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From Complexity to Clarity: How Systems Engineering Enables Faster, More Robust Development

The Challenge of Modern Engineering

Across the mobility and manufacturing industries, development cycles are under pressure. Products that once evolved over up to a decade are now expected to mature within a few years. At the same time, each new generation brings a higher degree of interconnection between mechanical, electrical, software, and service domains. What used to be a product is now part of a system of systems, with the need for continuous, iterative and backwards-compatible development, as products now need to be updated in the field over decades. Managing this complexity while delivering faster has become the defining challenge of modern engineering.

The Role of Systems Engineering

Systems Engineering provides the structure and mindset to meet this challenge. It combines a holistic understanding of the product with a disciplined approach to traceability, verification, and architecture. By linking requirements, functions, and physical implementations within one consistent model, teams can reason about the product before it exists, explore design alternatives, and anticipate integration issues early. Decisions become evidence-based instead of assumption-driven.

Acceleration Through Coherence

Acceleration does not come from working harder but from working with greater coherence. A clear system architecture enables parallel development across disciplines and suppliers. Shared models replace document handovers and reduce the friction of interpretation. Simulation and virtual validation shorten physical test loops and provide confidence in design maturity long before the first prototype exists. Robustness and speed reinforce each other when dependencies are visible and managed in real time.

A Potential Role for AI

AI (artificial intelligence) and systems engineering are not contradictions. Typically, the models describing our complex systems under development consist of thousands of artifacts, requiring sometimes tedious work to create, link, and they pose a substantial challenge to the human brain to understand as a whole. On the other hand, systems engineering models have a well defined ontology, which makes the data potentially easier to understand and to handle by AI systems. Which combination of AI technologies like LLMs (large language models), RAG (retrieval augmented generation) etc. with classical approaches like knowledge graphs will bring the largest support for creating, connecting, validating and using the models will be very exciting to experience in the coming years.

A Cultural Shift

Yet Systems Engineering is not achieved by deploying a new toolset alone. It requires a cultural shift. Engineers, architects, and managers must collaborate around shared data rather than local files. Leadership must value early investment in architecture as the foundation of later agility. Since systems engineering develops its full potential only when applied across the entire enterprise, leadership must ensure breaking up silos and getting commitment from everyone involved.

Establishing semantic consistency – a common understanding of data, models, and interfaces – is as important as technical excellence.

The Journey Ahead

The transition toward model-based and digitally connected engineering is both a technological and an organizational journey. It asks for new competences, governance models, and trust across an extended enterprise. When done well, it allows creativity and discipline to coexist: the freedom to innovate within a well-defined framework that ensures traceability and compliance.

Collaboration as an Accelerator

No company can master this transformation alone. Accelerating the adoption of Systems Engineering and Model-Based practices requires shared standards, interoperable methods, and open dialogue across industries. This is where associations such as prostep ivip play a decisive role. By bringing together experts from aerospace, automotive, IT, and other domains, they create a neutral environment for defining common architectures, data models, and reference processes. Such cooperation prevents duplication of effort, fosters interoperability, and ensures that progress in one sector benefits all. In short, it helps our industries learn faster, align earlier, and move together toward digital maturity.

From Ambition to Realization

As products become increasingly intelligent and interconnected, Systems Engineering will remain the backbone of innovation. It turns complexity into clarity, accelerates decision-making, and provides the confidence to deliver at digital speed – reliably, repeatedly, and across boundaries. And through collaborative platforms like prostep ivip, we can ensure that this transformation happens not only within our companies, but across the entire value chain of tomorrow's mobility.

Let's master the challenges of digital transformation together. We look forward to connecting with you!

Dr. Henrik Weimer

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Dr.-Ing. Annette Muth

Processes, Methods, and E/E Tools
BMW Group

prostep ivip
Scientific Award -
for engineers focusing on
virtual product creation

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AWARD
prostep ivip

Scientific Award

9

Are you a young engineer - and does your master/doctoral thesis focus on virtual product creation? Are you interested in introducing your ideas to representatives of leading manufactures and IT companies?

Here is your chance!

prostep ivip promotes tomorrow's PLM talents with €1,000 (master's thesis) or €4,000 (doctoral thesis) with the prostep ivip Scientific Award!

Who can apply for the award?

Any interested candidate who has submitted his/her diploma/master/doctoral thesis to a university by 31 January 2026 on a topic related to virtual product creation.

Theses written in German or English are eligible for submission, providing they do not fall under any conditions of non-disclosure. Please provide the graded thesis and the related opinion letter of the supervising professor.

The prostep ivip Scientific Award Jury will pick the winners from the submitted theses. The decision-makers include Dr. Henrik Weimer (AIRBUS), Prof. Dr. Rainer Stark (TU Berlin), Thomas Kamla (Volkswagen), Tomohiko Adachi (Mazda Motor Corporation), Jens Poggenburg (AVL | Chairman of the Board) as well as Philipp Wibbing (UNITY).

In addition to the prize money (1,000 € master thesis or 4,000 € doctoral thesis), we offer the winner in the field of doctoral thesis the opportunity to become part of the prostep ivip symposium and to report on the results of their studies as part of the "Scientific Track". A unique chance to leave a lasting impression on an expert audience and thus potential future employers!

The closing date for applications for the Scientific Award 2026 is 31 January 2026!

Send us your graded work and the corresponding expert opinion:

Dr. Alain Pfouga, Managing Director prostep ivip Association
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as well as

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SAVE THE DATE: Engineering Interoperability Day 2026 - JT & STEP AP242 for Digital Continuity

On Thursday, October 1st, 2026, prostep ivip Association invites you to the Engineering Interoperability Day at the nh Frankfurt Airport West. For the first time, this event brings together the JT Day and STEP AP242 Day communities in a joint forum. The objective is to unite experts and decision-makers from engineering and IT, as well as implementers of neutral format interfaces.

Look forward to top-level topics including traceability of product data and intelligent manufacturing information, handling of classified information, material properties, data exchange, and long-term archiving. In addition to inspiring industry presentations, you can expect practical application examples, updates from interoperability forums, and insights into LOTAR projects.

The event is embedded within a full meeting week (September 28th - October 2nd) focusing on STEP AP242 and JT topics, which attracts international participants from France, the UK, the USA, Japan, and beyond - an ideal environment for networking and knowledge exchange.

Venue: nh Frankfurt Airport West, Kelsterbacher Straße 19, 65479 Raunheim
Cost: Free of charge

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Review: Technical Steering Committee (TSC) Meeting on October 21, 2025

On October 21, 2025, the Technical Steering Committee (TSC) of prostep ivip e.V. met in Darmstadt. The meeting included presentations of current project results, discussions of strategic topics for 2026, and decisions on budgets and work priorities. The meeting also served as a forum for discussing the future direction of the association's activities.

The meeting began with an update on the Collaborative Digital Twins (CDT) project. The demonstrator developed for this project has been completed successfully. The Implementor's Lab demonstrator shows how digital twins from different disciplines can interact with each other via standardized interfaces. It demonstrates how consistent data flows and interoperability are implemented throughout the entire product life cycle. The final recommendation, which summarizes all project results, is scheduled for completion by the end of the year.

Meanwhile, the follow-up project, Live Collaboration Engineering (LCE), was announced and is scheduled to begin in early 2026. LCE builds on the results of CDT and expands them to include new aspects such as real-time collaboration, data rooms, and software-defined products.

Progress has also been reported in the areas of standardization and interoperability. The Functional Data Exchange (FDX) project will continue in 2026 to further develop semantic data models for simulation-relevant information and to attract new partners. The project groups working on the VEC Standard (VES/ECAD-IF) have successfully migrated their development environment to GitHub, which is an important step toward greater openness and collaborative development. Additionally, the introduction of the SysML v2 standard and its practical application in industry were discussed. A potential project group will examine how to integrate its implementation into existing processes.

The Standardization Strategy Board (SSB) presented updates on its ongoing projects related to sustainability, software-defined product development, and lean digital engineering. The goal is to integrate sustainability aspects more closely with technical standards and digital processes. To this end, the first prostep ivip Sustainability Day is planned for December 3 in Darmstadt. Registration is available via the prostep ivip website. More publications, fact sheets, and events are planned for 2026 to connect these topics with industrial practice.

During the meeting, the idea of a prostep ivip podcast was presented as a potential communication format under the motto, "Do good and talk about it." The committee welcomed the proposal and recommended that project groups consider the podcast as an additional communication option in the future. The concrete implementation is still in the planning stage.

The Technical Steering Committee concluded by emphasizing the importance of closer networking between projects and the practical implementation of standards. Topics such as model-based development, sustainability, data rooms, and software-defined engineering continue to be central to the association's work. The next meeting is scheduled for spring 2026.

„TSC 2025 showcased the association's diverse and forward-looking topics. The focus of 2026 will be networking between projects, partners, and technologies.“



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STEP AP242 Edition 4 and Implementation Guidelines Published

After two years of intensive work, ISO has recently published the fourth edition of STEP AP242. The long-awaited standard forms the backbone for model-based engineering and supports important new functionalities in its current version. These include so-called "external element references," which allow you to refer to specific elements within another file - e.g. a specific surface in a 3D model - and thus link information across files.

In parallel with the development of the standard, the relevant implementation guidelines were updated in the Implementor Forums. This enabled the data model extensions to be tested and the relevant STEP interfaces to be expanded, meaning that many programs now support the new AP242 edition. This applies to both "classic" STEP files and the Domain Model XML format.

In detail, the following implementation guidelines have been republished:

AP242 Domain Model XML (*.stpx)

- Product & Assembly Structure (v4.0)
- Configuration Management (v1.3)
- Change Management (v0.6)
- Kinematic (v1.3)

AP242 MIM EXPRESS (*.stp)

- Alternative Shapes (v1.0)
- Composite Materials (v4.3)
- Model Styling & Organization (v1.10)
- Persistent IDs (v1.6)
- Supplemental Geometry (v1.3)

Additional documents are being prepared and will be published in the coming months.

Source:

www.iso.org
 AP242 Edition 4: <https://www.iso.org/standard/84300.html>
 CAx Implementierungsrichtlinien: <https://www.mbx-if.org/home/cax/recpractices/>
 PDM Implementierungsrichtlinien: <https://www.mbx-if.org/home/pdm/recpractices/>

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[Read sample](#)

ISO 10303-242:2025

Industrial automation systems and integration —
 Product data representation and exchange
 Part 242: Application protocol: Managed model-
 based 3D engineering

Published (Edition 4, 2025)

VEC Media Types officially registered by IANA - a milestone for the VES/ECAD project groups

The Vehicle Electric Container (VEC) specification now features officially registered **IANA Media Types**. This is a significant step forward for standardization and interoperability in the development of vehicle electrical systems.

Global uniqueness and interoperability

Registration with the Internet Assigned Numbers Authority (IANA) guarantees that VEC data formats have globally unique, standardized identifiers. This allows systems and tools to reliably recognize and process VEC data. This improves the VEC's ability to integrate into modern IT landscapes and networked data rooms, providing a foundation for future digital data exchange.

The new IANA media types offer the following practical advantages:

- **Simpler implementation of the VEC** in existing processes and tools
- **Higher data quality** through standardized processing
- **Reduced complexity** in cross-company collaboration

What is the Vehicle Electric Container (VEC)?

VEC is an open, standardized data format for the complete description of electrical vehicle electrical systems. It enables the consistent, tool-independent exchange of data between OEMs, suppliers, and engineering service providers. The specification supports model-based workflows, reduces development effort, and facilitates archiving data throughout the entire product lifecycle.

In order to meet the increasing demands of the industry, the further development of the VEC is being carried out in close cooperation between the prostep ivip project groups VES-WF and ECAD-IF.

This success would not have been possible without the dedicated work of the prostep ivip community. A big thank you to everyone who contributed!

Contact

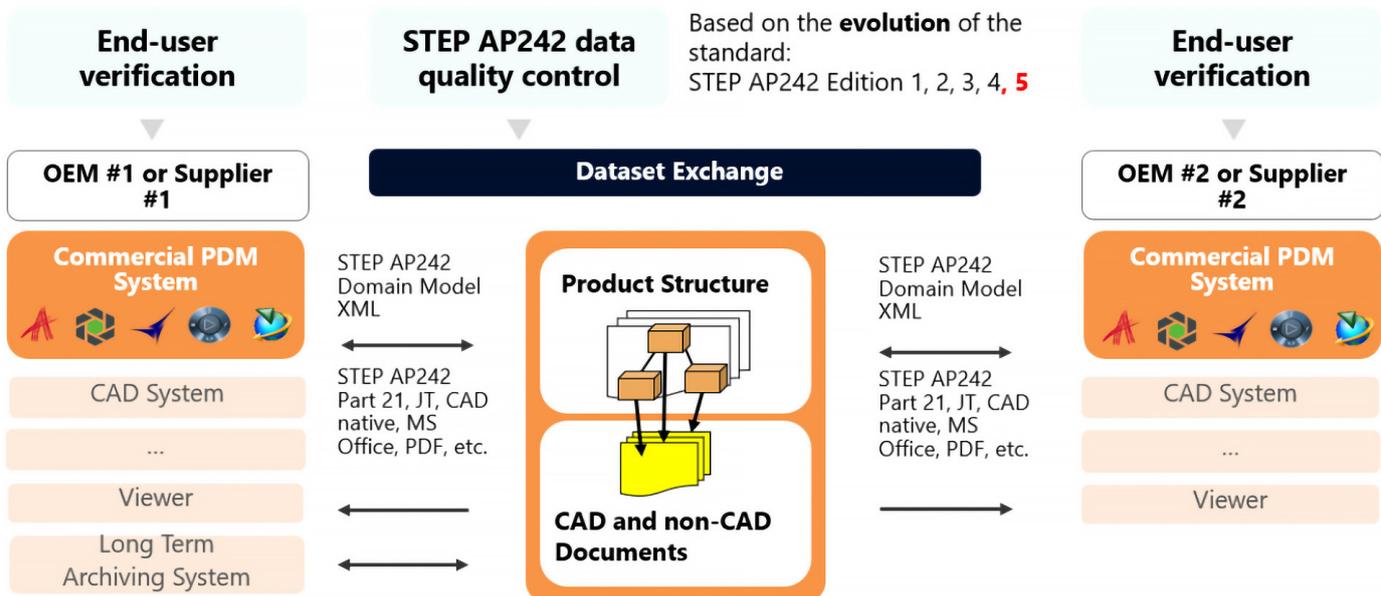
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What's new from the PDM Interoperability Forum?

PDM data exchange has been around for a long time, as has the PDM-IF, so what else needs to be clarified?

Exchanging product data has been a key issue in the industry for decades, and the PDM Interoperability Forum (PDM-IF), supported by prostep iViP and AFNeT, ensures this exchange functions reliably across company boundaries.

In addition to classic STEP files from the CAD world, the AP242 domain model plays a central role today. It facilitates the clear, XML-based exchange of product structures, variants, changes, and other PDM information. Through clearly defined use cases, structured test rounds, and regular benchmarks - supported by collaboration with CAX-IF, JT-IF, and LOTAR - this format has established itself as the industry standard.



The PDM-IF user group, consisting of OEMs from the aerospace, defense, and automotive industries, contributes practical requirements. These requirements currently include:

- Security classification and export licenses
- Further development and interchangeability of parts
- Variant and version logic similar to that used in software development
- Visual issue management
- Connecting elements (in conjunction with the χ MCF standard, more information here)
- Material data, properties, and material alternatives

Thanks to the close collaboration of various forums, including CAx-IF, JT-IF, EWIS-IF, and LOTAR, comprehensive and coordinated solutions are being developed and incorporated directly into the advancement of the STEP standard. Many missing functions will be addressed together in the upcoming AP242 Edition 5.

A key outcome of the PDM-IF is the Recommended Practices (here), which clearly describe how to correctly use the domain model. These practices help IT providers deliver their tools faster and in an interoperable manner, allowing users to enjoy new features reliably and early on. Additionally, since AP242 Edition 4, Schematron rules have ensured that exchange files are automatically checked for consistency and compliance with standards.

In short, the PDM-IF fosters close collaboration between industry, tool manufacturers, and standardization, thereby promoting reliable, modern PDM data exchange.

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Review: Bordnetze Digital 2025 in the ARENA2036



On September 25, 2025, more than 110 experts from industry, science and technology met at ARENA2036 in Stuttgart to discuss the latest developments in wiring system development and production. The event, which is now a permanent fixture in the industry calendar, combined specialist presentations, an exhibition with six exhibitors and numerous networking opportunities. Bordnetze Digital 2025 once again proved to be a lively platform for knowledge transfer and dialog.

A lively start

As in the previous year, the focus was on digitalization topics. In addition to the presentations, the exchange between participants and exhibitors was particularly important. Moderated by Georg Schnauffer (ARENA2036) and Dr. Alain Pfouga (prostep ivip), the second edition of Bordnetze Digital once again demonstrated its strengths: well-founded technical presentations and many personal discussions. Organized by ARENA2036 in cooperation with the prostep ivip association, the congress offers a solid platform for dialogue within the industry.

Topics and impulses from lectures & discussions

The programme of presentations made it clear how diverse the approaches to digitalization in the industry are. Dr. Detlef Zerfowski (ETAS) showed how the transformation to the software-defined vehicle is fundamentally changing the architecture in the vehicle. Mercedes-Benz focused on the consistent use of wiring harness data, which can ensure quality and reduce rework.

Several presentations focused on the use of AI: smartCable presented a model-based tool chain for simulation and variant management, the University of Stuttgart and IILS demonstrated the automated generation of cable harnesses, and the ISW presented approaches to AI-supported cable manipulation.

Another focus was on interoperability and standards. Contributions from ARENA2036, msg and 4Soft made it clear how Asset Administration Shell, VEC and data spaces will enable secure exchange and digital consistency in the future. In addition, Daimler Truck, S-IT and Siemens presented solutions for safeguarding variants and digitizing production.

Thomas Kost, CTO of Sumitomo Electric Bordnetze, summed it up as follows:

"Every year, Bordnetze Digital offers the opportunity to discuss the state of digitalization in our industry and to gain impetus for the future. Today, digital mapping of the wiring harness across all phases is the key to remaining competitive."

The conclusion of the lecture program: software, AI and standards are interlinked and form the basis for mastering complexity and developing future-proof vehicle electrical systems.

Exhibitor in focus: Innovation from different angles

Six companies and initiatives presented themselves at the trade exhibition to showcase their specific areas of expertise and their portfolio of solutions. Together, they reflected the diversity of wiring system development:

- With "Chat with a Bordnet", 4Soft showed how AI can support the development process and simplify wiring harness designs.
- Reallabor Industrial Metaverse presented virtual commissioning and production simulation using digital twins and VR.
- S-IT Application Engineering & Consulting presented its end-to-end approach for integrated development processes.
- smartCable demonstrated simulation solutions that can be used to validate electrical, thermal and assembly-related aspects at an early stage.
- Transformation hub Wire Harness presented itself as an information hub for innovations in the wire harness industry and provided information on projects such as the Robotics Challenge 2026 as well as planned innovation shows and trend outlooks.
- VOSS Automotive presented a smart assistance glove that supports assembly workers in real time. Sensors and AI detect whether a connector is correctly seated and issue a warning in the event of errors.

Outlook

The congress made it clear that digitalization, simulation, AI and automation are not individual topics, but part of an integrated transformation. The close interlinking of hardware, software, data models and process innovation is key.

We would like to thank all participants, speakers and exhibitors for their contribution and are already looking forward to continuing the discussion next year - **on September 24, 2026 in the ARENA2036.**

Website Arena2036: Review 2025 | ARENA2036



STEP AP242 Day 2025: Driving Digital Continuity Across Industry

On October 14, 2025, the STEP AP242 Day brought together leading industrial stakeholders in Paris for a full-day event dedicated to advancing interoperability through the STEP AP242 standard. Organized by AFNeT and prostep ivip, the conference focused on operational use cases, long-term data strategies, and the development roadmap for Edition 5 of the standard.



Jean-Pierre Souzy opened the event with a keynote emphasizing the strategic role of STEP in the aeronautics industry. With over 75% of aircraft components sourced from suppliers, the airframer's task is not only to produce the remaining quarter but to orchestrate the integration of the entire aircraft. Standardized data exchange formats like STEP are essential for this coordination, especially in the context of paperless certification and increasingly complex data types such as PMIs, electric harnesses, and composite structures.

Safran Helicopter Engines, represented by Guillaume Valentin, showcased a field-proven approach to long-term archiving using the LOTAR standard and STEP AP242 Edition 1. With legacy engines like the Alouette still in service after nearly 70 years, Safran's archival strategy ensures regulatory compliance and product support over decades. The next step is transitioning from graphical to semantic PMI, enabling machine-readable annotations and enhancing digital continuity.

Fumiki Ohtani, speaking for the Japan Automobile Manufacturers Association (JAMA), addressed interoperability challenges in Japan's automotive sector. Low adoption of 3D standard formats and inconsistent design practices among OEMs have led to issues such as excessive annotations – the so-called "hedgehog problem." JAMA is responding with initiatives including sample data publication, CAD best practices, and direct collaboration with vendors and ISO committees to ease supplier burden and foster a unified digital foundation.

