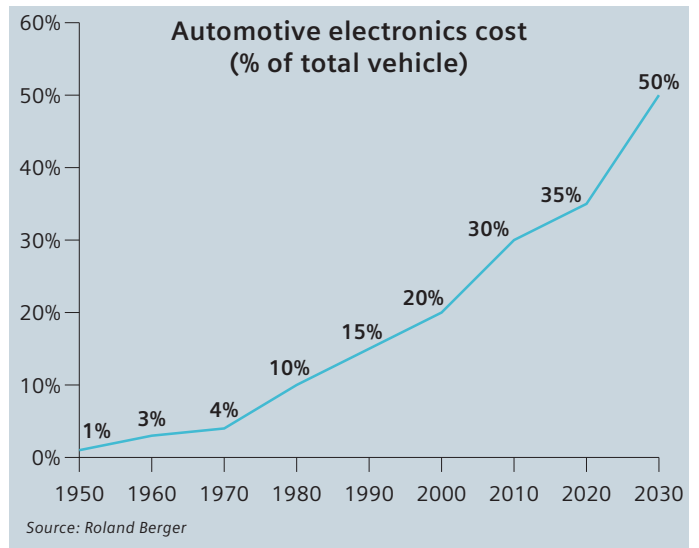

Figure 4: The electrical and electronic content in vehicles has exploded in recent years.

Change management

The immense complexity of modern vehicles results in hundreds or even thousands of tradeoffs and change orders impacting cable length, type, and physical placement. A robust change management methodology is paramount to integrated electrical and mechanical automotive design.

Mechanical defines the bend radius constraints of the wire bundle based on its physical structure. These bend radius constraints need to be communicated back to Capital to create the formboard upon which the wiring harness will be assembled. The formboard is used to physically place the wire bundles and connect the system together before the wiring harness is inserted into the vehicle. With the bend constraints from MCAD, Capital, for example, could alert the formboard engineer if they are creating a model that cannot be built.

With a more advanced car, a manufacturing engineer may need to move a LiDAR sensor from the location specified by engineering. This most likely would require rerouting the cable, or even adding a splice to accommodate the sensor location change. LiDAR sensors require extremely fast data rates, up to 600 MHz. So changing the cabling length or adding a splice could compromise the signal integrity of the safety-critical information coming from the LiDAR sensor. Changing the location of this sensor would spawn multiple change orders for both mechanical and electrical designs that would then need to be verified for cost, weight, balance, and functionality.

The challenge of change management, however, is how to track each other's changes quickly and efficiently. There are two major aspects of change management. First is the automatic merging of data and the clear display of changes to the designer. Capital is equipped with a robust change management tool that automatically creates a list of changes made to the design.

From this list, the electrical engineer can choose to accept or reject each change individually, rather than as a set of changes. The change management window in Capital is also able to live cross-probe with both the electrical and mechanical designs. As each part is selected in the change management tool, it will be automatically highlighted in either the MCAD or ECAD environments to help the engineer understand the change being proposed.

The change manager can also preview a set of changes in a flattened diagram. The flattening may be 3D, orthogonal, or unfolding (figure 5).
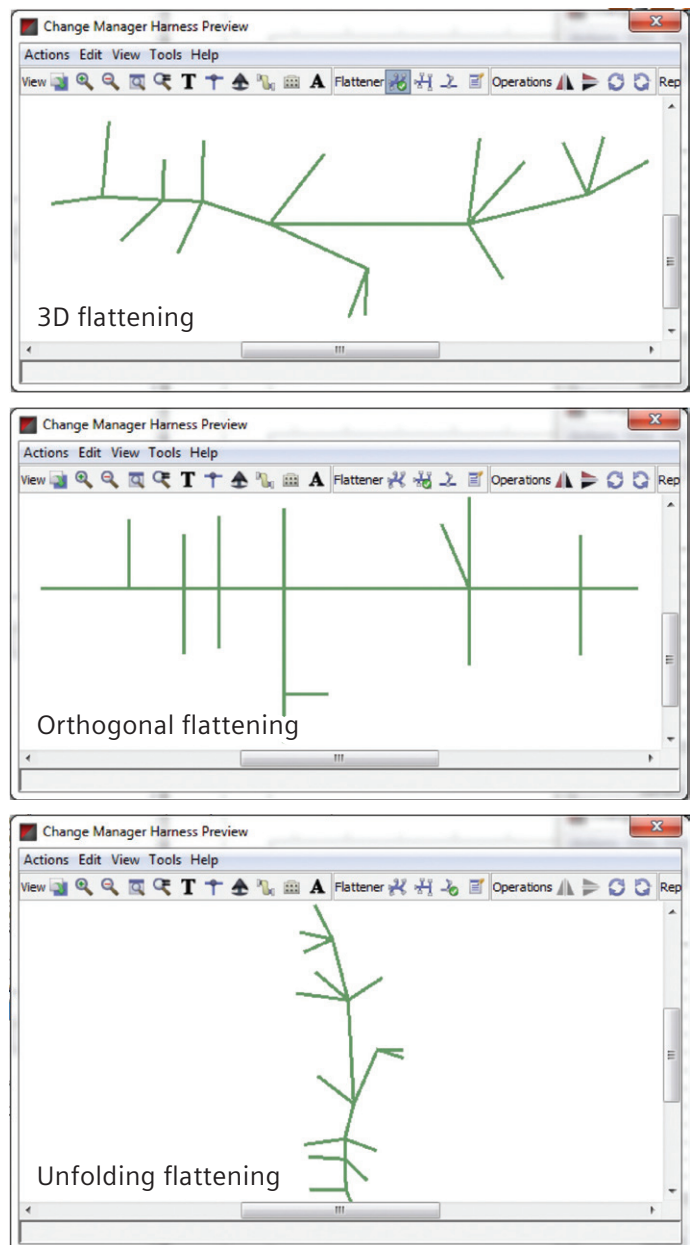

