Handwritten corrections on printouts, giant spreadsheets, and countless tool changeovers: these and similar approaches are used in an effort to keep a handle on the development of a vehicle wiring system. More efficient approaches are needed to control the complexity of modern electrical distribution systems in the long run. The model-based development methods already in successful use in many industrial sectors provide the needed tool for this.

The Earth is flat and a wiring harness is a drawing! We all know what became of the notion of a flat Earth. And we also know that uncritical adherence to established beliefs, behaviors, and habits slows down progress – or stops it altogether. From time to time it is good to ask: Are there new ways I can try? Can I apply knowledge and methods from other industry sectors to solve new challenges?

For vehicle wiring systems development, challenges include current multi-voltage electrical distribution systems, autonomous driving, electric drives, and increasing networking. These pose a challenge to many established development processes and bring them to their limit. Model-based development is an efficient and future-proof method for keeping the complexity of the coming electrical architecture generations under control over the long term.

**Development Process with Model-based Tools**

Digital modeling of subareas to whole vehicles has been a common practice in automotive mechanical engineering for many years. A digital model is built up from component parts with modern CAD systems. These component parts are linked with complex overall systems. If a change creates a conflict in an adjacent area, the tool points this out to the developer as a matter of course. The developer can directly intervene and eliminate the conflict immediately. This matter of course is also possible in the field of electrics/electronics (E/E) with model-based development tools such as PREEvision. The model-based approach promotes consistent development from a technical and timing point of

**Figure 1:** Consistent model-based tools, reuse concepts and variant management reduce the complexity of development processes in spite of increasing vehicle functionality (schematic diagram).
view. The basis for technical consistency is an overarching E/E data model: It includes the system requirements, architecture and design levels for software, network, and components as well as the wiring harness and the geometry. All object dependencies between these levels and elements are described in the data model. Time sequences and relationships are controlled by a versioning process and a central data storage (Figure 1).

**Modeling of the Wiring Harness**

The nonuniform tool landscapes often used in development departments are an impediment to achieving the desired technical consistency. Different tools are used for the component design, electronics logic, wiring harness engineering and variant management. Added to that is the manual transfer of data between development tools or an electronic exchange with time-consuming, error-prone consolidation. If the communication and coordination between separate team and department structures is not ideal, this quickly gives rise to misunderstandings and confusion. This leads to technical errors.

Another obstacle from the classic electrical architecture development is that the architecture is often still developed completely decoupled from the specific wiring harness. In the best case, the architecture specifies a loose framework for the vehicle project development. There is little or no interaction and exchange or common understanding; possible improvements based on feedback and “cross-fertilization” thus go unnoticed. There are many arguments in favor of improving the technical consistency in vehicle wiring system development.

The first step in the model-based development process is a uniform data model for all parties involved. This forms the basis of teamwork by all users, teams, and whole departments from the required technical areas of expertise. This standardized integrated model uses a defined description to ensure a common understanding for tasks and solutions. The consistency is already checked during acquisition of information. The data linked multiple times in the model permit efficient engineering of the wiring harness not only for an individual but also across area boundaries. When time-consuming and error-prone tool changeovers are eliminated because all development steps take place in one environment, this additionally contributes to technical consistency.

**Efficiency Through Feedback Loops**

An example of technical consistency from the architectural design to the detailed wiring harness: The architects group models the overarching design of the electrical architecture for the entire vehicle project. The wiring harness development does not start from zero. Rather, the design created in the model is used as a starting basis for development of the wiring harnesses of specific vehicles. The network archi-

---

**Figure 2:** Technical consistency from the network architecture, electronics logic and wiring harness to the geometry. All drawings are based on the same model data (exists only once) and represent the desired sub-aspects.
tecture is the binding specification from which the electronics logic is derived and developed. Here the potentials are defined and the power supply of the components and their fusing is supplemented. The result is a wiring harness with all wires, cables, connectors, and pins. The assignment of the wiring harness components to a vehicle geometry and the automatic routing of the wires give rise to the cable harness with isolation points as well as cable protection and mounting points. As a result of continuous further development and refinement across the individual areas of responsibility, time- and resource-saving development is made possible.