Several software vendors presented their contributions to STEP implementation. Elysium reaffirmed its commitment to open interoperability through active participation in CAX-IF and user-driven updates. CoreTechnologie and Dassault Systèmes emphasized the embedded role of STEP AP242 in their conversion and visualization tools. Datakit demonstrated support for Edition 4 via its CrossCADWare SDK, while Open Cascade highlighted its free and open-source STEP kernel, already powering tools like FreeCAD and KiCad.

User companies also shared compelling use cases. MBDA illustrated how export control metadata embedded in STEP files enables compliant data sharing across international programs. Mercedes-Benz Vans and T-Systems introduced a semantic twin approach, transforming STEP data into knowledge graphs for automated validation and traceability. Airbus, a key contributor to the LOTAR project, presented strategies for ensuring data survivability beyond software lifecycles – a critical need in aerospace, where products may remain in service for half a century.

Jean Brangé (AFNeT Services) presented the roadmap for STEP AP242 Edition 5, currently under ISO development. Key priorities include improved traceability, expanded semantic PMI support, and enhanced coverage for composites, electrical systems, and classified data. The new edition aims to maintain backward compatibility while streamlining modular architecture, with publication targeted for 2026.

Further contributions from Threedy, T-Systems, Open Design Alliance, Kubotek Kosmos, and PROSTEP AG demonstrated STEP’s evolving role in enabling real-time collaboration, secure data exchange, and lifecycle connectivity. The event concluded with Alain Pfouga (prostep ivip) reaffirming STEP AP242 as the foundation of digital continuity across the extended enterprise – a standard shaped by industry, for industry.



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Follow-up on JT Day Express 2025

The 9th JT Day Express on October 22 was a great success. Unfortunately, we had to forgo an in-person event this year. The current economic situation in the user industry is challenging, and travel restrictions as well as budget cuts among our participants led us to hold the event online.

The prostep ivip Association hosted its JT Day Express and invited the JT community to a cross-industry meeting on October 22, 2025.

This year's theme was "**JT for the Digital Future.**" Renowned international speakers from the industry shared insights on the practical application and benefits of the JT standard format, both nationally and internationally, and provided an outlook on JT's role in digital transformation.

The event began with a warm welcome from Thomas Ott (Aumovio) and Bernd Watzal (Mercedes-Benz), the two project managers of the JT Workflow Forum. We then enjoyed five exciting presentations from the speakers.

The first presentation was given by Takao Senko (Honda), who reported on the use of semantic PMIs. More specifically, Senko addressed the following questions:

What are semantic PMIs? How are they related to graphical PMIs? How are they linked to the MBE maturity model? What advantages do they offer in a digital surveying process?

In the second presentation, Bernd Watzal (Mercedes-Benz) spoke about the validation of JT integration based on attributes calculated from the source system (validation properties). He also discussed the process already in place at Mercedes-Benz for validating the completeness of PMI within JT and gave an outlook on future developments in this area.

The third presentation emphasized the untapped potential of JT when used with External Element References (EERs) in the digital chain. It was noted that 3D visualization is the key to intuitive understanding of products, effective communication, and efficient collaboration.

In this presentation, Johannes Lehnen (:em AG) explained and demonstrated how the 'Digital Data Package' provides a semantic representation of technical information related to geometry, such as different materials, mechanical features, paint and coatings, markings and labels, heat treatment, joining technology and bending specifications. He also showed how this information is compared with the digital thread and 3D visualization using the brand-new JT 'External Element References'.

In presentation number 4, Dan Ganser described how Gulfstream works with JT in aircraft construction projects. He demonstrated how the 'build to model' process has evolved and changed over the last 20 years. He also explained why it had ultimately become necessary to introduce a technical data package.

The presentations concluded with an outlook on the standardization activities currently being coordinated and promoted between JT WF and JT IF. Bernd Feldfoss from Airbus, Jochen Boy from prostep, and Bernd Watzal from Mercedes-Benz reported on the status of the standardization of JT 10.5 as ISO standard 14306 Ed.3 and the recently published ISO 10303-242 Ed.4, the next level of STEP AP242 XML, which e.g. makes the External Element References (EER) mentioned in previous contributions possible in the first place. In addition, we gained insight into the plans for transforming national JT standardization from the existing DIN SPEC 91383 to a future new DIN standard.

A final participant survey confirmed that the event received excellent feedback. All of the presentations were very well received by the audience.

One of the participants summarized JT Day Express as follows: 'JT Day is an event that brings together internationally renowned speakers and SMEs in this field. On this day, a wealth of interesting experiences and specialist knowledge is exchanged. If you are a company or individual looking to switch to a neutral CAD environment, this is the right platform for you'.

We would like to invite you all to participate in this platform and share your experiences!

You can access the presentations via the following link:
https://www.prostep.org/fileadmin/events/jtday2025/JT-Day_Express_2025_presentations_final.zip

We look forward to seeing you at the next JT Day, which will be held in person again in 2026.

Bernd Watzal, Thomas Ott, Lars-Christian Bütow, Jochen Boy

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Tokyo Systems Engineering Summit 2025: Bridging Continents

The Tokyo Systems Engineering Summit on November 14, 2025, at Marunouchi Hall set new benchmarks: With over 300 registrations, the venue was filled to capacity - impressive evidence of this event's growing significance. What began just a few years ago has evolved into an established platform and is a special passion project for prostep ivip: offering the steadily growing community in Asia, with a focus on Japan and South Korea, intensive international exchange.

Recipe for Success: International Partnership on Equal Footing

Behind this success is a strong partnership: Tomohiko Adachi from Mazda Motor Corporation and prostep ivip Board Member, along with the team at NTT Data as a founding partner, have been driving the Summit forward with





passion and commitment. "The unique value of this event lies in connecting different continents and enabling genuine knowledge transfer across borders," emphasized Dr. Alain Pfouga, Managing Director of prostep ivip Association.

Thanks to Our Premium Partners

Special thanks go to our Premium Partners NTT Data, HCLTech, and PTC: their support makes it possible to offer an event of this caliber free of charge. Together with all other exhibitors, they create the foundation for a Tokyo Systems Engineering Summit that excels not only in content but also in organization - accessible to all, without financial barriers.

From Agentic AI to Engineering Societies: Keynotes with Substance

The program featured high-caliber speakers who illuminated current challenges from different perspectives:

- Jens Poggenburg (Executive Vice President, AVL) opened with "Revolutionizing Software-Defined Vehicles through Agentic AI" - a vision of how artificial intelligence is fundamentally transforming vehicle development.
- Dr. Henrik Weimer (Director, Airbus) demonstrated in "Transforming Product Development with AI" how the aerospace industry leverages AI to make development processes more efficient and innovative.
- Professor Seiko Shirasaka from Keio University looked beyond traditional boundaries: "From Engineering Systems to Engineering Societies" expanded the systems engineering discourse into societal dimensions.
- Takao Sugai (Project GM, Toyota Motor Corporation) brought practice into play: His "Practical Systems Engineering Use Cases" showed how Toyota translates theory into concrete development processes.

The subsequent Q&A session evolved into a lively dialogue between participants and industry leaders - exactly what makes the Summit special.



From Practice for Practice: In-Depth Case Studies

The afternoon sessions provided concrete insights into the digital transformation of leading companies:

- Kenji Hashimoto (Mazda) took participants on Mazda's ALM journey - authentic and with valuable lessons learned.
- Dr. Thilo Jania (Senior Vice President, Olympus) demonstrated how product and process structures can be integrated into a comprehensive data model.
- Takeaki Koga (Toyota) presented advanced testing methodologies: Use case analyses with traceability to MILS functional tests.
- Dr. Hasan Esen (Denso Automotive Deutschland) posed the crucial question: "How to make Systems Engineering Smart?" - and delivered compelling answers at the intersection of intelligence and engineering.
- Thomas Kamla (Volkswagen) provided insights into VW's Transformation Roadmap, showing the strategic direction of one of the global players.
- Prof. Dr. Rainer Stark (TU Berlin) rounded out the program with academic expertise: New virtual engineering and prototyping approaches for integrating MBSE and SDV.

Premium Partners with Technical Depth

The Premium Partners also delivered substantial contributions:

- Christoph Braeuchle (PTC) demonstrated how to leverage the intelligent Product Lifecycle in engineering.
- Nikhil Joshi and Deodatt Bawachkar (HCLTech) showed with "From Silo to Mainstream" how MBSE connects with ALM and PLM.
- Jens Krueger (NTT Data) explored the use of Agentic AI in SDV development.





Networking That Works

Twelve leading solution providers presented at the exhibition: Accenture, LieberLieber Software, Contact Software, Dassault Systèmes, Keysight, Jambe, AVL, NTT Data, HCLTech, PTC, Zuken, and Dentsu Soken. The breaks and extended social event from 6:00 to 8:00 PM were particularly bustling – exactly the atmosphere that enables productive exchange.

In strategically placed Exhibitor Pitch Sessions, all exhibitors presented their latest solutions concisely – efficient and informative.

With over 300 registrations, the prostep ivip team faces a welcome challenge: How can they meet growing demand in 2026 without losing the intimate networking atmosphere that makes the Tokyo Summit so special?

“This problem demonstrates the enormous value our community places on this international exchange,” said Dr. Pfouga. “We’re already working on solutions that enable growth while preserving the collaborative spirit.”

Conclusion: Connecting Continents Creates Innovation

The Tokyo Systems Engineering Summit impressively demonstrates: When experts from different continents, cultures, and disciplines come together, unique impulses for innovation and progress in systems engineering emerge. The combination of high-caliber keynotes, practical case studies, and intensive networking makes this event an important date for everyone shaping the future of systems engineering.



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Fraunhofer IEM



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The Fraunhofer IEM (Fraunhofer Institute of Mechatronic System Design) in Paderborn is a leading research institute for intelligent technical systems and modern engineering. Its focus lies on developing innovative methods for the engineering of the future – from the initial business idea to market launch. The institute follows an interdisciplinary approach that combines Advanced Systems Engineering, model-based development, agility, and AI-driven tools.

Artificial intelligence is applied across all phases of engineering – from describing tasks in natural language to automatic code generation and quality assurance. Digital twins and automated toolchains enable a continuous virtual product development process. Hybrid modeling and simulation approaches integrate data-driven and physical models to create adaptive and explainable systems.

A particular emphasis is placed on software development for complex mechatronic systems. Here, AI-based methods are used for code generation, system integration, and automated testing. In the field of robotics, the IEM conducts research on intelligent control and collaboration of robotic systems – especially cobots and mobile robots – as well as on AI-assisted automation solutions for production.

The developed solutions are applied broadly across industries such as automotive, mechanical engineering, software development, and production automation. Sustainability and digitalization are key components of the institute's strategy: the IEM supports companies in transforming toward sustainable and circular value chains and develops solutions for life cycle assessment, digital product passports, and green-by-design approaches.

With the IEM Academy, the institute also offers a comprehensive training program for professionals and executives to strengthen competencies for the engineering of the future.



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Synera

Synera is an AI agent platform that accelerates engineering processes tenfold, reduces complexity, and controls costs. Since its founding in Bremen in 2018, Synera has expanded to include a location in Boston. The platform integrates over 70 CAx tools from leading providers, including Altair, Autodesk, Hexagon, PTC, and Siemens. Synera's customers include OEMs, tier 1 suppliers, and 12 of the global Fortune 500 companies in the manufacturing sector.

In addition, the company works with vehicle technology specialists such as ARRK and EDAG, as well as leading global consulting firms such as Accenture and Capgemini.

Synera's AI agents work side by side with engineering teams, leveraging over 100,000 workflows to enable exponential scaling of engineering capacity.



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Willert Software Tools GmbH

Founded in 1992, Willert Software Tools have gained decades of expertise in engineering complex systems and software. We support clients with the selection, deployment and application of adequate tools, processes, and methods for sophisticated engineering projects. We provide market-leading systems and software engineering tools plus high-performance add-ons for fully integrated tool solutions. Our clients are in Automotive, Aerospace, Defense, Railways, Medical Equipment and other regulated industries. We help clients get their products to market faster and with higher quality by integrating development tools, increasing team productivity and fostering team collaboration.



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Standardization Strategy Board (SSB)

Peter Tabbert, :em engineering methods AG

The Standardization Strategy Board (SSB) develops strategic recommendations for the use of engineering IT standards in cross-company systems engineering. It addresses current challenges with regard to synchronous, cross-company collaboration in product and system development. The goal is to enable a seamless digital development process based on interoperable standards across company boundaries.

IT standards are indispensable for cross-company systems engineering - but which ones are best suited for this purpose?

This question is addressed by the Standardization Strategy Board (SSB), a project group jointly funded by the prostep ivip Association and the German Association of the Automotive Industry (VDA), and hosted by the prostep ivip Association. The group was founded in 2016 with the vision of enabling and promoting Collaborative Systems Engineering (CSE) based on engineering IT standards.

To realize this vision, the SSB continuously analyzes relevant standards, assesses their maturity, and derives strategic recommendations for their application. The aim is to ensure comprehensive coverage of the business objects required in the CSE process - especially in the context of virtual prototypes and digital twins in cross-company collaboration. The SSB uses the V-model of product development - a process model that represents product development as a sequential process with corresponding verification and validation steps - to systematically assign standards to the phases of systems engineering, identify gaps and needs for action, and forward these to appropriate committees or other project groups within the association.

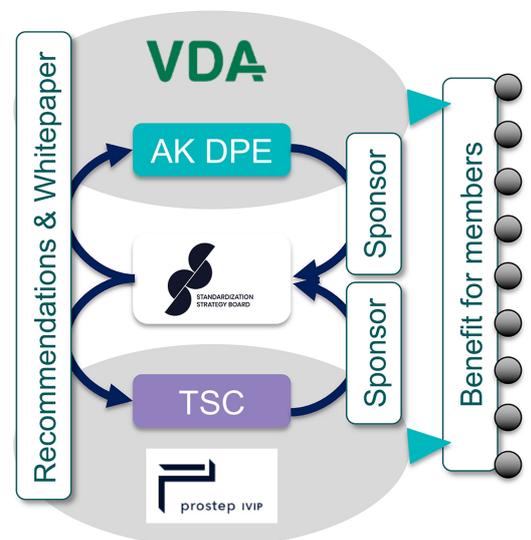
In addition to technical analysis, the SSB also addresses strategic challenges arising from current developments in product development and collaborative systems engineering. The following thematic areas illustrate how the SSB tackles these challenges and translates them into concrete initiatives.

Since 2016 project group of prostep ivip and VDA AK DPE with the end-user companies:

- **AIRBUS**
- **AUDI**
- **AVL**
- **BMW**
- **BOSCH**
- **CONTINENTAL**
- **MERCEDES-BENZ**
- **PORSCHE**
- **SCHAEFFLER**
- **SIEMENS**
- **STELLANTIS**
- **VOLKSWAGEN**
- **ZF**



Project coordination by :em



PLM IT Architectures and Synchronous Collaboration

A central area of action for cross-company systems engineering is the design of powerful PLM IT architectures and the support of synchronous collaboration processes.

As early as 2024, the SSB conducted a prostep ivip-wide survey to determine the relevance of engineering IT standards in the product development processes of member companies. The focus was on the requirements for PLM IT architectures and the ability to enable seamless and synchronous collaboration across company boundaries.

The results of this survey were published in spring 2025 in the prostep ivip white paper „Relevance of Engineering IT Standards for Collaboration and Future PLM Architectures.“.

Software Defined Products (SDP)

With the increasing influence of software on products and systems, product development is undergoing fundamental change. Software Defined Products (SDP) - products whose functionality and behavior are largely determined by software - place new demands on processes, tools, and standards.

The SSB addressed this development as early as 2021 and conducted a survey among member companies. The results were published in 2022 in the prostep ivip white paper “Flow of Software Components” and form the basis for further activities within the association.

A milestone was the Software Day 2024, initiated by the SSB. In addition to expert contributions on the development of embedded and product-related software, new challenges were identified that are now being addressed in various project groups - including the SSB itself.

Sustainability - The Challenge of Our Time

Another forward-looking topic addressed by the SSB is sustainability - including the responsible handling of materials and substances as well as compliance with relevant standards and regulations.

In 2025, the SSB conducted a prostep ivip-wide survey to identify challenges and solution approaches for meeting regulatory requirements in the field of sustainability. The results are currently being evaluated and will be presented and discussed on **December 3, 2025**, as part of the **Sustainability Day** initiated by the SSB and organized by the prostep ivip Association.

The Sustainability Day is currently in the planning phase and will feature compelling contributions from member companies of the prostep ivip Association - presented by those responsible for sustainability in their respective organizations.

Summary & Outlook

The four thematic areas - PLM IT architectures, Software Defined Products, Sustainability, and the overarching vision of Collaborative Systems Engineering - illustrate how the SSB systematically addresses current developments and identifies needs for action within the prostep ivip Association. These are either assigned to existing project groups or tackled through targeted new initiatives.

In addition, the SSB regularly publishes fact sheets on new and relevant standards, which are available for download on the prostep ivip Association's website.



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Collaborative Digital Twins Enable Live Collaboration in Engineering

Sebastian Schweigert-Recksiek, Jessica Kos, Jakob Trauer (:em engineering methods AG),
Sebastian Handschuh (Mercedes-Benz AG), Peter Gerber (SCHAEFFLER)

The Collaborative Digital Twins (CDT) project group is a joint initiative of the prostep ivip association and the German Association of the Automotive Industry (VDA). CDT pursues the goal of enabling cross-company, synchronous collaboration in engineering. As part of the project, key concepts and technical foundations were developed that pave the way for a new form of digital collaboration. At the end of September, the final on-site workshop of CDT took place, preparing for the scheduled completion of the project at the end of the year. The results achieved to date are presented in this article.



Figure 1: Final on-site workshop of the Collaborative Digital Twins (CDT) project group at the end of September 2025 in Darmstadt

Through the successful implementation of a „Digital Twin“-capable IT architecture in a showcase, it is demonstrated how the project results contribute to shortening lead times, reducing manual efforts and data inconsistencies, and accelerating delivery. These advantages are exemplified through an end-to-end exchange of requirements between multiple companies.

Furthermore, an initial effective collaboration between prostep ivip and Catena-X within the CDT Implementors Lab is presented. The results of the CDT project form the foundation for the new Live Collaboration in Engineering (LCE) project group, which is scheduled to launch in early 2026.

The Collaborative Digital Twins (CDT) project group aims to enable cross-company, synchronous collaboration in engineering.

Results of the CDT Project Group

The project group was founded in 2022 with the objective of developing a definition and conceptual framework for Digital Twins from prostep ivip's perspective and consolidating current activities. Despite the relevance and high level of attention in publications and within the community, there was no clear positioning by the prostep ivip association on the topic of Digital Twins. Moreover, several existing project groups were working on topics related to digital twins or whose results could be utilized in building digital

twins. CDT therefore hosts and consolidates the relevant discussions within prostep ivip on Digital Twins from both methodological and technical perspectives. In terms of content, CDT contributes to enabling cross-company, synchronous collaboration in engineering. As part of the project, key concepts and technical foundations were developed that pave the way for a new form of digital collaboration.

At the end of September, representatives from over 20 participating companies met in Darmstadt to discuss the preliminary results and prepare for the scheduled completion of the project group at year-end (see Figure 1).

The following topics were addressed within the project:

- Cross-industry insights and user journeys for cross-company collaboration,
- Ontologies for semantic description of engineering data,
- IT architectures for the digital twin,
- Concepts for cross-domain configuration and variant management.

Of particular note is the implementation of a CDT-capable IT architecture in a demonstrator that shows how lead times can be shortened, manual efforts reduced, and data inconsistencies avoided. This was demonstrated exemplarily through an end-to-end exchange of requirements between multiple companies.

Development of a Demonstrator

Since a direct connection of IT environments of industrial users within the project group was not possible, cross-company collaboration between development partners in engineering was realized through three IT environments provided by implementation partners of the project group. One environment each was set up by PROSTEP AG, SSC-Services GmbH, and Accenture.

To validate the developed concepts, a demonstrator was implemented with the participation of several PSI members. The implementation is based on two user journeys:

- User Journey 0 - Collaboration Model Setup: Definition of collaboration models, roles, access rights, IT architecture, and archiving models.
- User Journey 1 - Collaborative Requirements Content Management: Release of requirements, change notifications, change requests, and release management.

The Catena-X aspect model for requirements was used for the common semantics. The exchange was conducted via a data space based on Catena-X principles in a sandbox environment. Three exchange partners each used an EDC-as-a-Service to connect to the data space, including a Digital Twin Registry. Different engineering tools were employed in the respective environments: ReqMan, 3DEXperience, and Cameo Systems Modeller. The implementors each realized data mapping to convert the data from the tools into the exchange format according to the Catena-X aspect model.