Figure 5: Capital's change manager can preview in 3D, orthogonal, or unfolding flattening.

Task	Tool
Capture signal separation requirement	Teamcenter
Associate requirement with electrical designs	Capital + Teamcenter
Define wire bundle routes (3D harness technology)	NX
Associate 3D harness topology with electrical designs	Capital + NX
Execute rule enforcing signal separation during creation of wiring	Capital
Complete electrical design (e.g. DC simulation) and run verifica tion DRCs	Capital
Back annotate wiring data to complete mechanical design (e.g. vibration simulation)	Capital + NX
Release electrical design/BOM and verfication report to PLM	Capital + Teamcenter

Figure 6: An integrated ECAD-MCAD flow creates a digital thread through the design.

The other critical piece is a change policy that defines the master of the data and the direction in which changes will flow. Capital has a robust set of options that allow for the automatic control of how data is changed. Ownership over data is determined piecewise so that the change policy can be tailored to individual design flows. The pieces available for selection are highly detailed, such that rules may be set for specific attributes of individual components. For example, a rule may be set that MCAD is only able to update the weight attribute of a connector, but not the electrical characteristics.

Variant management compounds the complexity of change management. Any given vehicle model can be equipped with a variable array of electronic systems and features, meaning hundreds if not thousands of different versions of a wiring harness will exist. An intelligent federated management tool and database for the harness design variants is needed. This manager would intelligently provide mechanical and electrical engineers with up-to-date variant information relevant to their domain without forcing either discipline to adapt to the other's database.

Looking ahead: all electric vehicles and autonomous drive

As all electric vehicles become mainstream and autonomous car technologies are adopted the need for tight ECAD-MCAD integration will only increase. For level 5 autonomous vehicles, continuous interaction between ECAD and MCAD throughout the design process will be the only way to achieve the advanced designs on a realistic schedule. Most likely, a centralized powerful processing system will connect and interact with a network of dozens of sensors such as LiDAR, radar, cameras and more. Many of these sensors, like

high-resolution cameras, will require high speed connections that are especially sensitive to changes in wire length or splicing. Optimizing the weight of the wire harness and its distribution throughout the vehicle may require rerouting wire bundles, dramatically impacting wire lengths and signal performance. Further complicating the design task will be the inclusion of new light weight technologies, like metal lattice structures for the car body, introducing a whole new set of constraints.

Autonomous drive will also make the task of meeting safety and functionality requirements more challenging for the electromechanical design. For example, wires carrying high-voltage power signals will need to be separated from data wires to prevent electromagnetic interference from distorting the data signals. In addition, redundant electrical systems will need to be incorporated to preserve safety-critical functions during electronic failures or accidents. Redundant systems increase the overall complexity of the car design, making accurate and smooth transfer of design changes between electrical and mechanical engineering crucial. ECAD-MCAD integration ensures an unbroken digital thread exists between the domains so that the electromechanical design meets all requirements (figure 7).

Furthermore, an intelligent change management solution will become vital as the industry moves towards all- electric fleets. Mechanical engineers will have to optimize the weight distribution and trimming of the wiring harness, spawning hundreds of change orders. In addition, any problems or limitations identified in operational vehicles should be identified and solutions incorporated as fast as possible back into the manufacturing line. This will require a tightly automated and highly synchronized feedback loop between engineer, manufacturing and the field.

Conclusion

Achieving first-pass success

ECAD-MCAD co-design has long been recognized as a potential enabler to increasing productivity and ensuring a robust design. With modern CAD tools designers are able to synchronize their data more efficiently and collaborate more effectively on critical design items between domains, thereby ensuring that the design intent is properly implemented.

During design, seamless cross-probing between the electrical and mechanical environments helps designers understand their counterpart's domain. This enables incompatibilities to be identified and resolved early, reducing costly design iterations. ECAD-MCAD codesign, with rich change management support, provides a key enabler for design teams to increase the probability of achieving first-pass success.

For more information:
https://www-preview.plm.automation.siemens.com/ global/en/products/electrical-electronics/electrical- system-networks-harness.html

References

1. Pearley Huffman, J. (2016, May 23). "It takes a lot of wiring to keep a modern vehicle moving (witness this Bentley's harness)", Car and driver. Retrieved from *https://www.caranddriver.com/news/ it-takes-a-lot-of-wiring-to-keep-a-modern-vehicle-moving-witness- this-bentleys-harness*

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