The efficiency gain arises not just from one direction. The tight integration means that findings from wiring harness development are directly taken into consideration again in the underlying architecture, thereby increasing the quality of the design each time. The model-based development and data management also facilitates the technical consistency check. After all, a variety of semantic framework conditions in the technical data model do not permit faulty modeling in the first place. Moreover, further rules and checks can be easily defined and executed. Through these rules and checks, the user will receive direct warnings of inconsistencies during development of the wiring system. In this way, technical errors will be discovered early and eliminated (Figure 2).

Central Data Storage and Time Consistency

In order to work on an integrated development model together with many other people, time consistency must be ensured in addition to technical consistency. The backbone of such a solution is the central data storage in a database, which results in a uniform and, if necessary, globally available database. This database ideally contains a finely subdivided versioning of the development artifacts, which can be reverted to at any time if necessary. Model-based development tools like PREEvision meet this requirement, for example, by managing artifacts of a development line in revisions or by building up parallel development lines using branches. Intermediate versions can always be made independent of the release of a version in the central data backbone. They are then also available to other employees at all times.

Nowadays, processes, work steps, and process-oriented working methods are also digitally supported during electrical architecture development. Here, a tool changeover should be avoided because information is thereby separated from the technical data and exported from the model – the time consistency would no longer be ensured. For this reason, model-based development tools support the management and release of data using life cycles in the technical model. With these life cycles, the current status can always be directly recognized and there is no need to look for this in another tool. This impedes errors such as the use of incomplete or faulty releases and versions.

Change management also plays an important role in time consistency, since a wiring harness undergoes many changes on the way from development to production. During this life cycle, all changes must be recorded, managed, compared, evaluated, and finally implemented on the wiring harness. Model-based tools can also provide effective support to the vehicle wiring system developer here. As a precondition, they must include an integrated ticket-based change management process that is located in the same system as the technical data.

Besides enabling the efficient management and evaluation of changes in one tool, the creation of “change sets” is also possible. Change tickets are linked directly to the relevant technical data. Each change is ideally documented and completely traceable. A model-based system also offers the advantage of maintaining changes centrally in the model data. Because all drawings, bills of materials, and reports are based on the model data, they are always current. The tedious manual entry of corrections in many different places is eliminated (Figure 3).

Required and Unwanted Complexity

The concentration of functions important for wiring harness development in one tool minimizes unwanted complexity from redundancy and unintended variance. Besides the technical complexity, there are other aspects that argue for the use of a comprehensive model-based development tool. If different tools are used in the development process, training and expertise is needed for handling each of them. Checks and corrections of transferred data at tool changeovers make development processes lengthy and-
Future Wiring System Generations

The model-based approach is an alternative that has already proven effective in other application areas and opens up new and future-proof opportunities for vehicle wiring system development. The use of model-based development tools such as PREEvision from Vector Informatik in the E/E area is a progressive step that can be used to master development projects in the automotive industry today and in the future. It allows competitive solutions and ever shorter development cycles.

However, immediate replacement of all established development processes overnight is not possible. Before that can happen, organization-wide rethinking is necessary that launches a change process and allows new, model-based processes on an incremental basis. Wiring harness developers, in particular, will benefit from a powerful tool they can use to face future wiring system generations with ease. After all, they know that keeping a handle on the wiring harness of the future requires more than a drawing.

Dipl.-Ing. Tobias Bitzer

Tobias Bitzer studied aerospace engineering with a concentration on control technology at the University of Stuttgart. He has worked in product management at Vector Informatik since 2007, where he initially concentrated on the issue of collaboration. Since 2013 he has been responsible for the hardware architecture, electrical design and vehicle network design in PREEvision.

Translation of a German publication in Elektronik automotive, issue S4/2016 “Bordnetz”

Image rights: Vector Informatik GmbH

But even that is not enough – the data volumes that arise when developing wiring harnesses for vehicles, vehicle families, and whole platforms must also be structured and controlled. The product line approach has proven to be useful here. For managing model-based data in vehicle wiring system development, frequently used units, such as connectors, wires, and add-on parts as well as components or whole subsolutions, are provided in libraries. Individual vehicle projects help themselves from this central library; they reuse component parts or larger units without having to rebuild them completely again. Error-prone and redundant developments are thus avoided and unwanted complexity is further reduced (Figure 4).