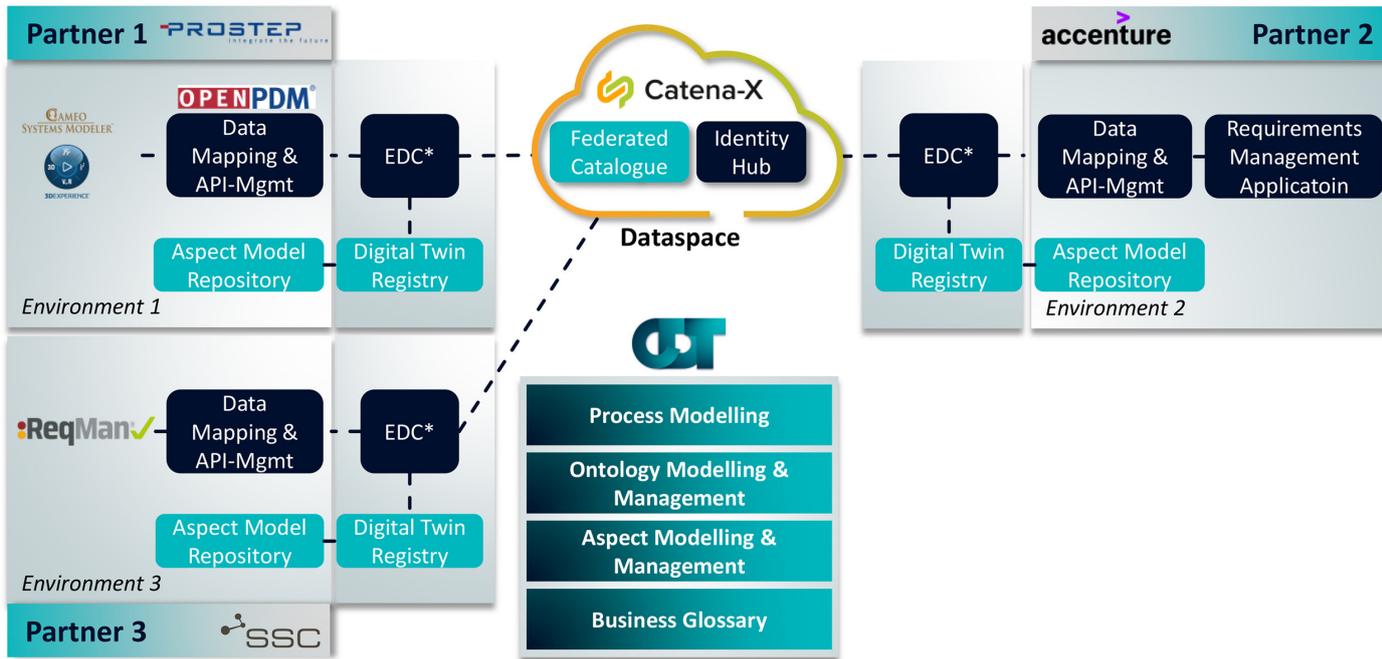


Figure 2: Architecture of the CDT demonstrator consisting of three partner environments

Collaboration with Catena-X

Through a Memorandum of Understanding (MoU) between the Catena-X association and prostep ivip, direct exchange between the CDT project group and Catena-X's Engineering Working Group was facilitated.

During the demonstrator implementation, the Catena-X aspect model was aligned with the CDT ontologies. This revealed a significant difference: while the Catena-X model is domain-specific and contains relevant exchange aspects, CDT pursues a modular approach with separate ontologies for domain-specific and process-related aspects. CDT's core ontology addresses, among other things, change requests, feedback, and versioning. This separation allows for flexible reuse of process-specific components across different domains.

Despite these differences, the Catena-X aspect model could be used for implementation in the CDT demonstrator, thus demonstrating the practical relevance of the CDT results. A mapping between the aspect models ensures that the CDT ontology can be represented through the Catena-X aspect model.

Outlook: Live Collaboration in Engineering (LCE)

The results of the CDT project form the foundation for the new Live Collaboration in Engineering (LCE) project group, whose kick-off is planned for early 2026. The objective is to advance the developed concepts and further strengthen live collaboration in engineering.

The LCE initiative pursues the goal of enabling synchronized, federated real-time collaboration along the entire V-model - from requirements through development to integration and testing.

The following priorities are in focus:

- **Standardization of real-world use cases:** LCE derives practical use cases from industry and standardizes them for cross-company collaboration along the V-model.
- **Utilization of data spaces:** Building on proven data space technology, LCE provides strategic guidance for adjacent initiatives - including coordinated semantics and ontologies.
- **Enabling software-defined products:** Through the deployment of advanced digital twin technologies, variant management, and data standardization, LCE supports the development of software-defined products.
- **Practical implementation:** The potential of networked, synchronous collaboration is made tangible and communicated practically through a joint demonstrator.
- With LCE, the vision of the CDT project is being advanced - towards a future-proof, digital, and collaborative engineering landscape.
- The project group is organized into four work packages (see Figure 3):
- Work Package 0: Organization, Strategic Networking with other Project Groups & Initiatives, Business Value
- Work Package 1: Cross-Industry Exchange on Boundary Conditions of Collaboration
- Work Package 2: Use Cases for LCE (consisting of Subproject A: User Journeys and B: Ontologies)
- Work Package 3: IT Implementation & Showcase (led by two co-leads representing the perspectives of industrial users and vendors/implementors respectively)

Would you like to become part of the new LCE project group?

Let us know your interest - simply scan the QR code and complete the brief survey.

Conclusion and Recommendation

The CDT project was concluded with a final workshop. As a recommendation, a joint presence at the psi Symposium at the prostep ivip booth is proposed, where the demonstrator will be presented and a guided tour offered. The first complete end-to-end chain - from user journey through data standard to technical implementation - was successfully realized using the example of requirements exchange.

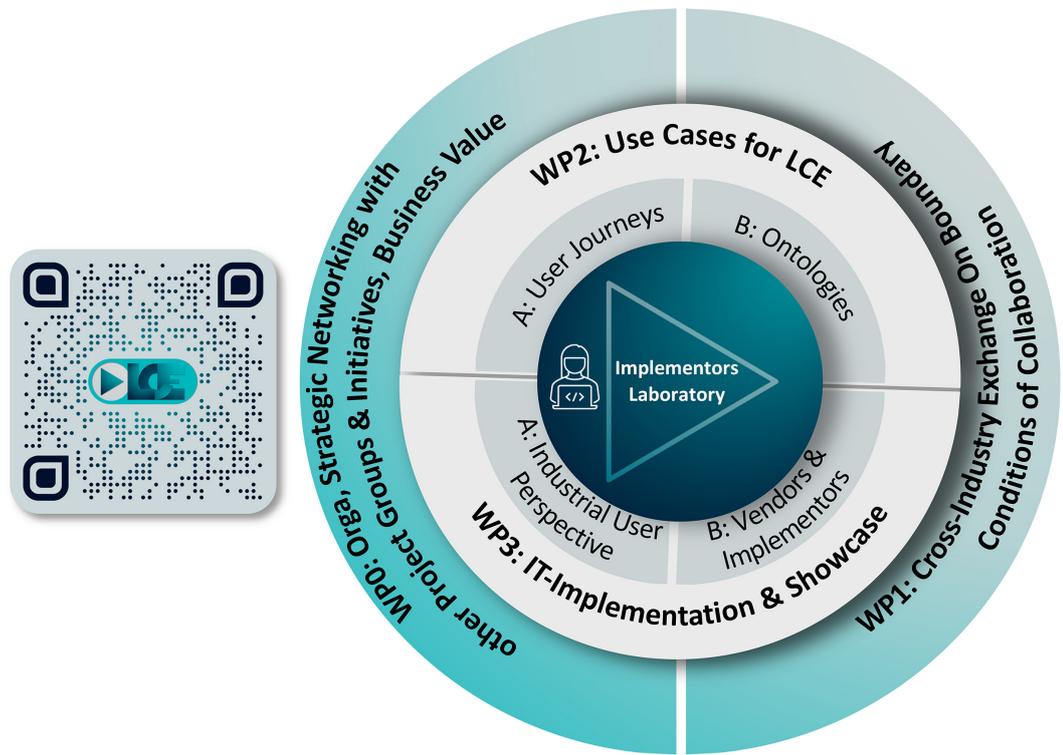


Figure 3: Work package structure and QR code for participation in LCE



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Smart Systems Engineering (SmartSE) Standards for Simulation-Based Systems Engineering in Connected Supply Chains

Hans-Martin Heinkel, Robert Bosch GmbH
Philipp Thorwarth, BHC GmbH

The development of complex mechatronic systems, such as those in the automotive or aerospace industries, is increasingly under pressure to be faster, more efficient, and more cost-effective. A key lever to achieve this is the use of Systems Engineering methods combined with virtual validation through simulation. Since these development processes typically span multiple levels of the supply chain, there is an urgent need for standardized simulation processes and interoperable data formats to enable efficient exchange and reuse of models and relevant information between partners.



The SmartSE Project Group

Against this backdrop, the Smart Systems Engineering (SmartSE) project group of the prostep ivip Association has set itself the goal of developing application-oriented concepts for cross-company collaboration in simulation-based Systems Engineering. In the current project phase 6 (2025–2027), the group, consisting of over 25 companies, is focusing on four key areas:

1. Best Practices for Simulation in Networks and Supply Chains

Development of practical recommendations for the use of simulations with a focus on traceability and credibility.

2. Handling Levels of Abstraction in the Supply Chain

Development of approaches for modeling and collaboration across different supplier tiers – particularly with regard to varying levels of abstraction and modeling approaches.

3. Virtual Electronic Control Units (V-ECUs)

Analysis of technical and organizational challenges in exchanging V-ECUs and definition of concrete requirements for extending existing standards.

4. Standard Hub for SmartSE-Relevant Formats

Establishment of a central hub for standards such as FMI, SSP, SSP Traceability, and SysML, including support for the creation of demonstrators and use cases. The results directly contribute to the further development of these standards. Collaboration takes place both with internal groups like “Collaborative Digital Twin” and external partners such as JAMBE.

MIC Core - Harmonization of Metadata Standards

A key outcome of SmartSE activities in 2024 is the development of the MIC Core specification - a freely available standard for harmonizing metadata attributes for simulation models. The aim is to avoid ambiguities and incompatibilities between existing standards and to create a common foundation for the exchange and reuse of models.

The specification is aimed at developers of metadata formats who can adopt MIC Core attributes through a declaration of conformity and integrate them into their standards. Semantic versioning allows for controlled evolution and expansion. MIC Core is based on years of collaboration between IRT SystemX and prostep ivip's SmartSE and is open to future transfer to an official standardization organization.

The international relevance of MIC Core is reflected in recent cooperation and alignment activities:

- In 2024, successful alignment was achieved with the Japanese project JAMBE (Japan Automotive Model-Based Engineering). This alignment strengthens global interoperability and highlights the strategic importance of MIC Core.
- In 2025, another milestone was reached: MIC Core attributes were harmonized with the established LOTAR standard (Long-Term Archiving and Retrieval). This alignment enables consistent and traceable long-term archiving of simulation models and their metadata.

The corresponding mapping and further information are available as Appendix B on the official MIC Core homepage. Section B4 also provides detailed insights into the LOTAR standard and the organization behind it.

Publications and Outreach

To improve visibility and understanding of activities related to Smart Systems Engineering, the SmartSE Recommendation V4 was published in May 2025. This comprehensive recommendation documents the project group's results and insights from recent years and forms the basis for the strategic advancement of simulation-based methods in Systems Engineering. It includes:

- the SmartSE V-model for structured development of connected mechatronic systems,
- concrete use cases and interaction scenarios,
- requirements for simulation models in collaborative scenarios,
- as well as recommendations on processes, standards, and organizational frameworks.

Based on this recommendation, an executive summary was created that concisely summarizes the key content and objectives. It is particularly aimed at decision-makers, specialist departments, and organizations seeking a quick overview of the relevance and benefits of simulation-based standards in Systems Engineering.

Both documents - the Recommendation V4 and the Executive Summary - are freely accessible via the official homepage of the prostep ivip Association and make a significant contribution to disseminating project results and promoting international collaboration in model-based development and simulation.

Conclusion

The SmartSE project group demonstrates how targeted standardization and international collaboration can lay the foundation for efficient, simulation-based Systems Engineering. With the MIC Core specification and alignment with standards such as JAMBE and LOTAR, an important step has been taken toward harmonizing metadata. The publication of Recommendation V4 and the Executive Summary enhances visibility and underscores the strategic importance of the results for industry and research.



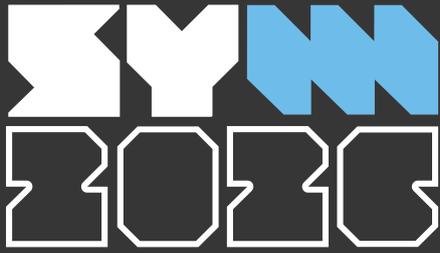
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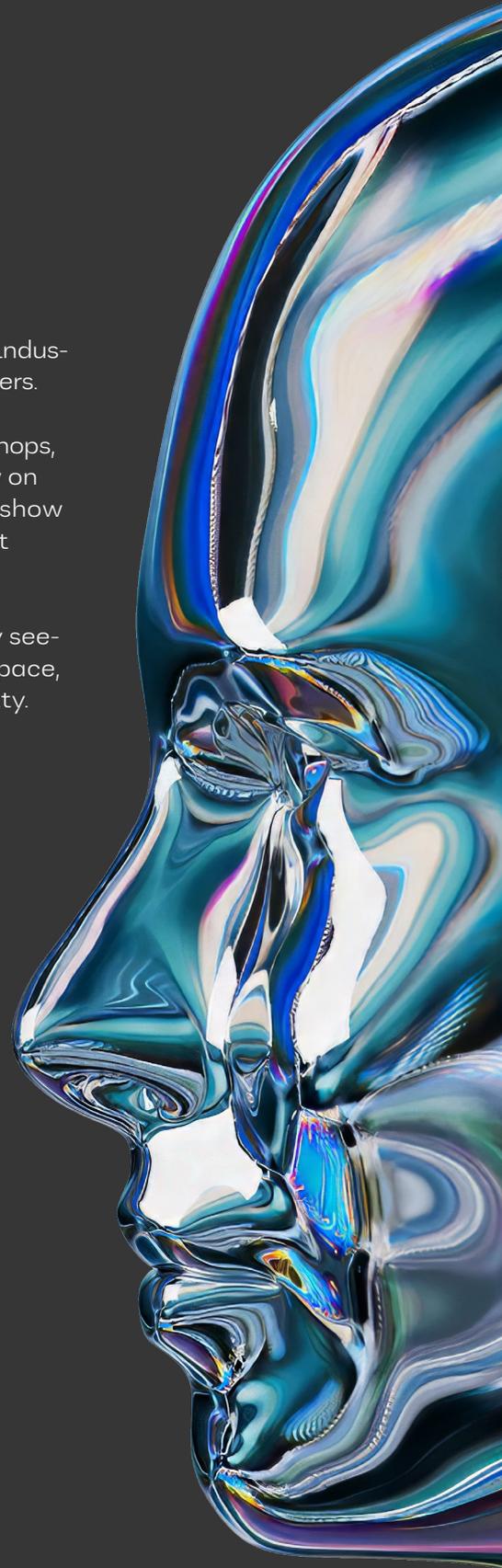
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THE NEXT FRONTIER:

AGENTIC AI AND THE RISE OF SOFTWARE- DEFINED INDUSTRY

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Review of Technical Drawings Using Artificial Intelligence

Automated Drawing Inspection

Dr. Tobias Beutel, Volkswagen AG
Jann Pehle, Dr. Christian Kohlschein, Accenture

Technical drawings are a fundamental component of the product development process in the automotive sector. Their review, including checks against formal criteria, is carried out manually by product data management experts, which is a time-consuming process. As the subject of a project, an AI-based tool, the Drawing Verification Wizard (German: Zeichnungsprüfungsassistent, ZPA), has been developed to automate this inspection process, utilising methods from computer vision.

Automated Drawing Inspection

According to Bitkom e.V., artificial intelligence (AI) is familiar to over 90% of Germans [1]. AI is not only a concept but has also found practical applications in everyday life, thanks to the easy accessibility of tools like OpenAI's ChatGPT and others, whether for text generation, translation of foreign languages, or image creation. The capabilities of generative AI systems and their components, large language models (LLMs), have quickly gained popularity among the general public and in the media [2].

In the automotive industry, however, AI systems have been developed and actively used in various areas for several years [3], e.g., in administration, supply chain management, and production. Particularly in the field of quality assurance in production, "traditional" AI systems have achieved a high level of maturity through computer vision and have become an integral part of automotive manufacturing [4]. AI systems are also employed in the complex domain of vehicle development to make processes more efficient, faster, and cost-effective. Here, AI systems are utilised throughout the entire value chain of the product development process (PDP, German: "Produktentstehungsprozess", PEP) (Figure 1).

During the PDP, components are continuously developed from models into physical parts. Technical drawings serve as a fundamental medium for exchanging information among all involved parties. When it comes to the dimensions and shapes of the design, digital 3D models are used to prevent unwanted component collisions or to assess production processes and aesthetic aspects. However, when it comes to physical properties (e.g., weight, material) or the standards to be adhered to (surface properties, labelling, required tests), technical drawings have been the key document for reliable information for many decades.

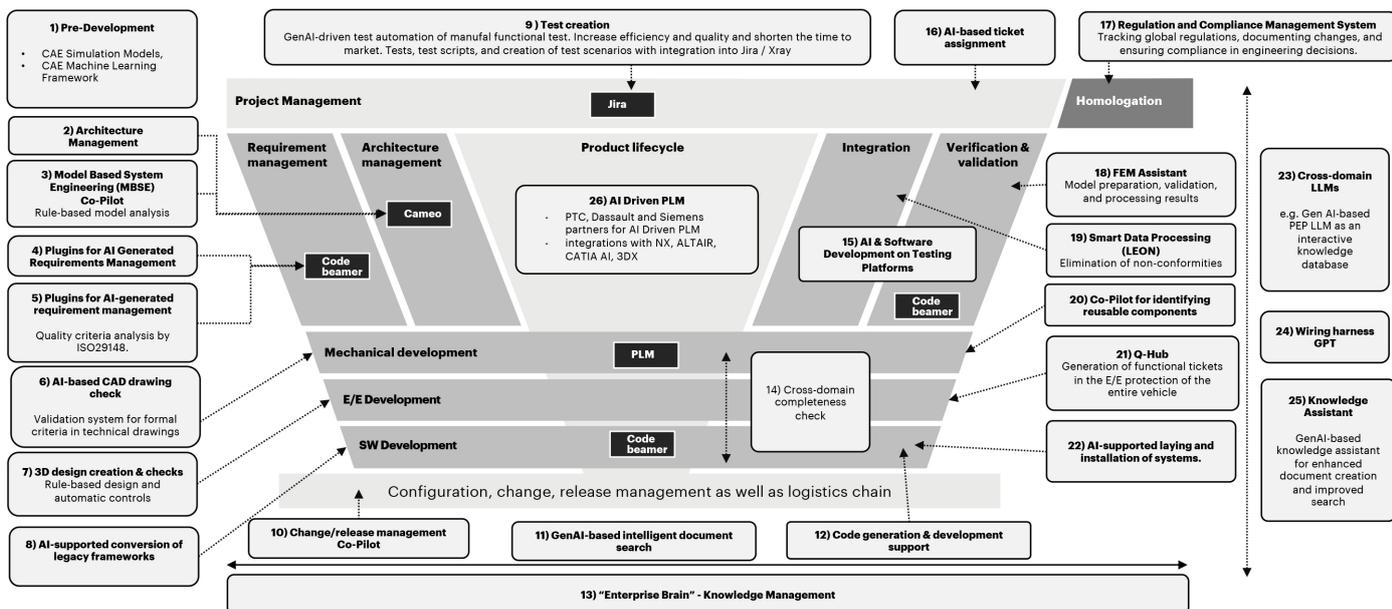


Figure 1: Overview of Accenture AI Projects in the Engineering Domain

The aim of an automated drawing review is to eliminate the current disadvantages:

- Until now, the drawing review has been conducted manually. Each new version of a drawing requires a complete review, even if only certain sections have been modified. Automation significantly reduces the manual effort required from reviewers.
- The review is subsequent to the internal technical approval from the design engineering team. This means that the actual drawing review is conducted separately afterwards. This sequential approach considerably extends the approval process. Immediate feedback on the readiness for approval right after saving would help address this issue.
- The strong global interconnection of design engineers, development service providers, and suppliers leads to indirect communication between the original drawing creator and the reviewer when technical drawings are revised. As a result, correction loops can be lengthy and may need to be repeated. Direct communication regarding the content to be revised would be very beneficial.
- Correction notes are distributed verbally or via email and vary greatly in quality. A consistent and clear communication of all aspects, with traceable comments related to the specific drawing, would be desirable.
- Review processes can vary across different areas of responsibility. Depending on technical and organisational focuses, different approaches and interpretations may develop. A uniformly automated review would achieve a harmonisation of the review system across departments and brands, creating comparability of results.

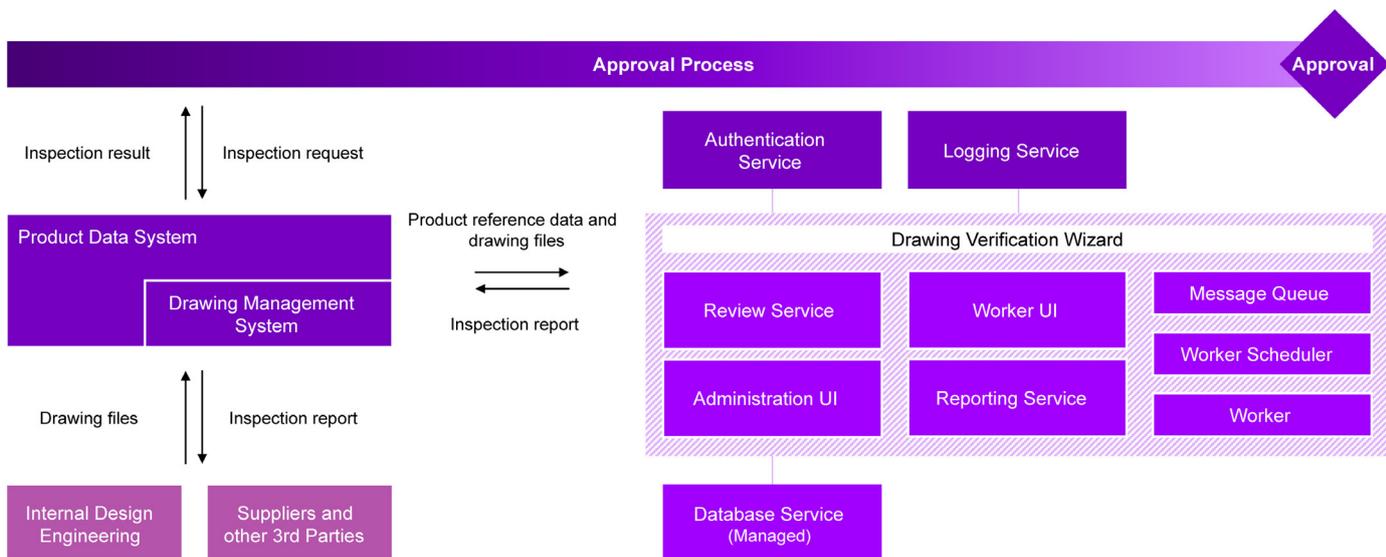


Figure 3: Process and Architecture Diagram

Architecture and Technical Method

The chosen solution for the automated review of technical drawings is a centrally operated system, particularly distinguished by its functionality for extracting information from technical drawings and conducting the actual review.

Figure 3 illustrates the inspection process and the key components of the Drawing Verification Wizard. The drawing data (drawing document and reference data) is retrieved from the leading design data management system upon creation or modification, the inspection process is carried out, and the results are returned to the system in the form of a detailed inspection report. This report is accessible to the relevant stakeholders in the context of the inspected document version and the design status, or they can be actively notified, for example, via email.

The core components for extraction and testing are supplemented by additional services, either as local system components (e.g., user interfaces), components managed by the system (e.g., database content) or as interfaces to infrastructure functions such as the central authentication service. The local task management system, which includes an asynchronous queue (Message Queue) and worker management, forms the foundation for the system's scalability.

In addition to the appropriate integration into the approval process, various formats were discussed as input data for the review. Due to the consistent format present in the product data system and the resulting ability to process drawings from different CAD tools uniformly, the image files of the technical drawings were established as the source format, with computer vision identified as the technical solution approach.

The field of computer vision generally focuses on the processing, analysis, and extraction of information from image and video data. A subdomain of computer vision is known as Optical Character Recognition (OCR). The role of OCR is to automatically derive and convert numbers, words, and texts into a machine-readable format based on visual input data - the information can be in handwritten or printed form. OCR can be applied, for instance, in scanning historical books, recognising traffic signs, or processing addresses on letters. A notable example of training AI systems for OCR is the MNIST database, which contains several tens of thousands of sample data of digits

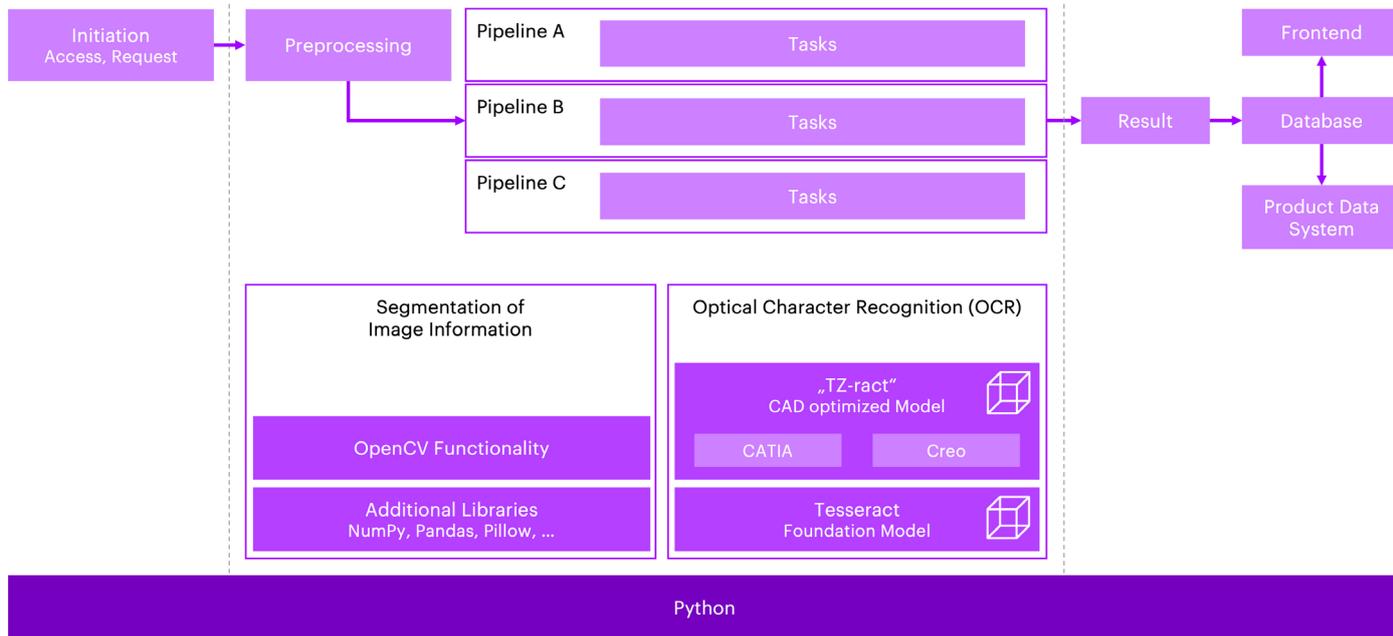


Figure 4: Technical Processing Approach

[5]. A crucial component of any OCR process is the automatic segmentation of the original input data (e.g., capturing a page of a book) into various areas, such as partitioning them into elements containing just text or images. The segments with text information are then processed in the subsequent OCR process. To integrate OCR into custom software development, there are various options available, such as cloud APIs, as well as offline programming libraries and frameworks. One of the most well-known frameworks is Tesseract [6], which is open source and available under the Apache licence.

In the Drawing Verification Wizard, Tesseract is used as a foundational model and is specifically adapted for technical drawings from various CAD tools. The models employed in the ZPA have been trained using supervised machine learning (ML) on extensive training datasets containing labelled excerpts from technical drawings.

The OCR functionality is embedded within an architecture that supports drawing- and component-specific inspection processes and offers high scalability. The respective processing pipelines are controlled depending on the inspection process being applied (Figure 4). Such differentiation is necessary, for example, between individual part drawings, assemblies, and drawings with usage restrictions. Additionally, the inspection logic is historically documented, allowing a granular application of the criteria relevant to drawing version and inspection aspect.

Process Integration

During developing the drawing inspection, seamless integration into existing processes and systems was a central requirement. This aimed primarily to reduce communication efforts while simultaneously increasing overall acceptance. For the design engineers (user), this means that the file they have saved is immediately registered for inspection without any further action required. After the inspection, the results can be viewed next to the file version within a few minutes. Thus, it is always clear whether the drawing is ready for approval.

The inspection result is displayed in an aggregated form as an overall outcome. If needed, the results of all partial inspections can be shown. Should a partial inspection not be clearly passed, the user is provided with guidance on the identified deviation. This makes it very transparent what exactly needs to be adjusted. The user must then determine whether the drawing needs to be modified or if the metadata for the component need to be revised.

To provide reliable results from the outset in the operational system, a test environment was established prior to the widespread rollout. This allowed trained users to conduct tests using data from the production system without the results being reported back to the system. However, this test system enabled the output of test results as pre-formulated emails, allowing testers to derive practical benefits from the test system. The circle of testers was continuously expanded as maturity increased, initially across design engineering areas and later across brands.

The development was accompanied by ongoing communication with the engineering departments and also with the product data management areas. The aim was to ensure the early and optimal involvement of all interface partners. With over 100,000 users of the design data management system worldwide, the communication effort alone through specialist committees is unmanageable, which is why online communication was also offered in multiple languages across different channels.

After the system went live, users were informed about the new features and the implementation status in a staggered manner, with references to online information channels. Training for users was not necessary due to the integration into the existing system, especially as there was no user interface. However, it became apparent that some correction notes needed to be adjusted to reduce follow-up queries.

The system was developed using an agile approach and in several phases. These included the creation of a proof of concept (PoC) to demonstrate technical feasibility and a minimum viable product (MVP) to showcase the procedural and economic benefits before the system was fully deployed for operational use. The current scaling phase focuses on expanding to additional corporate brands and further use cases in the context of technical drawings.

The foundation for all phases, particularly the initial ones, was continual requirement gathering and analysis, where the organisational context, usage goals, and framework conditions were examined and structured into development objectives and tasks through direct collaboration with process stakeholders, in close cooperation between the product owner (PO), proxy PO, and the development team. To evaluate the functionality implemented during development sprints, a test operation was conducted with participants representing a cross-section of the relevant direct and indirect users of the Drawing Verification Wizard.

To ensure a successful transition of system operations to the corporate IT department, the development was guided by the company-wide model for the introduction of IT products, known as IT-PDP. This ensures operations comply with requirements for technical standards, IT security, documentation, and organisational aspects. Through close collaboration within this framework, the transfer of operations was carried out as planned, and the system was successfully put into productive use.

Evaluation

The system is currently productive across nearly all brands. Up to 5,000 documents are reviewed daily, with as many as 2,000 documents in certain hours alone. These peak loads occur, for example, when source systems restart after a disruption and the data supply is caught up. These numbers do not correspond to the number of documents that were reviewed prior to automation, as now every version of a drawing is checked, regardless of its maturity. Before the system was implemented, only drawings that had already been internally approved by the engineers were sent for review by product data management. Nevertheless, it is clear that the manual effort and consequently the demand for resources would be substantial.

With the introduction of the system, the average review time has been reduced from several days to just a few minutes. Given that multiple correction loops were often necessary, the impact is even greater. As this process is on the critical path, the product development process has been shortened.

However, the efficiency gains cannot be solely attributed to the reduction in testing efforts; they also significantly impact design engineering, which benefits greatly in this context. The development process has undergone a lasting transformation, as input from suppliers can now be addressed much earlier in the process. As a result, the technical drawings exhibit a markedly higher quality in the early stages, as errors are not carried through to the approval attempt.

The integrated reporting functionality contributes to increased transparency regarding the review processes and the quality achieved in the drawings. Interactive dashboards allow not only for an assessment of overall system performance but also for the evaluation of statistics related to individual review steps, success rates, and deviations, enabling appropriate actions to be taken if necessary.

Summary and Outlook

The AI-based Drawing Verification Wizard contributes to the ongoing digitalisation of the product development process. Through seamless integration into the underlying processes of technical development at VW AG, this tool supports the individuals and departments responsible for reviews in their daily work. The Drawing Verification Wizard has significantly reduced the average review time and contributed to a markedly higher quality of technical drawings even in the early stages of development. As such, the Drawing Verification Wizard has become an integral part of the Product Development Process and has contributed to its shortening. A key success factor in its agile development process has been the efficient and consistently transparent collaboration between specialist departments, software engineers, and IT.

Plans are in place to utilise the Drawing Verification Wizard for the extraction of additional content from technical drawings, further contributing to the digitalisation of the technical knowledge base. While the Drawing Verification Wizard itself is continuously being developed and enhanced with new features, the underlying AI methodology also has the potential to be extended to other standard-based review processes within the PDP. If similar efficiencies can be achieved as with the review of technical drawings, the PDP could be further shortened.

Footnotes

- [1] <https://www.bitkom.org/Presse/Presseinformation/Digitale-Teilhaber-Kuenstliche-Intelligenz-fast-allem-Deutschen-ein-Begriff>
- [2] <https://de.statista.com/infografik/33526/nutzung-von-ki-tools-in-deutschland/>
- [3] <https://arxiv.org/pdf/1709.01989>, „Artificial Intelligence and Data Science in the Automotive Industry“
- [4] <https://arxiv.org/pdf/2007.01857>, Deep Learning Models for Visual Inspection on Automotive Assembling Line
- [5] https://en.wikipedia.org/wiki/MNIST_database
- [6] <https://github.com/tesseract-ocr>



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Generative AI in Systems and Software Development

Uwe Möhrstädt, Fabio Isopp, Deloitte

The rapid development of artificial intelligence (AI) is largely driven by the use of Large Language Models (LLMs) - a special form of generative AI. LLMs are designed to understand natural language and generate human-like text. Generative AI is considered a key technology that has the potential to fundamentally transform business processes, including through highly automated agent systems. It enables the efficient creation of content in various formats, including text, program code and even 3D models. The development of such systems is based on training with large data sets and requires considerable computing resources.

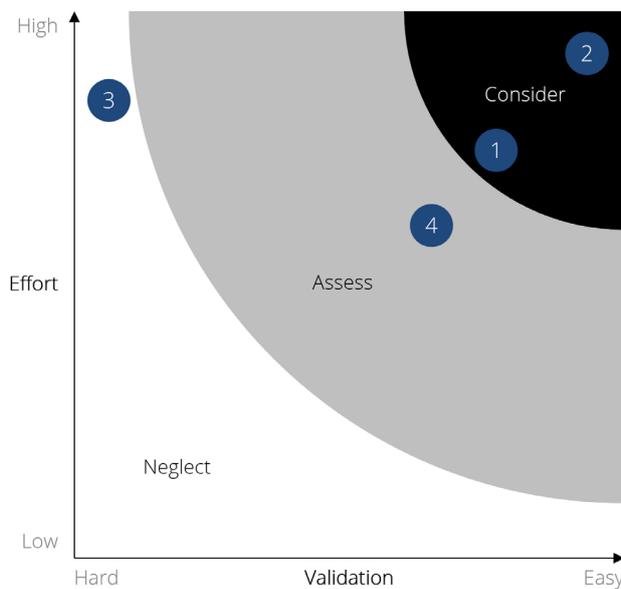
Generative AI has gained importance in recent years, especially in systems engineering. It serves as a valuable companion for tasks such as writing, researching, programming, and designing, and drives progress in various industries. Its potential to increase productivity through the increasing adoption of workflows makes it an important building block in shaping the future of systems engineering.

The market prognosis speaks for itself: by 2032, the global market for generative AI will grow to over USD 967 billion – at a compound annual growth rate of 39.6%. As early as 2027, companies worldwide will invest more than USD 143 billion in corresponding technologies, underscoring the profound change in digital value creation.

Generative AI is thus fundamentally changing the way we work, develop and communicate. This article sheds light on the role of generative AI in system and software development and uses four use cases to show how companies are already realizing concrete added value along the development process.

Narrowing Application Areas

AI unfolds its full potential in combination with human input. The sweet spot for generative AI applications are use cases where the human effort involved in generating the data is significant, while the validation process is relatively straightforward. Conversely, tasks that require specialized knowledge or innovative approaches are usually not ideal candidates for AI automation.



Examples

- 1** Generate test cases for a software application
It takes a lot of effort to identify scenarios, inputs and outputs when generating test cases for software. Validating these can be easier, as it involves running tests and comparing actual results with expected ones.
- 2** Generate product requirements for a new feature
Creating product requirements for a new feature is a labor-intensive process. Large projects can generate thousands of requirements that need to be documented and validated through review with the product team to ensure alignment with project goals.
- 3** A-SPICE Process Coaching
Deep Domain Expertise Work that requires highly specialized knowledge or deep, niche expertise such as process improvements based on A-SPICE often lead to incorrect GenAI suggestions that need full rework by the experts.
- 4** Simulation of E/E Control Units
Simulating Electronic/Electrical (E/E) control units is a complex process that requires significant effort and resources. The simulation involves the collection of extensive data and the validation of the simulated units, which can sometimes require detailed and time-consuming procedures.

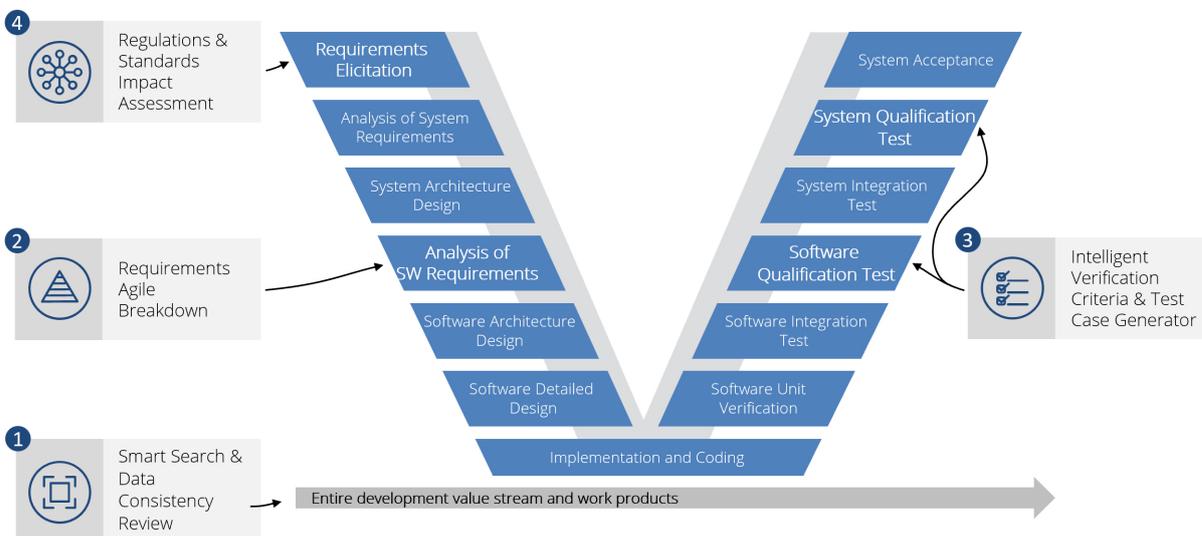
Figure 1: Methodically determined AI sweet spot

Generative AI in Systems and Software Development

Deloitte uses a methodology to support the assessment of the feasibility of using generative AI for practical use cases. The method focuses on two important factors: the human effort required to generate the data and the effort required to validate the AI output. Use cases are classified taking these elements into account.

Use cases along the V-model

Our four use cases are based on the V-Model and illustrate in a practical way how generative AI can be used along the entire system and software development process.



1 **Smart Search & Data Consistency Review**
 PoC already implemented
 The combination of Smart Search Chatbot and Consistency Review provides a comprehensive approach to project documentation management. It provides efficient insight and consistency across artefacts by seamlessly integrating data extraction and consistency analysis through generative AI.

3 **Intelligent Verification Criteria & Test Case Generator**
 PoC already implemented
 This AI application enhances PLM by automating system requirement analysis and test generation. It integrates relevant product data, identifies impacts on cost and timing, and provides detailed outputs for efficient quality assurance.

2 **Requirements Agile Breakdown**
 PoC already implemented
 Generative AI transforms the requirements breakdown process in system and software development, as exemplified by the Requirements Agile Breakdown use case. By automating the generation of user stories from features, organizations can accelerate development and increase agility in response to evolving project needs.

4 **Regulations & Standards Impact Assessment**
 Generative AI can help organizations comply with new standards by assessing their relevance and impact on projects and operations. It uses regulatory inputs and product use cases for its analysis, provides implementation strategies, ensures compliance, and improves project outcomes.

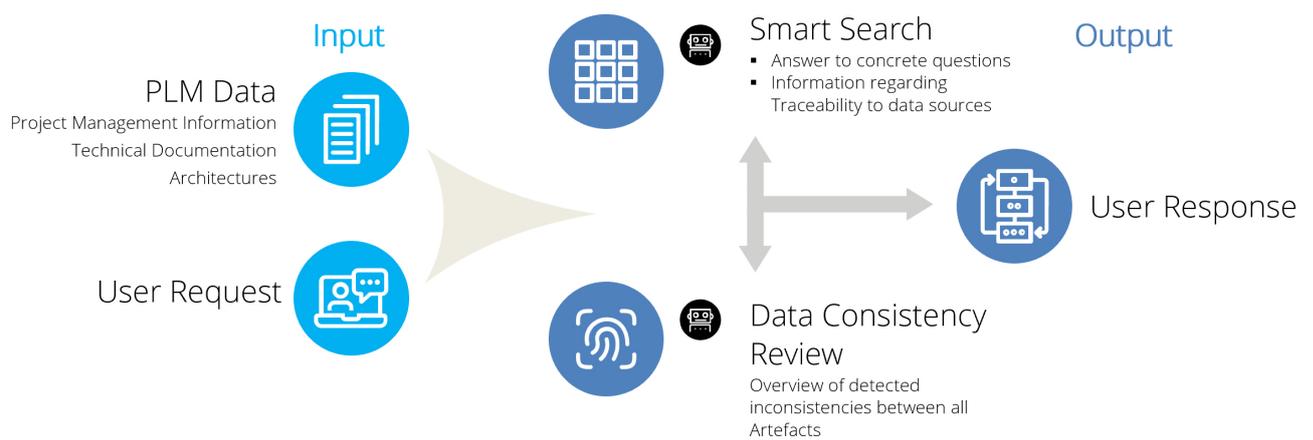
Figure 2: Overview of use cases along the V-model

Use Case 1: Smart Search and Data Consistency Review

The Smart Search Chatbot efficiently analyzes data and technical documentation and considers traceability between artifacts for a holistic understanding of the project. By considering additional inputs such as product use cases and business requirements, nuanced recommendations are made. Via an agentic Retrieval Augmented Generation (RAG), the tool can make decisions about which data sources should be accessed.

Data Consistency Review uses generative AI to analyze the consistency of product lifecycle management (PLM) artifacts. To this end, the relationships between stakeholder requirements, system architecture, software design and test cases are examined. The aim is to identify inconsistencies and gaps in the documentation in order to ultimately ensure the coherence of the technical project documentation through the implementation of proposed solutions.

By integrating the two applications, we establish a comprehensive approach to project documentation management. The combined process increases efficiency, streamlines decision-making, and ultimately leads to improved project outcomes by reducing risk and increasing overall performance.



Legend

Generative AI enabled

»» Reach out for a live demo of the Smart Search chatbot PoC! ««

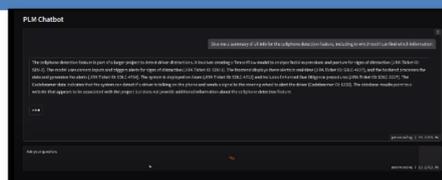


Figure 3: Use Case 1

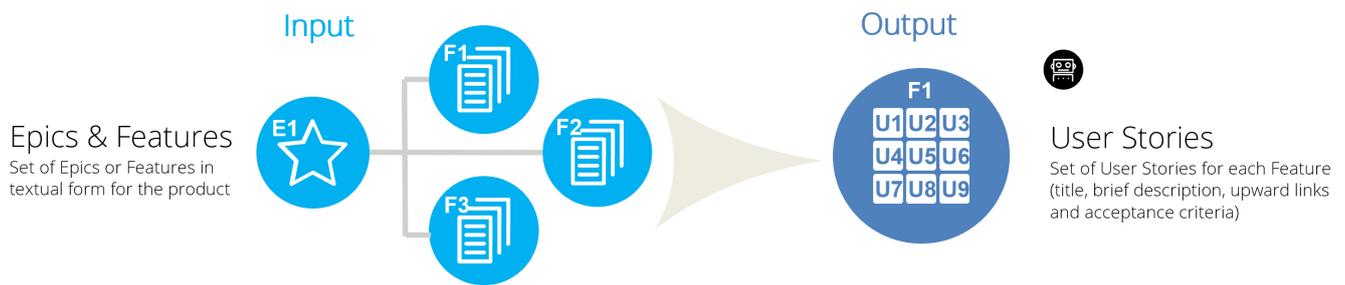
Use Case 2: Requirements Agile Breakdown

Introducing automation into the requirements breakdown process helps speed up development and increase agility in response to changing project needs. Generative AI technology can be integrated into PLM/ALM tooling to generate user stories from features, considering acceptance criteria.

The inputs for this use case include epics or features, decomposition directions, product use cases, business requirements, and domain knowledge. These inputs help the AI system generate meaningful user stories aligned with the given requirements.

Sample data consists of example epics broken down into features, which are further broken down into user stories with acceptance criteria. This data helps the AI system understand which requirements need to be taken into account when generating the user stories and how their content should be structured. The outcomes are features and user stories including titles, descriptions and links that can be used directly for implementation by software developers.

Overall, the use case uses generative AI to automate the generation of user stories and make requirements breakdown and development more agile and efficient. The AI-powered process improves creativity and solution class determination, improving the overall development process.



Reach out for a live demo of the implemented PoC!

Legend
 Generative AI enabled



Figure 4: Use Case 2

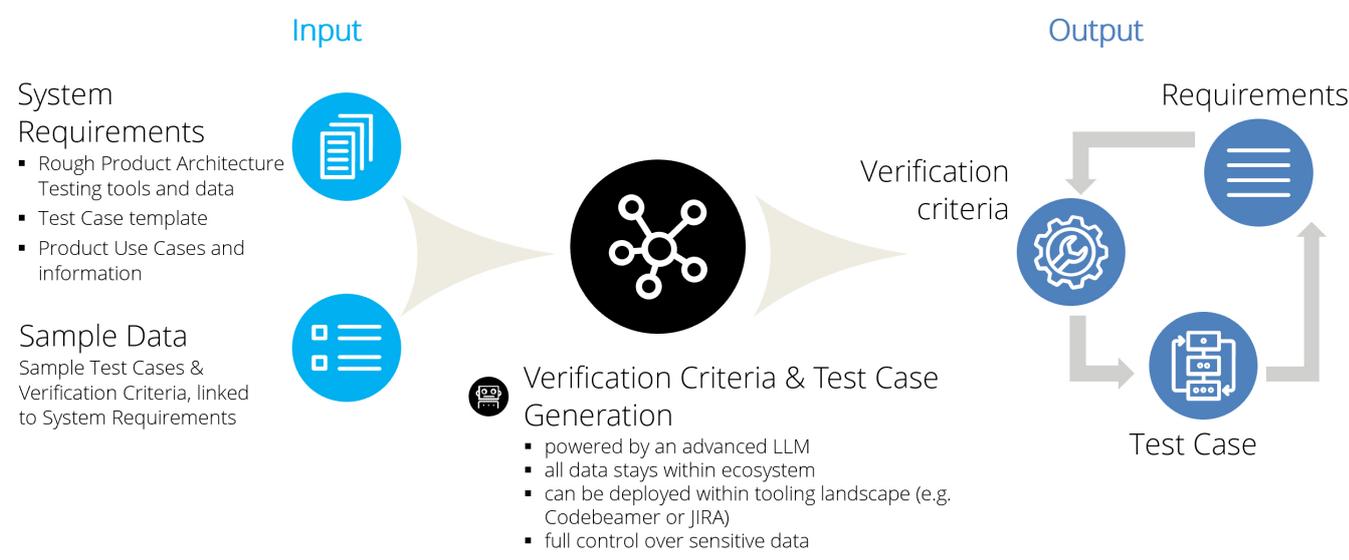
Use Case 3: Intelligent Verification Criteria and Test Case Generator

This cutting-edge application aims to revolutionize PLM/ALM through the use of generative AI technology, leveraging LLMs. It automates crucial tasks such as analyzing system requirements and generating corresponding verification criteria and test cases. This ensures efficient quality assurance and robust verification processes.

By integrating system requirements with additional inputs like textual representations of product architecture, testing tools, and domain knowledge, the application provides a comprehensive analysis framework. It adeptly identifies risk factors for the potential impact of these requirements on technology, cost and schedule, enriching the development process.

The tool's results include detailed insights from the requirements analyses and customized test cases that allow teams to quickly address and review the specifics of each requirement.

This tool is ideal for a variety of development scenarios. Its high scalability and comparatively low integration requirements make it a strategic asset for optimizing PLM processes. It supports consistent quality assurance and makes a substantial contribution to the market readiness and competitiveness of technical products.



Legend
Generative AI enabled

Reach out for a live demo of the implemented PoC!

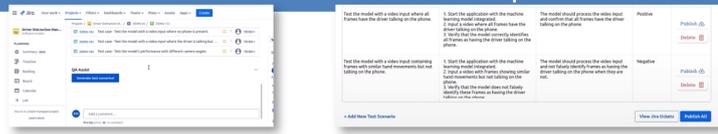
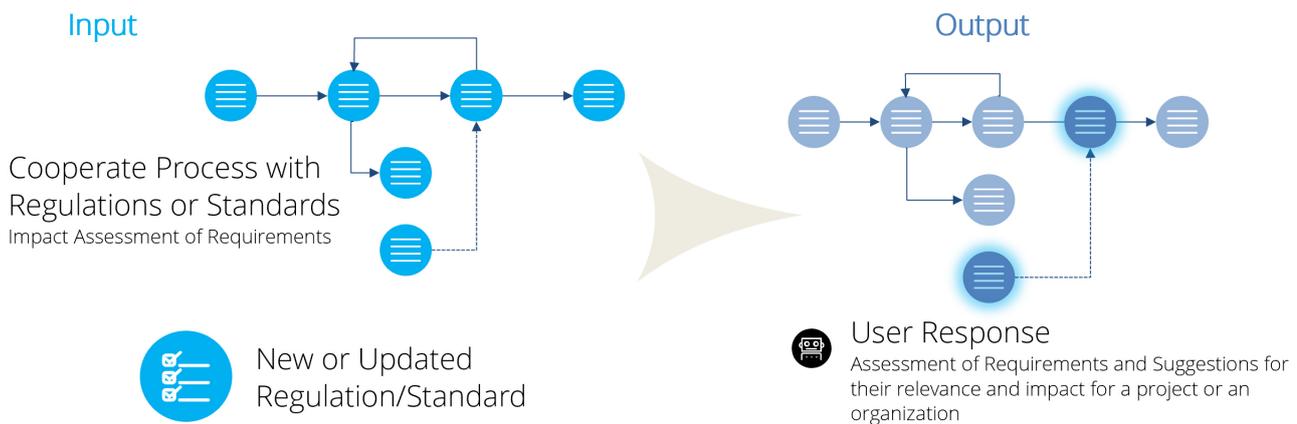


Figure 5: Use Case 3

Use Case 4: Regulations & Standards Impact Assessment

This use case helps companies understand and implement new regulations and standards. It assesses the relevance and impact of these regulations on projects and organizational processes. The case uses primary inputs of new regulations and standards, as well as supplemental inputs such as product use cases and information. These inputs empower the use case to provide a nuanced understanding of the regulatory landscape’s impact. It conducts an impact assessment of requirements, facilitating informed decision-making and ensuring compliance with regulatory standards.

The output includes an assessment of the requirements as well as recommendations on their relevance and impact on the project. In addition, concrete implementation strategies can be derived within the framework of existing project or quality management processes. Overall, the use case could provide a rapid initial assessment of new regulations, enhances compliance efforts, and improves project deliverables.



Legend

 Generative AI enabled

Figure 6: Use Case 4

Ongoing Challenges

Traditional systems face challenges that hinder their effectiveness in supporting product development. Their decision-making ability is often limited because they are based on rigid sets of rules and can only process contextual information to a limited extent.

Processing heterogeneous data sources leads to fragmentation, makes collaboration difficult, and increases the susceptibility to errors. Manual, time-consuming processes slow down development and reduce responsiveness to market demands.

A lack of predictive analytics capabilities, as well as limited support for creative design processes, inhibits innovation. Integration of business systems such as ERP and CRM also remains technically challenging and has a negative impact on data consistency and efficiency.

After all, it is essential to systematically use learnings from projects with successful solutions in order to avoid repeating mistakes. This illustrates the importance of structured knowledge management as a basis for the continuous improvement of problem-solving processes and systems engineering. Addressing these challenges entails advancements such as utilizing generative AI and adopting more intuitive interfaces. Overcoming these obstacles will enhance decision-making, collaboration, innovation, and overall efficiency in product development.

Outlook

As LLMs mature, new fields of application are opening up that provide automated and intelligent support for complex tasks. Deloitte recognizes the transformative potential of generative AI in the context of system and software development and supports companies in their strategic implementation.

Our engagement starts with a thorough understanding and analysis of your organization's current situation - identifying your specific needs, challenges, and business goals. We then tailor our established Minimum Viable Product (MVP) use cases to foster an efficient and innovative product development process.

Our strategy is built on three pillars: advanced data integration, intuitive interfaces and the strategic use of Generative AI in problem-solving. This is done with full consideration of key factors such as heterogeneity, trust and safety. By adapting proven use cases to individual requirements, we enable a seamless integration process. Once the implementation is complete, we provide ongoing support to maintain optimal operation.

At Deloitte, we invest in resources and strategies that enable the seamless integration and utilization of Generative AI. Our goal is to help your business revolutionize its product development practices and take efficiency and excellence to the next level.



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Going Digital: The Future of Material Sampling in Automotive

From Paper Chaos to Intelligent Quality Assurance

Dr. Heike Ulmer-Langner, Mercedes-Benz Group AG

The automotive industry is currently undergoing a radical transformation. Due to increased competition, manufacturers must also significantly shorten their development times to remain competitive. One component for faster product development is more efficient quality assurance (QA) of purchased parts. But what can intelligent QA look like in the digital age?

The following example shows the potential for time savings when standardization and the use of a platform come together with the long-standing knowledge of materials experts at Mercedes-Benz. The demands on quality assurance remain high; thanks to efficient processes, the experts can concentrate even more on what is essential: reliable products.

From Paper Chaos to Intelligent Quality Assurance

The quality assurance of purchased parts in the automotive industry is generally regulated by VDA Volume 2. A major component of this is the verification of material and component properties. Comprehensive tests and analyses ensure that defined criteria such as geometry, function, haptics and chemical composition are met.

The process, at the end of which this quality assurance stands, starts much earlier: The material selection must take place during the design and construction of a component, and with it the definition of the tests required for the material and application. These specifications define the framework for later quality assurance. If a component is not produced in-house, the specifications are passed on to the supply chain, which uses test plans to generate the required test results on the components. The transfer of the results to the client ensures that the required quality is delivered. If the test results are positive, the client issues a release for series delivery and product development is complete.

The evaluation of the test results is often still carried out manually today. They may be documented in a database. There are no uniform standards for the interfaces between the parties and systems involved. Depending on the application, in-house specifications may exist.

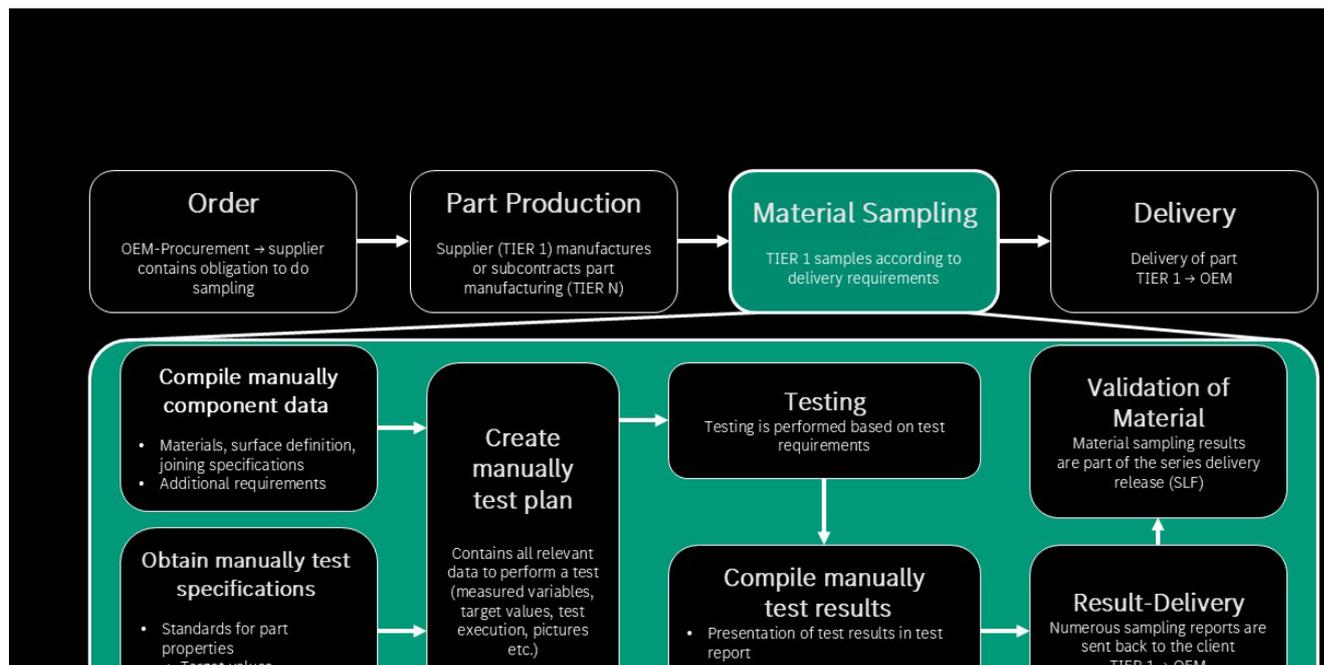


Figure 1 shows the current process

Standardization is at the beginning of a digital process chain: the cross-industry standards VDA 231-300 and VDA 231-301

In the future, the current transmissions, which often represent isolated solutions and are usually based on Excel templates, are to be replaced by a uniform standard for data exchange across company and system boundaries. This will enable everyone involved in the process chain to understand the data and implement solutions for their in-house documentation. Manual entries are avoided and, ideally, the data chain from the testing machine to the OEM is closed, so that everyone can access unadulterated test results.

Key components here are the standardization of the transmission of material definitions and test conditions and the standardization of the data chain created by the test results. For this purpose, two new recommendations, VDA 231-300 and VDA 231-301, were developed and published as part of a VDA project group.

VDA 231-300 regulates how material definitions and the definition of the standards applicable to the material are to be stored in the 3D data record. With the help of the JT standard according to ISO 14306, unique value pairs per body are generated, which can be passed on to the supply chain in a way that is readable for both humans and machines.

VDA 231-301 enables the structured and digital mapping of test report results. In cooperation with the University of Stuttgart, IKTD, a general generic data model was developed that underlies all test report results. This was translated into a JSON schema, which was made freely available on Github to enable collaborative development. This allows a trustworthy data chain to be built without having to retype. Ideally, it extends from the testing device to the OEM.

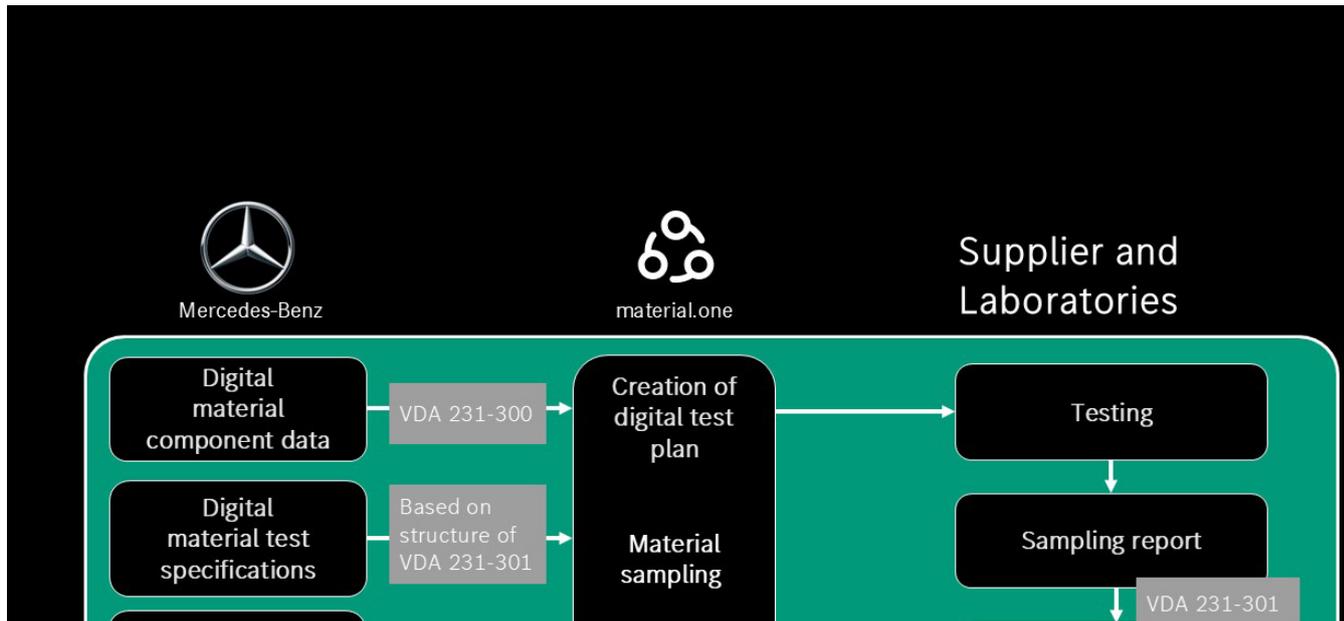


Figure 2 shows the new process

Integration of a platform for data exchange

Another crucial element in this data chain is the use of a collaborative platform. It serves as a communication hub and interpreter of all data streams and people involved throughout the QA process. In addition, it can enrich the process chain with additional information. For example, a client can make requirements derived from the standards available to the platform in digital form. Such an enriched data chain opens up the possibility of an automated target-actual comparison. This happens in real time and supports the QA employee in evaluating the submitted data. Another advantage of digitally recorded requirements from standards is the high level of transparency for everyone involved, because the standard for the specific application has been interpreted in advance by a QA employee for the entire supply chain. This interpretation can then be used again and again in other applications.

Via the platform, the collected information can be made available as specific data packages according to the need-to-know principle to all supply chain participants, even without a direct supplier relationship.

Another advantage of this overall process is that the individual QA processes can take place at any time and independently of the timing of the processes of the respective client. If, in addition, a system-supported preliminary check of the results takes place on the platform, all participants in the supply chain will be able to recognize at an early stage whether the test results meet the requirements of the client. If the requirements are not met, improvements to the component or component properties can be initiated immediately, so that the required test results in accordance with the target values can be transmitted to the client quickly and reliably at the agreed time. This

temporal decoupling gives the supply chain more time to meet the requirements of QA and at the same time reduces the time required for the QA process at the client.

The platform also takes on the role of communication hub for the test results, i.e. the required data flow back to the end customer. The way in which the QA data is made available to the final client can be regulated via an interface definition, with VDA 231-301 playing a central role. The validation of the transmitted data before sending it to the respective client ensures that all interfaces can be operated correctly.

In the next step, the standardized supply of test data storage for the client opens up significant time savings in the subsequent processes of QA.

Application Example: VDA 278 Check at Mercedes-Benz

The following example is an application case for test results in the field of interior emissions according to VDA 278. Previously, each user created their own Excel template for how the test results should be documented. The template is provided to the testing institutes, which then document their test results in the desired form. They send them back to the client and its supply chain, for example, as completed Excel files. With the help of parsers, these documents can be imported into the client's own databases. A common problem is that the testing institutes interpret and process the standard specifications differently, which means that the client's parsers cannot import the data into their systems. This requires considerable post-processing effort, e.g. supporting the testing institutes in providing the data in the required Excel format. With the help of the subschema for VDA 278 according to VDA 231-301, the results of the emission measurements can now be provided in a uniform data format and their data structure can be validated at the same time. As soon as the previous parsers have been updated to the new format, the measurements can be read into all subsequent systems in an automated process, and the format can be rolled out along the entire supply chain.

The QA in interior emissions is made transparent by rolling out the digital process and is faster and more reliable for all partners involved.

Generative AI: **Revolutionizing Vehicle Development**

Dr. Wolfgang Puntigam, AVL List GmbH
Robert Lokner, Microsoft Corporation

The automotive industry is undergoing a profound transformation driven by generative artificial intelligence (AI), digitalization, and the imperative for rapid innovation. This article synthesizes and critically compares two perspectives on the role of generative AI and design in vehicle development. It explores the transition from hardware-centric to function-oriented engineering, the integration of AI agents and digital twins, and the organizational and technological enablers required for success. This article proposes a framework for leveraging generative AI to accelerate development cycles, enhance product quality, and foster sustainable innovation in the automotive sector.

The automotive industry is undergoing a rapid transformation, driven by the need for faster development cycles and more efficient methodologies. The industry faces unprecedented challenges: increasing complexity, global competition, workforce shortages, and the need for rapid, customer-centric innovation. Traditional, hardware-focused development models are no longer sufficient. Generative AI and digitalization are key to overcoming these hurdles. It emphasizes both codifying engineering knowledge and human-centered design, while prioritizing organizational agility, digital infrastructure, and practical AI agent deployment.

Challenges in Vehicle Development

The automotive industry faces several significant challenges, including the need for speed in development and the shift from hardware-centric to function-oriented development. The competitive advantage of certain regions, such as China, is attributed to factors like invested manpower, cost advantages for raw materials and energy, and a pragmatic approach to development. This competitive edge has resulted in vehicle development times that are twice as fast as those in other regions. This rapid pace is not an isolated phenomenon but part of a broader set of competitive advantages, including:

- Strategic allocation of manpower and resources
- Cost efficiencies in raw materials and energy consumption
- A “fail fast, fail early” approach that enhances agility in the development process
- A 360-degree customer experience that integrates feedback loops across the product lifecycle

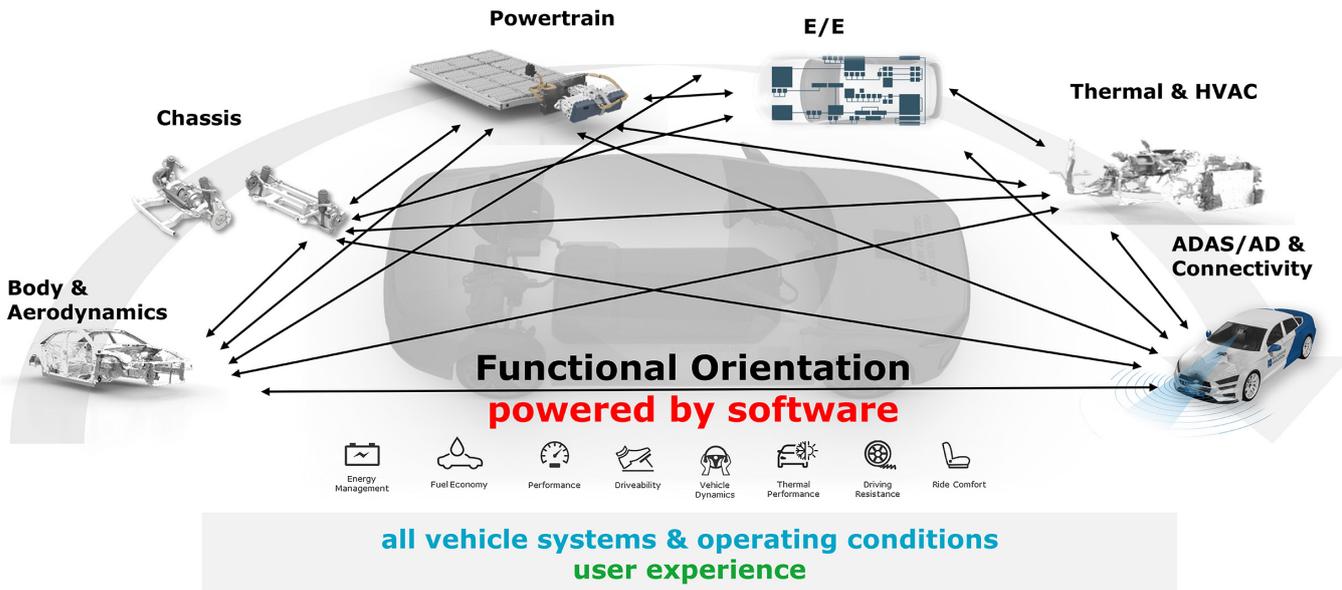


Figure 1: The transformation from hardware-centric to function-oriented development

A fundamental transformation is reshaping the automotive development paradigm: the shift from hardware-centric engineering to a function-oriented development model, increasingly defined and enabled by software [Fig. 1]. This evolution is not merely about the emergence of the “software-defined vehicle” (SDV); rather, it is about the rise of the user-oriented, function-defined vehicle, where both hardware and software coalesce to deliver seamless, intelligent functionality.

Historically, there was a direct 1:1 correlation between hardware components and vehicle functions – for example, braking was exclusively managed by mechanical systems. Today, however, the function of deceleration can be achieved either through regenerative braking via the electric motor or through traditional mechanical brakes. The decision-making process that blends these two systems is governed by software algorithms, which dynamically optimize performance, efficiency, and user experience.

This decoupling of functions from specific hardware components represents a significant shift. Functions are now distributed across multiple hardware domains, and their orchestration is increasingly reliant on software integration and control logic. In this context, software acts as the critical interface, the “glue”, between the vehicle’s physical systems and the end user.

Another pivotal development is the emergence of advanced electrical/electronic (E/E) architectures, particularly zonal architectures that consolidate electronic control units (ECUs) into centralized computing domains. These architectures reduce complexity, weight, and cost, while enabling real-time data processing and service-oriented software deployment. At the heart of this transformation lies the growing importance of semiconductors and silicon technologies, which now form the backbone of modern automotive innovation - from sensor fusion and AI inference to connectivity and cybersecurity.

Together, these shifts underscore a new reality: the future of vehicle development is function-first, software-driven, and silicon-enabled. Embracing this transformation is essential for maintaining technological leadership and delivering the next generation of intelligent, user-centric mobility solutions. Several key challenges have been identified in the current landscape. Firstly, organizational productivity is failing to keep pace with the exponentially increasing complexity seen across various industries. This disparity is notable as complexity grows at a rate of $2N$, whereas productivity increases at N^2 , highlighting a significant productivity gap.

Secondly, the process of identifying the most qualified domain experts and forming effective cross-organizational virtual teams is both time-consuming and challenging. This often results in products that reflect the company's organizational structure, essentially shipping the organizational chart, whether that is intended or not.

Lastly, IT engineering systems are often siloed, operating in different "languages," and due to budget constraints, there is little opportunity for legacy system modernization.

Generative AI as a Game-Changer

Generative AI is poised to be a game-changer in the automotive industry. It can capture enterprise knowledge by automatically extracting, organizing, and contextualizing information from vast data sources, making it easily accessible and actionable for everyone. AI agents can act on behalf of functional experts, inheriting their domain expertise and access permissions, and providing immediate answers to complex questions.

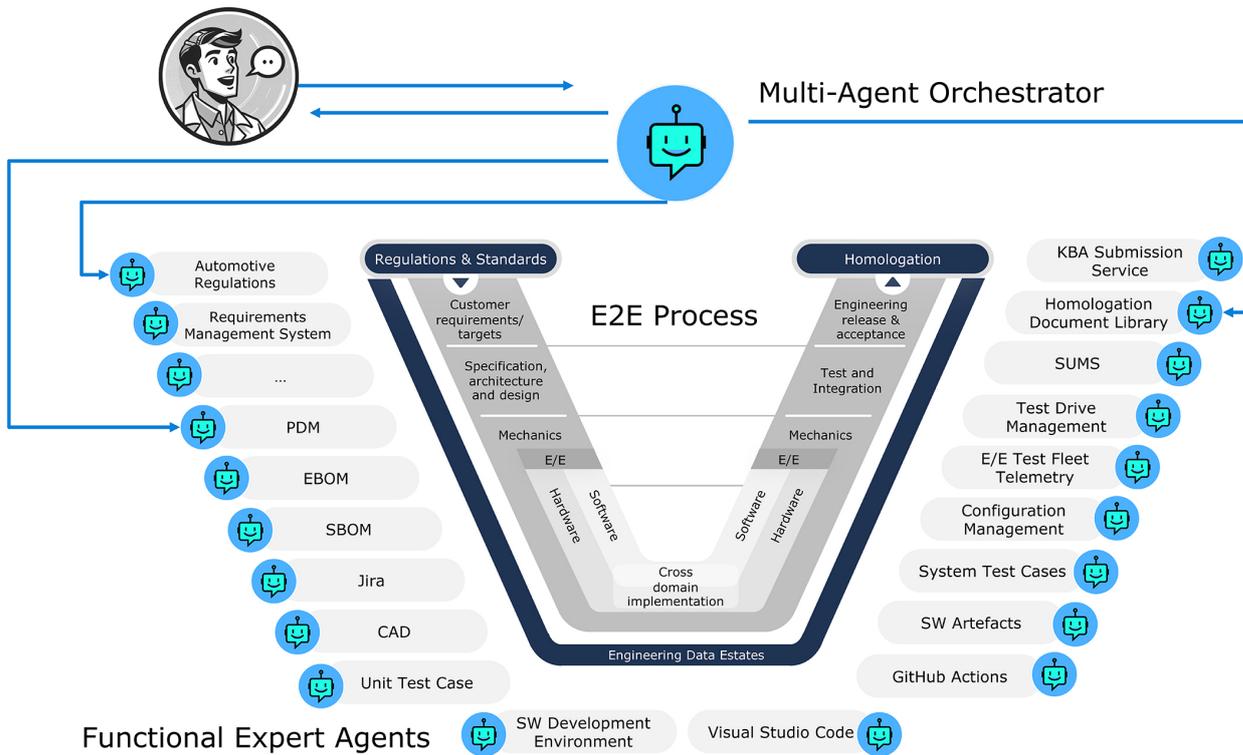


Figure 2: the V-Model with AI agents across different stages: how AI agents are integrated into various stages of vehicle development.

Generative AI enables the codification of expert knowledge into machine-readable models. Simulation Agents leverage knowledge databases, generative language models, and conversational interfaces to democratize access to engineering expertise. Engineers can specify design goals and receive simulation-ready models, accelerating the initiation of new projects. AI agents and copilots act on behalf of functional experts, providing personalized, context-aware support and facilitating multi-agent collaboration through protocols like Model Context Protocol (MCP) and Agent2Agent (A2A). Data Agents focus on testing and validation, enabling engineers to interrogate measurement data and simulation results using natural language.

Several key AI concepts are crucial to understanding the impact of Generative AI on vehicle development. Human augmentation and AI agents are pivotal innovations. Copilot, an expert system that works autonomously, and Agentic AI, which interacts with its environment to perform complex tasks independently, are highlighted as significant advancements. These AI systems can accelerate vehicle development by providing personalized assistance and a consistent user interface for employees to interact with AI.

At the core of every technological transformation lies human ingenuity. While tools and platforms evolve, it is the creativity, insight, and decision-making of people that drive meaningful progress. In this context, Copilot emerges as a trusted AI assistant, designed to understand users and their work environments, offering personalized, context-aware support through a unified and intuitive interface.

This paradigm shift can be summarized in two foundational principles:

- Every person will have a Copilot
- Every business process will have an agent

These principles reflect a future where AI is seamlessly embedded into daily workflows, augmenting human capabilities and automating routine tasks across the enterprise.

In complex PLM ecosystems where hundreds of applications must exchange data seamlessly, the Model Context Protocol (MCP) and Agent2Agent (A2A) offer transformative advantages. MCP provides a standardized framework for AI agents to interact with tools and data sources, enabling modular, scalable, and context-aware orchestration across distributed systems. It decouples application logic from tool execution, allowing enterprises to build flexible AI workflows that dynamically adapt to changing inputs and business needs. Meanwhile, A2A facilitates secure real-time communication between autonomous agents, regardless of their underlying architecture or vendor. This protocol enables agents to discover each other, delegate tasks, and share intermediate results, making multi-agent collaboration efficient and resilient. Together, MCP and A2A eliminate data silos, reduce integration overhead, and unlock intelligent automation across the product lifecycle. Organizations benefit from faster decision-making, improved data consistency, and enhanced agility in responding to market changes. These protocols are especially valuable in environments where interoperability, scalability, and security are critical to managing complex product data and workflows.

Software Vendors who want their applications to participate in modern AI-driven ecosystems, and remain competitive, should seriously consider implementing and providing MCP server. This is the logical next step for real Code of PLM openness (CPO).

Generative AI in Vehicle Development

One of the most critical questions facing OEMs today is: How can we shorten time-to-market for new products while still meeting evolving customer requirements? This challenge lies at the heart of many organizations' missions, and while the development of these solutions, particularly voice modules, is still ongoing, the good news is that human creativity remains essential. Despite the rise of automation and AI, innovation still depends on the ingenuity of people.

The application of AI systems in vehicle development is demonstrated through several examples. Generative design in the early stages, digitalization and virtualization methodologies, and the advanced DVP method supported by data intelligence are identified as key levers to speed up development.

- **Generative Design in Early Development Stages:** By integrating generative design tools at the concept phase, engineers can explore a broader solution space, optimize for multiple constraints, and reduce the number of physical prototypes required.
- **Digitalization and Virtualization Methodologies:** The consistent use of digital twins, simulation environments, and virtual validation allows for earlier detection of design flaws, faster iteration cycles, and reduced dependency on physical testing.
- **Advanced Design Verification and Planning (DVP):** A structured and predictive DVP approach ensures that validation activities are aligned with functional requirements from the outset, reducing late-stage changes and rework.
- **Continuous Support Through Data Intelligence:** Real-time data analytics and machine learning models provide actionable insights throughout the development process, enabling proactive decision-making and continuous improvement.

Building Up Functional Models – Simulation Agent

Based on Model Libraries

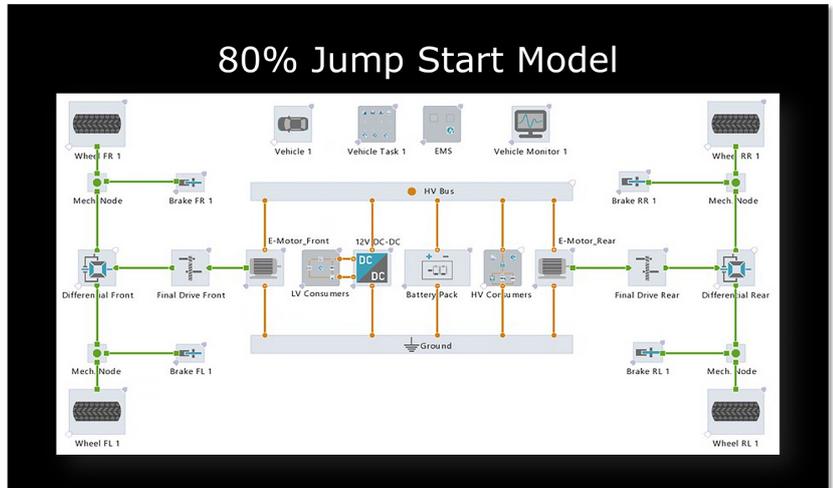
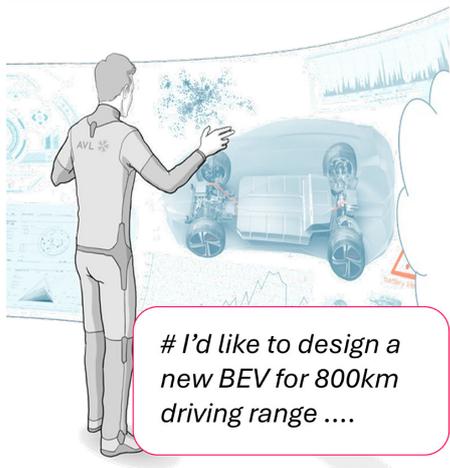


Figure 3: Simulation Agent, based on model libraries

While these concepts may sound like buzzwords at first glance, they represent a concrete, integrated strategy for transforming product development. A recurring theme is the centrality of human ingenuity. While AI and digital tools are transformative, it is the creativity, insight, and decision-making of people that drive meaningful progress. The future envisions every person with a copilot and every business process with an agent, seamlessly embedded into daily workflows. The vision of fully integrated, AI-driven generative design is not a distant aspiration. The necessary tools, models, and architectures are already under development. The challenge is to embrace change, codify knowledge, and build AI tools that will guide the industry forward.

From concept to simulation-ready model, the Simulation Agent bridges the gap with AI-driven speed and precision. The Simulation Agent concept addresses this challenge head-on by offering an AI-powered assistant that delivers a significant head start, an 80% Jump Start Model, for functional simulation [Fig. 3].

At its core, the Simulation Agent leverages a codified AVL Knowledge Database and generative large language models (LLMs) to transform engineering intent into actionable outputs. Whether the user needs textual explanations, Python code, or even a simulation-ready model, the agent responds through a conversational interface

Testing and Validation – Data Agent

Talk to your data

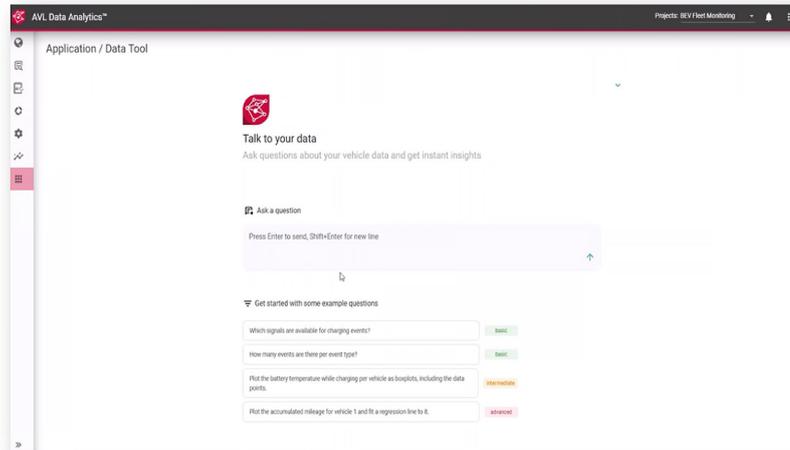


Figure 4: Data Agent, talk to your data

The Data Agent, a counterpart to the Simulation Agent focused on testing and validation [Fig. 4]. The Data Agent allows engineers to interrogate measurement data and simulation results using natural language, uncovering insights that might otherwise remain hidden.

The architecture of the Data Agent closely resembles the Simulation Agent, utilizing measurement artifacts and simulation desktops as data sources, and featuring a conversational interface powered by generative LLMs. This setup enables users to ask questions and receive clear, actionable responses. This democratization of data access empowers engineers to make informed decisions without needing deep expertise in data formats or analytics tools.

Vehicle Composer – Concept Agent

Balancing dependencies between affected systems

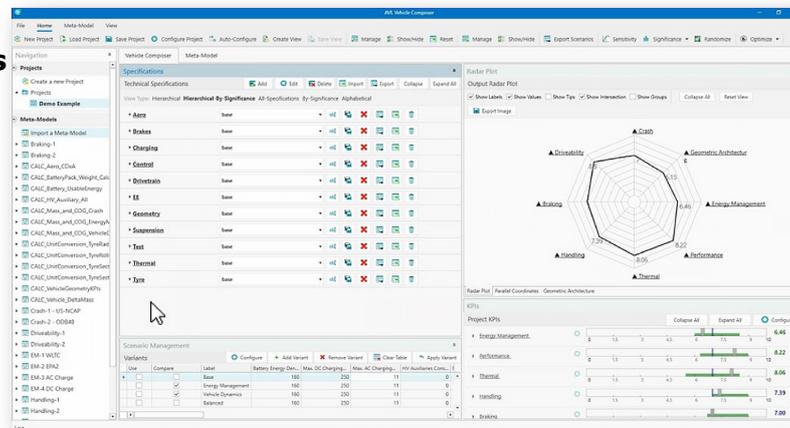
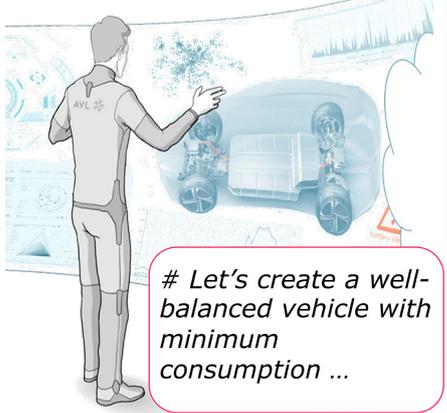


Figure 5: Concept Agent, balancing dependencies between affected systems

Figure 5 shows the Vehicle Composer, a conceptual AI-based assistant designed to support early-stage vehicle concept development. It aims to help engineers balance different interdependencies between various vehicle systems while optimizing performance and efficiency. Through a conversational interface, the Vehicle Composer guides developers in creating behavioral models for new vehicle concepts. It allows users to adjust design parameters and observe real-time impacts on vehicle attributes.

The goal is to provide a Vehicle Concept Jump Start by codifying expert knowledge and enabling efficient, informed concept development with minimal energy consumption and optimal system balance.

Generative AI and design represent a blueprint for the future of automotive engineering. By centering human needs, leveraging AI, and transforming complexity into opportunity, industry can achieve unprecedented levels of innovation and efficiency. The integration of digital twins, AI agents, and collaborative partnerships is essential for maintaining technological leadership and delivering intelligent, user-centric mobility solutions.

Conclusion

Generative AI is set to revolutionize the automotive industry by significantly shortening development cycles and enhancing overall efficiency. The insights presented in this paper underscore the importance of embracing AI technologies to stay competitive in the global market. Industry stakeholders are encouraged to explore the potential of Generative AI and integrate it into their development processes to achieve faster, more efficient outcomes.

Together, AVL and Microsoft are enabling a new paradigm in vehicle development, where AI-driven generative design accelerates innovation, enhances design quality, and reduces time-to-market through the intelligent fusion of engineering knowledge and digital infrastructure.

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Laying the Foundation for AI in Industry

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There is no shortage of articles on the potential of artificial intelligence (AI), particularly AI agents. While these capabilities are undisputed, their effectiveness in practice depends entirely on the quality of the underlying data. This article explores what manufacturing companies need in order to fully harness the potential of AI.





AI has already evolved far beyond being a set of helpful tools - it is increasingly becoming an integral part of business strategy. This trend is not only evident in discussions with industrial companies but also confirmed by a recent IBM Institute for Business Value study: 64% of AI budgets are allocated to core business functions. However, only a quarter of AI initiatives have delivered the expected return on investment in recent years, and merely 16% have achieved enterprise-wide scale (IBM CEO Study).

The reasons are manifold, yet two facts appear especially relevant: 72% of CEOs surveyed consider their company's proprietary data to be key for leveraging generative AI effectively, while 50% admit that their technological infrastructure is fragmented and poorly coordinated.

This is a situation we encounter frequently. Data often resides in disconnected documents and systems - so-called silos - and exists in various formats and quality levels. This fragmentation means that data is barely usable for AI applications, making it difficult to achieve the expected outcomes. Furthermore, processes remain disjointed, hindering cross-functional collaboration. Development and production frequently operate in isolation, leading to delayed detection of changes, lower product quality, and inefficiencies that curb innovation.



The Intelligent Product Lifecycle spans the entire product lifecycle, is powered by product data and fueled by AI. (Image: PTC)

From Silos to an Intelligent Product Lifecycle

The first step is to establish a consistent technical foundation – an integrated, data-driven approach that spans the entire product lifecycle, from initial requirements and design through manufacturing and service, and back into definition and development. When enhanced with AI, this becomes the Intelligent Product Lifecycle.

At its core are the product data that flow through all areas of the enterprise. These data represent the company's DNA – its intellectual property and unique value proposition. Enterprise-wide access to accurate, up-to-date product data across the entire lifecycle is essential to increase efficiency, reduce costs, and accelerate time-to-market for innovative products. It also provides the necessary foundation for deploying AI meaningfully across all functions and workflows.

From Development to Service - and Back Again

The starting point of the Intelligent Product Lifecycle is product development, where the fundamental data are created – defining hardware, software, and system requirements as well as materials. These form the basis for 3D CAD models and bills of materials (BOMs).

Development itself comprises numerous processes, from requirements and product line engineering to testing, design, simulation, BOM, and configuration management. To ensure collaboration and traceability across these activities, the relevant systems must be integrated.

As physical products increasingly rely on software, it becomes crucial to align software and hardware development through a unified view of product data. This requires ensuring associativity and bidirectional traceability between software requirements and corresponding physical components.

The result is a “single source of truth” for product data within development. Importantly, this does not require all data to be stored in one system – integration allows the aggregation of data as needed.

The benefits are tangible. For instance, a global machinery manufacturer working with PTC used to require weeks for design changes to reach production. Today, changes, BOMs, and 3D work instructions are synchronized in real time. This has led to faster ramp-ups, reduced scrap, greater agility, and unified teamwork across borders and continents.

On this foundation, AI can make information instantly accessible and generate valuable insights. Generative design enables engineers to develop better designs faster. AI agents can automatically detect changes in requirements, design data, or system models, analyze their impact, and identify relevant objects. They can notify team members and suggest potential follow-up actions, allowing them to take timely measures – improving and accelerating product development. AI also becomes indispensable in identifying reusable components or solutions, a key driver of efficiency.

Beyond development, this integrated product data backbone benefits the entire enterprise. Manufacturing engineers can use accurate product data to prepare production processes earlier, facilitating better planning and coordination. Data can also flow back to engineering for continuous improvement. PLM-based 3D work instructions derived from these data further reduce rework and waste while enhancing quality.

Such integration also supports the “design anywhere, build anywhere” paradigm – a major competitive advantage in times of geopolitical uncertainty and volatile supply chains.

Procurement can respond faster to design changes, strengthening supply chain resilience. Similarly, service operations benefit from access to comprehensive product data – improving maintenance scheduling, spare parts management, and first-time fix rates. Moreover, these capabilities enable new “as-a-service” business models. For instance, performance monitoring services allow manufacturers to build long-term, mutually beneficial relationships with customers.



AI agents can play a crucial role here. In PTC's ServiceMax field service management solution, for example, a multi-agent architecture is used: a service history agent can answer natural language queries based on work order data, while a scheduling agent can check a technician's calendar and plan events accordingly.

Many manufacturers already leverage operational data from connected IoT devices. Using AI and machine learning, predictive maintenance plans can be developed to increase equipment uptime. When this data is integrated into the Intelligent Product Lifecycle, it can also inform smarter marketing and sales strategies, enhance the customer experience, and feed back into development – creating better products that deliver true customer value.

Key Success Factors for Implementing AI

With such an integrated technological infrastructure in place, companies have laid the foundation for effective AI deployment. To ensure success, three key factors must be considered:

1. Establish the right framework

To deliver precise and reliable insights, AI requires not only consolidated systems but also clear governance rules and linkage between core artifacts such as requirements and BOMs.

2. Start small

Launching with selected, well-defined use cases minimizes risk and allows for early wins – critical for maintaining stakeholder support. Initially, AI should operate in close collaboration with humans. As trust and tangible value grow, automation and AI scalability can be expanded incrementally.

3. Foster an AI-first mindset

Digital transformation cannot be achieved through technology alone. Teams need AI literacy, governance frameworks for responsible use, and a culture that promotes human-AI collaboration.

Securing the Future

In the near future, AI agents will unlock even greater opportunities – evolving from assistive roles to autonomous execution of specific tasks. On a solid foundation, agent-based AI will be capable of operating across supporting systems such as CAD, PLM, ALM, ERP, MES, SLM, and IoT platforms.

A key principle must be seamless integration, ensuring that AI functions align with workflows, rules, and access controls. Only through this transparency can trust in AI be established.

Technical prerequisites include openness and interoperability through standardized interfaces. Companies that build on open, scalable platform architectures secure long-term flexibility – and are well prepared for whatever developments AI will bring next.



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SysML v2 - A Game Changer for Model-Based Development?

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:em engineering methods AG

The increasing complexity of cyber-physical products and their development involving interdisciplinary and distributed teams, raises the importance of model-based processes, methods, and tools. In Model-Based Systems Engineering (MBSE), the system model serves as the single-point-of-truth for the product description across all engineering domains.

Industry has adopted formal modeling languages such as SysML (Systems Modeling Language) to create system models in MBSE. However, this leads to challenges when it comes to connecting authoring tools seamlessly with neighboring disciplines like Requirements Management (RM) or Product Lifecycle Management (PLM) systems. Additionally, access to the model content is difficult for stakeholders from engineering domains as well as management due to the need of an authoring tool. In this article, significant improvements of introducing SysML v2 for MBSE are presented.

Current challenges in applying system models

The application of a system model as single-point-of-truth (SPOT) for the development involving different engineering domains is a major measure to coordinate the engineering domains [1]. Thus, the system model is the core artifact of model-based development in general and in Model-Based Systems Engineering (MBSE) in particular. All formalized models do have in common, that an authoring tool is needed to create, change and even read the model. This holds true, independently from whether a standardized language like SysML or a proprietary language of a single tool provider is used - while nevertheless there are special mechanisms available to publish models, e.g. to a web server for reading access by some tool vendors. Thus, the usage of the model content is limited to the capabilities of the authoring tool, causing the provision of Stakeholder-specific access to the content of the system model to be one of the main challenges in industry [2]. Similarly, the connection of the model (the modelling tool, respectively) to neighboring

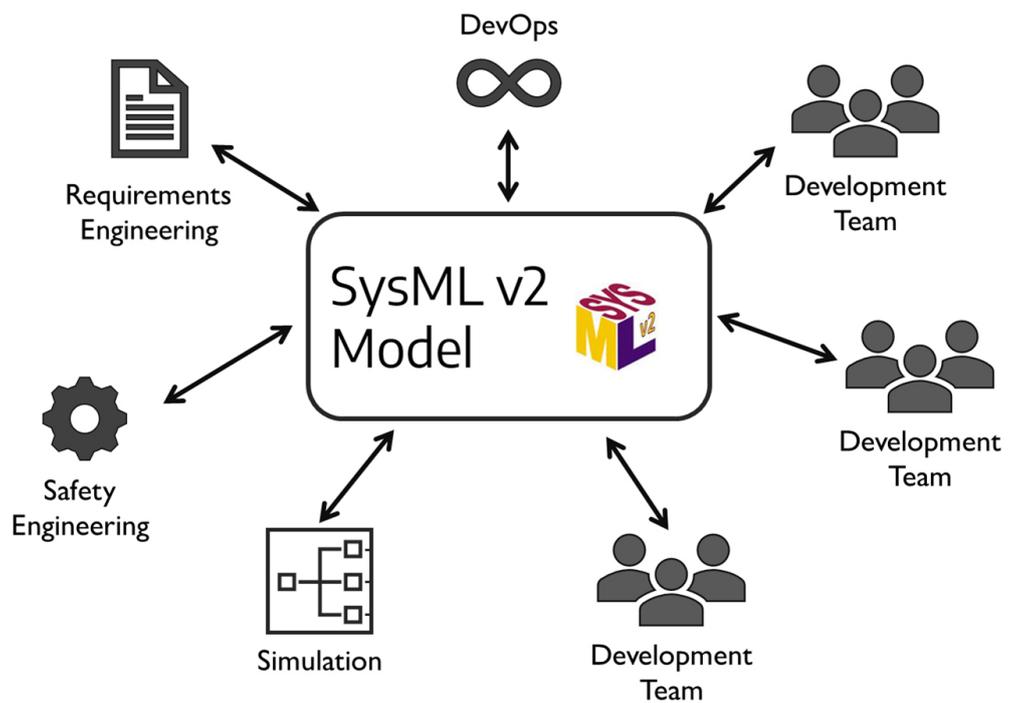


Figure 1: System Model as core artifact in model-based development. Image Source for SysML v2 Logo: OMG.

engineering disciplines like Requirements Engineering/Management or PLM is not sufficiently solved [2]. In the current state of the tool-landscape even within the same kind of model, a SysML model, interoperability across solutions of different tool vendors is not free of impediments. Vendors frequently implement the specification differently, resulting in heterogeneous interpretations and reduced model portability [3].

Besides the technical limitations coming with tool implementations, there are also usability concerns due to the diagram-centric nature of the language, which requires extensive training and can pose a hurdle for engineers outside of systems engineering disciplines [4].

These challenges have led many organizations to invest in costly customizations, middleware solutions, or limited MBSE adoption, which undermines the intended benefits of a shared system model as a SPOT.

Potential benefits of SysML v2

SysML v2, like SysML v1 before, is standardized by the Object Management Group (OMG) and has been accepted for release in July 2025 [5]. The aim of SysML v2 is to improve precision, expressiveness, usability, interoperability, and extensibility compared to SysML v1 [6].

The main improvements of SysML v2 in terms of language capabilities are a more integrated and consistent specification of requirements, behavior and structure and the enhancement of the language with concepts for e.g., product variability. This is related to a switch from UML as a meta-model to a new meta-model based on KerML [6].

Additionally, there are new technical possibilities coming with SysML v2 (Figure 2). Besides the already known graphical syntax, including diagrams, there is also a textual representation of the model with a clear syntax. This enables for example the handling of the system model by means and tools of software engineering and the connection to artificial intelligence (both reading and writing). Further, there is also a new possibility to access the model content via an Application Programming Interface (API). All three ways are accessing the same model content in the repository.

Especially the access via API promises significant improvements both in connecting the SysML v2 model content to specialized tools of engineering domains or neighboring disciplines like RM or PLM (and by that eventually establish the Digital Thread) and to enable interoperability when it comes to the usage of tools of different vendors.

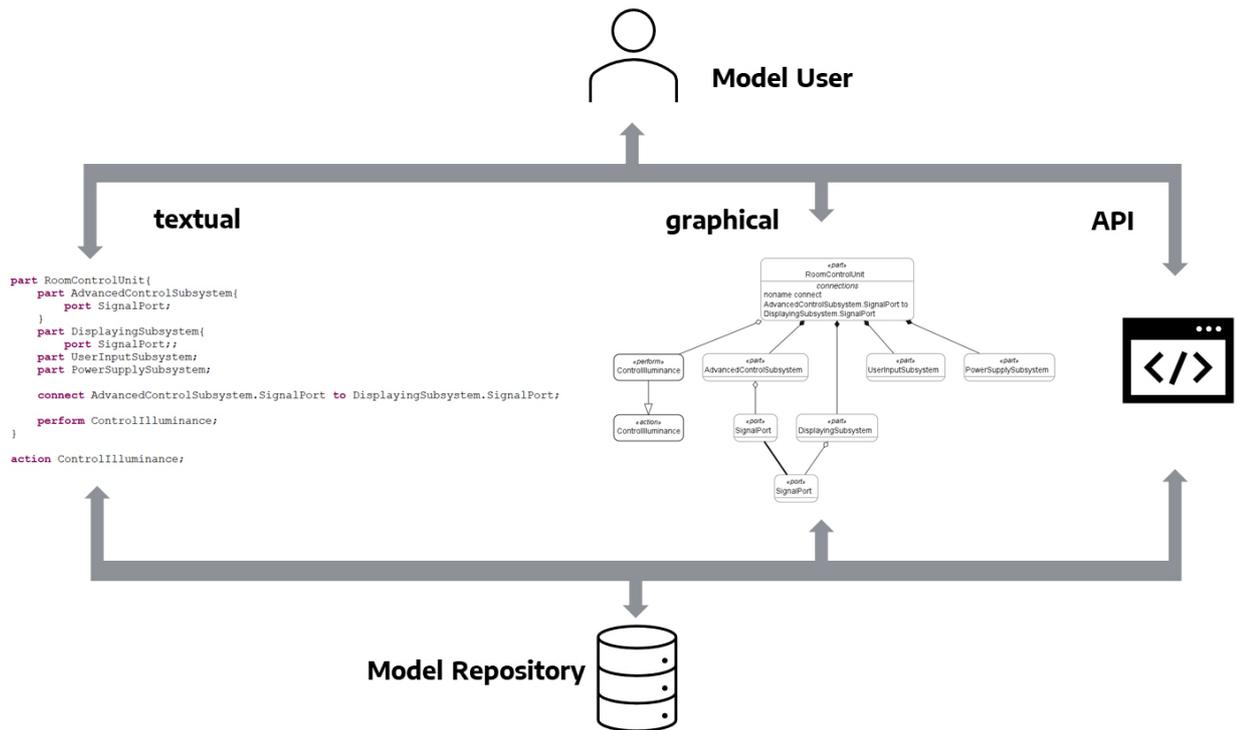


Figure 2: Access possibilities of a SysML v2 Model. Exemplary Training-Model “Room Control Unit”.

Essential considerations for organizations

Organizations dealing with product development now must develop a strategy for the near future, while there is already significant interest in the adoption of SysML v2 and planning of pilot projects within the industry [7]. Depending on the current situation, if the organization is already working with MBSE, two scenarios are to be differentiated:

Scenario 1: Introduction of MBSE

If an introduction of model-based development, or Model-Based Systems Engineering in particular, is planned or ongoing, the decision for a modelling language is a crucial point. Since the modelling language is in principle independent from the selection of the modelling tool and the method, in practice the selection of these so-called Three Pillars of MBSE is not free of mutual constraints. None of the available tools at the market can work with every language, thus there are technically limited combinations of tool and language. Additionally, the selected tool (and hence the modelling capabilities) and the language pose significant implication to the applied method.

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Scenario 2: Migration

If a company already has profound knowledge of MBSE and possesses a significant amount of digital data stored in models (e.g. SysML v1 or a tool-vendor-proprietary language), a strategy whether at all and if so, how to migrate to SysML v2. Both the timing and the selection for a tool accompanied by the assessment of necessary changes to the method are important points. A readiness assessment should first evaluate the organization’s current MBSE maturity, as organizations currently struggling with foundational SysML v1 practices may find the transition premature.

In both scenarios, it is recommended to analyze first needs to be addressed with MBSE and to consider the full tool chain to ensure compatibility with existing PLM, ALM, and simulation environments. Additionally, Human Resources is equally critical. Engineers will require training in SysML v2’s textual syntax and new collaboration practices, bridging the gap between systems engineering and software engineering disciplines.

The transition to SysML v2 (Figure 3) is not merely a technical upgrade; it represents an organizational transformation. Organizations should adopt a structured management approach, which can also be accompanied by external consulting and support.

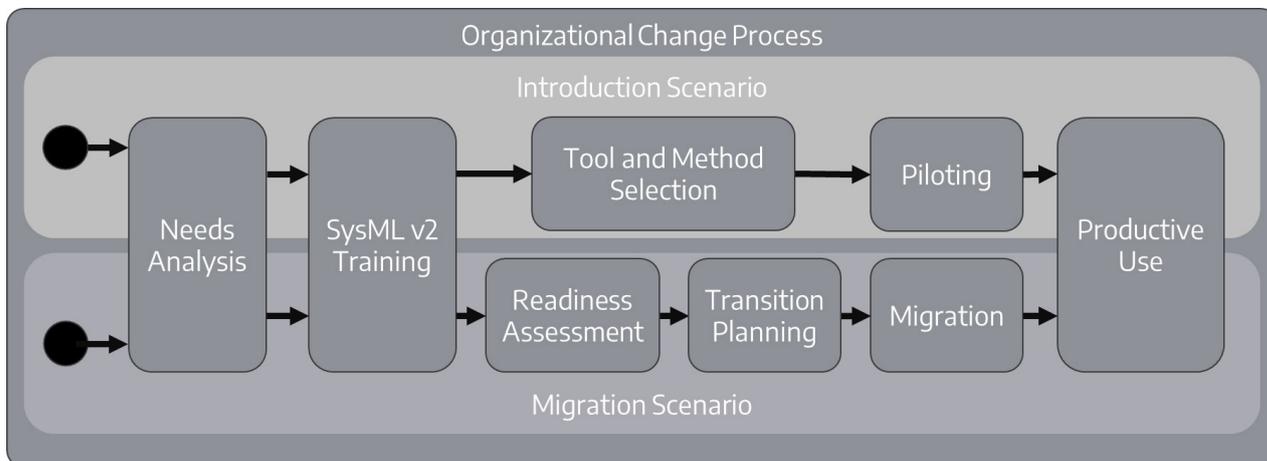


Figure 3: Possible SysML v2 Adoption Process for the two named scenarios. The process steps, in particular the Transition Planning step, may contain several sub-activities [8].

Will SysML v2 be a Game Changer?

Even though SysML v2 will not be the silver bullet for all current challenges in model-based development, its innovations - particularly textual notation, formalized semantics, and API-driven interoperability - represent a qualitative leap compared to SysML v1. For organizations where digital continuity and cross-domain integration (Digital Thread) are strategic goals, SysML v2 has the potential to be a key enabler.

However, the speed of adoption across the relevant players in the industry, including tool vendors and regulatory bodies, and the organizational readiness of companies to embrace the cultural and procedural changes inherent in a more software-oriented systems engineering approach will significantly influence the success of SysML v2.

Summary

SysML v2 is the new standard notation for MBSE and eliminates some of the main shortcomings of SysML v1 (and to some extent of other non-SysML-based languages) through a more formalized, expressive, and integrative language, aligned with modern software engineering practices. Hence, SysML v2 tackles the challenges of system complexity of cyber-physical and software-defined products. Organizations planning to adopt SysML v2 must consider the introduction not only as a pure technological upgrade, but as an organizational change process requiring strategic planning, tool chain integration and investments in tools and Human Resources. While not being a silver bullet, SysML v2 has the potential to significantly improve and advance model-based development in general and MBSE in particular. Under the premise of a standard-compliant implementation at all relevant tools along the tool chain, SysML v2 may turn out to be a Game Changer for model interoperability and Digital Thread. Thus, the prostep IVIP organization started a new project group on SysML v2 and all members are invited to join the working group in order to enhance processes and methods to drive innovation, develop systems and collaborate successfully in future using MBSE.



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implementation at various levels
of complexity:

The digital product passport in industrial practice

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Digital product passports as a driver of complexity for companies

The introduction of digital product passports (DPPs) is considered a key instrument for promoting the circular economy in Europe (EU 2024). They can improve resource use, traceability, reuse and recycling, especially in raw material-intensive industries such as electronics, automotive and construction, and reduce dependencies on global supply chains. In practice, however, implementation is proving complex: companies must collect relevant data, integrate it into often historically grown IT infrastructures and standardise data exchange between internal and external stakeholders (Jansen et al. 2023). In addition, requirements vary greatly depending on the product group, the company's role in the life cycle (e.g. supply chain, OEM, end-of-life) and the regulatory context (Wautelet and Ayed 2024), making a uniform implementation approach unrealistic.

The European Commission has created a binding framework with the Ecodesign Regulation for Sustainable Products (ESPR) and other regulations, including those for batteries, toys and construction products. The 2025-2030 working plan specifies requirements for prioritised product groups such as steel and aluminium products, textiles, furniture and tyres, and sets out a timetable for implementation for regulatory compliance. These specifications provide guidance for the design of digital product data structures (EC 2025). The prioritised groups differ greatly in terms of material complexity, supply chain structure and environmental impact, which influences the design of the respective DPPs. Their introduction requires differentiated solutions that consider regulatory requirements and industry-specific characteristics in parallel. Requirements also vary within one value chain: manufacturers, suppliers and recyclers will interact differently with the DPP based on their roles. A systematic consideration of the dimensions of data, infrastructure and organisation is therefore crucial for practical and scalable solutions. Several companies have already begun implementing DPPs, while others are in the early stages of adoption.

In light of this, Fraunhofer IPK has presented a model for the strategic design of DPP projects (Steiner et al. 2025). A structural model for the internal implementation of DPPs was also derived from industrial implementation projects. In the following article, the structural model is presented as a practical basis for decision-making, which companies can use to develop concrete strategic approaches for DPPs.

Digital Continuity: The foundation of successful DPPs

The ESPR formulates basic information requirements that are horizontal (across all product groups) and vertical (specific to individual product groups). Horizontal requirements concern, for example, repairability, recyclability and the CO₂-footprint of products. Vertical requirements, such as those for battery passports, go much further and require detailed data on chemical composition, CO₂ emissions per production stage, recycling rates and critical raw materials (DIN 2025). With regard to data and system architecture, the ESPR distinguishes between the DPP data artefact and the DPP system (Jansen et al. 2023).

The DPP data artefact is the digital product passport itself, a structured data set containing product-specific information on materials, origin, environmental impacts and social aspects, provided by various actors along the value chain. It forms the basis for traceability, reuse and sustainability assessment (Ducuing and Reich 2023; Koppelaar et al. 2023; Jansen et al. 2023). The DPP system refers to the IT architecture that collects, consolidates and links this data, uniquely links products to digital representations, and enables exchange between stakeholders through registers, interfaces and identity management (Jansen et al. 2023).

Depending on the purpose, the information requirements must be referenced at the model, batch or individual product level (instance-specific, such as serial number). The example of the battery passport (DIN 2025) shows that information such as chemical composition is sufficient at the model or cell type level, while data such as CO₂ emissions per production stage or usage history must be recorded on an instance-specific basis. A distinction is made between static and dynamic data: static data does not change over the life cycle, while dynamic data, such as usage and repair data, is continuously updated (DIN 2025). As the proportion of dynamic data grows, so does the complexity of recording it and the demands on IT systems.

The complex information requirements for DPPs place high demands on the underlying IT systems. The systems must not only integrate heterogeneous data from ERP, PLM and MES solutions, but also enable context-dependent access via differentiated role and rights concepts. In addition to regulatory compliance, they should offer functional added value and at the same time be designed to be energy-efficient, modular and sustainable in the long term to survive as critical infrastructure for the digital circular economy.

Due to the diverse information requirements and high demands on data exchange, the DPP proves to be a prime example of digital continuity of product data - a multidimensional use case along the dimensions of organisation, data and infrastructure.

Not all DPPs are the same: Why companies need differentiated implementation approaches

The implementation of DPPs is not the same for every company: the impact depends on product groups, target markets and strategic corporate decisions. Although specific information requirements already exist for individual product types such as batteries (DIN 2025), there is a lack of clear guidelines in many areas, which makes it difficult for companies to reliably identify use cases for DPPs in their own context. In addition, the expected sectoral differentiation through delegated acts and various related regulations (e.g. energy labelling) could lead to widely varying requirements within individual industries, such as household appliances and consumer electronics (Wautelet and Ayed 2024). In this context, initiatives by ISO/IEC JTC 1 and the European JTC24 are being pursued with a view towards international harmonisation of DPPs (ANSI 2025).

The technical specifications of the EU DPP-system are not yet complete, so companies do not have a reliable basis for planning and strategy. At the same time, numerous pilot projects with proprietary technologies are emerging, whose limited scope and lack of interoperability hinder scalability (Wautelet and Ayed 2024). Examples such as the battery passport or the Catena-X reference application show promising approaches: Catena-X offers a semantic model, a front end for visualisation, and identity and access management, but it is strongly tied to its own ecosystem and tailored to the automotive industry. A key bottleneck remains the availability of data along the supply chain. Identifying relevant information is company-specific and resource-intensive; in addition, cross-sector data exchange requires interoperability between ecosystems such as Catena-X and Aerospace-X (Manoury et al. 2025).

The analysis of use cases in batteries, electronics and textiles shows that a uniform DPP approach is not sufficient. Different stakeholders, from manufacturers to repair shops to recycling companies, have sometimes widely diverging requirements in terms of data formats, granularity and access rights. For example, repair shops need precise usage data, while recycling companies need information on material composition (Wautelet and Ayed 2024).

However, by structurally linking comprehensive product data, DPPs not only enable regulatory compliance, but also future analytics and AI applications, from predictive models and dynamic CO₂ reporting to new data-based business models (Voulgaridis et al. 2024; Borah et al. 2024; King et al. 2023). Companies should therefore systematically integrate strategic future questions about expanded business models into their DPP implementation. Uniform standards and interoperable systems are essential for this but must leave room for sectoral adjustments to make the DPP an effective tool for the circular economy and new business models.

Making complexity tangible: Structured approaches to implementing DPPs

The characteristics of DPPs differ from company to company depending on their role within the value chain, their exposure to regulatory requirements, the complexity of their products and supply chains, and their own level of digital development and that of their partners. Therefore, the implementation of DPPs is not a binary decision (“DPP yes or no”), but a gradual development across different stages. The structural model for DPPs presented here offers a systemic framework for classifying company-specific initiatives (Figure 1). It specifies the strategic concept for DPP projects developed by Fraunhofer IPK (Steiner et al. 2025), with DPP implementation approaches ranging from pure basic data provision to advanced DPPs with full integration of analytical and collaborative functions, based on increasing complexity in three dimensions (organisation, data, infrastructure).

Figure 1 shows three approaches to implementing DPPs (Steiner et al. 2025), graded according to complexity in the dimensions of data, infrastructure and organisation. The illustration shows how increasing regulatory requirements lead to greater data complexity, which in turn requires deeper system integration and expanded organisational structures.

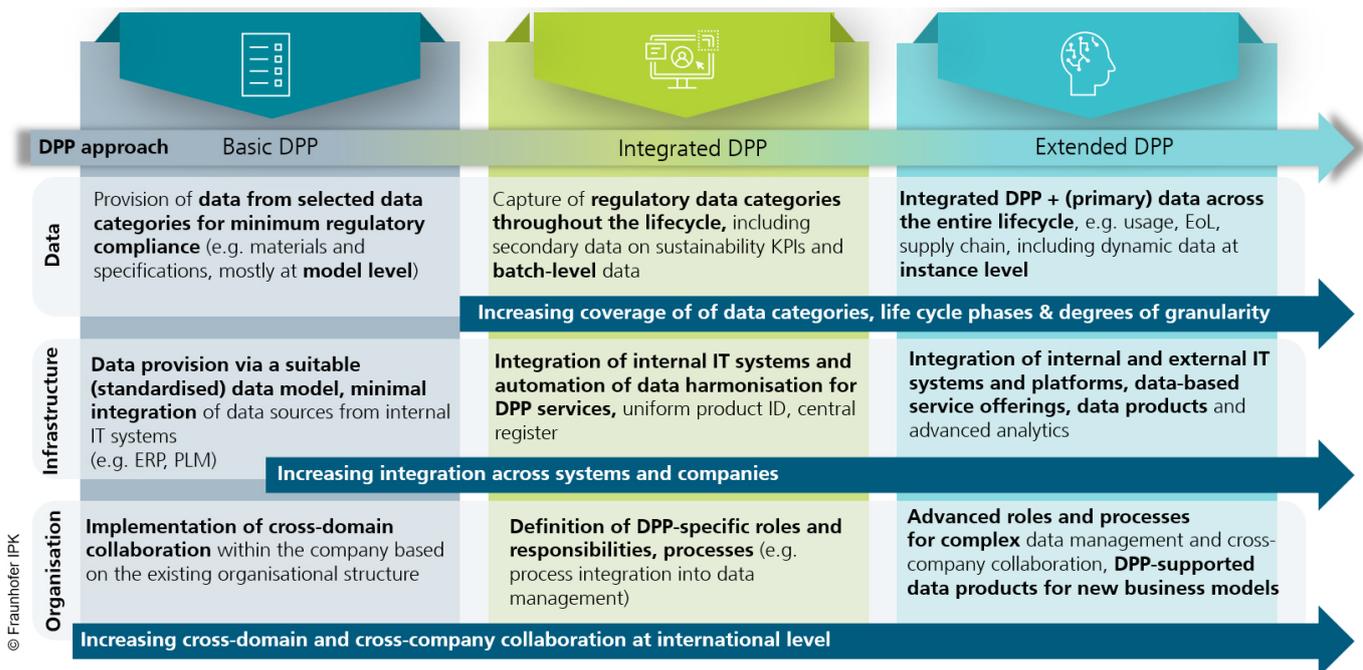


Figure 1: Complexity dimensions applied to differentiated DPP implementation approaches (Steiner et al. 2025)

The digital product passport in industrial practice

The model is characterised by a holistic perspective: it links technical, data-related and organisational requirements and shows how their interaction determines the complexity and benefits of DPPs. The three dimensions serve as central levers that companies can use to systematically analyse where they currently stand and what development steps are necessary for more complex DPPs.

The selection of a suitable approach depends largely on the company's starting position. Differences in the role within the value chain, for example as a distributor, supplier or material recycler, lead to varying requirements for data provision and system integration. Indirect impact is particularly relevant: even companies without direct regulatory obligations (as opposed to direct impact as responsible economic operator placing the product on the market) will in future have to provide information as data suppliers that is necessary for downstream players to comply with DPP requirements. In addition, data availability, quality and the degree of digitisation of the IT infrastructure influence the feasibility of more complex functions.

Against this background, graduated implementation approaches are necessary in order to address the complexity of DPP introduction in a differentiated manner along technical, organisational and regulatory requirements. The classification of a company into a suitable DPP implementation approach should be based on key dimensions. Differences in organisational role, regulatory impact, data availability and technical infrastructure are key factors in determining which approach is practicable. Figure 2 specifies these dimensions in the context of DPPs and defines criteria for systematic classification.

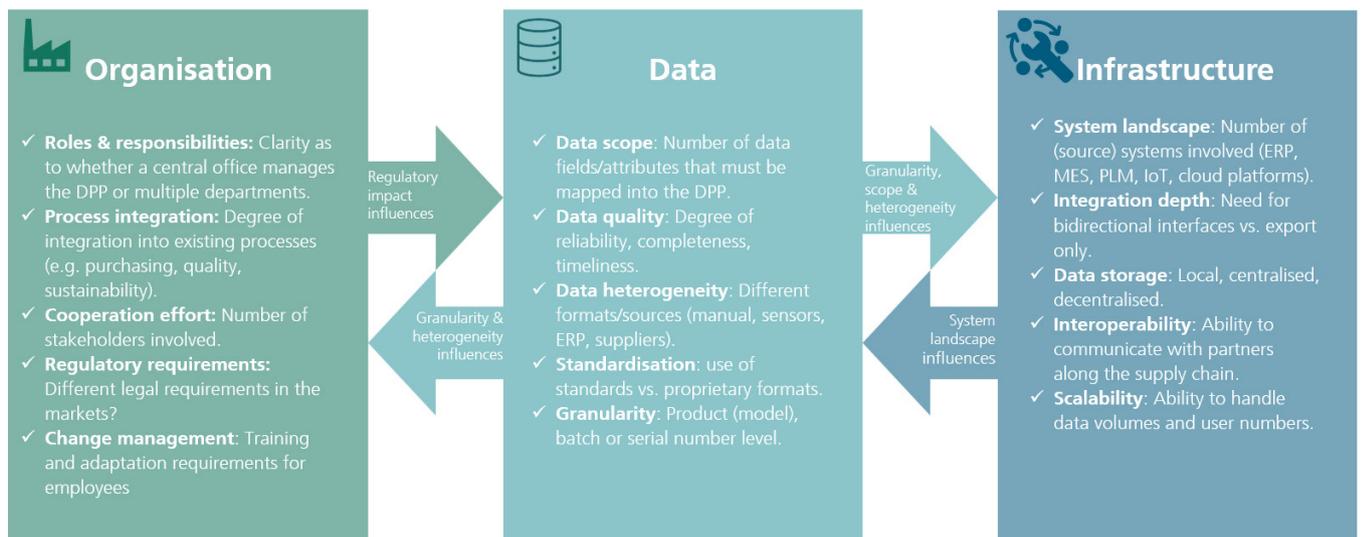


Figure 2: Dimensions and criteria for DPP complexity

The three dimensions - data, infrastructure and organisation - influence each other. Figure 2 shows the dimensions and defined criteria that can be used to classify the degree of complexity of a DPP implementation. The criteria help companies to classify the complexity of DPPs for themselves and decide on a suitable implementation approach. Regulatory requirements determine the scope and granularity of the data, thereby increasing the complexity of sources and formats. The heterogeneity of the data has a direct impact on the amount of cooperation required and the depth of process integration. The scope and level of detail of the data also determine the necessary depth of integration and interoperability, which in turn shape the future system landscape. Conversely, the existing system landscape influences how standardised data formats are and how diverse the sources are, with a direct impact on organisational complexity.

The three DPP implementation approaches differ significantly in their complexity along the dimensions of data, infrastructure and organisation. Figures 3, 4 and 5 show the dimensions of organisation, data and infrastructure of the DPP approaches and their increasing complexity, respectively, based on the criteria defined in Figure 2.

Criterion	DPP implementation approach		
	Basic DPP	Integrated DPP	Enhanced DPP
Roles & Responsibilities	Clearly assigned, few participants	Spread across several departments	Many stakeholders, both internal and external to the company
Process integration	Complementary, not business-critical	Embedded in core processes	Profound redesign of several processes
Cooperation effort	1-2 partners	Several partners, some complex partnerships	Many international partners, high coordination costs
Regulatory requirements	Uniform requirements	Partially different requirements	Highly differentiated/country-specific or product-specific regulations
Change management	Low training requirements	Selective training required	High continuing education and communication costs

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Figure 3: Organisation - DPP complexity according to criteria

Criterion	DPP implementation approach		
	Basic DPP	Integrated DPP	Enhanced DPP
Data scope	Few attributes (e.g. basic product data such as the weight of a component)	Extended attributes (e.g. material specifications, energy-related data)	Many attributes (e.g. lifecycle, recycling, CO ₂ data)
Data quality	largely complete & consistent	Partially incomplete, plausibility checks necessary	High risk of errors, data gaps and timeliness must be continuously optimised
Data heterogeneity	Homogeneous, from 1–2 sources	Multiple sources, some with different formats	Many sources and widely varying data formats (ERP, IoT, suppliers)
Standardisation	Fully compliant with current standards	Partially standardised	Proprietary/incompatible formats
Granularity	Model – product level	Batch level	Batch & series/individual level, combination

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Figure 4: Data - DPP complexity according to criteria

Criterion	DPP implementation approach		
	Basic DPP	Integrated DPP	Enhanced DPP
System landscape	1–2 systems	Multiple internal systems	Complex landscape with many internal and external systems
Integration depth	Simple exports / manual transfers	Semi-automated interfaces	Bidirectional real-time integrations
Data storage	Local or centralised system	Hybrid (cloud) solutions	Distributed/ decentralised architectures
Interoperability	Purely internal use	Limited exchange with partners	Comprehensive supply chain-wide interoperability
Scalability	Designed for current data volume	Moderate scalability	Highly scalable, international, many users & high data volumes

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Figure 5: Infrastructure - DPP complexity according to criteria

In the **data dimension**, this is reflected in the scope, granularity and heterogeneity of the data sources: while the Basic DPP relies on a few standardised attributes from homogeneous sources at product level, the Integrated DPP uses an extended database with partly heterogeneous formats and batch references. The Enhanced DPP goes further and integrates extensive, often unstructured sustainability data from internal and external sources, right down to the batch, series, or individual product level.

The **infrastructure** also scales in complexity along the three implementation approaches: Basic DPP works with a manageable system landscape and simple export interfaces for extraction of the needed data. In the Integrated DPP approach, multiple systems are connected via semi-automated interfaces. The Enhanced DPP requires a highly networked, often decentralised

architecture with bidirectional real-time integrations and high interoperability along the supply chain to support dynamic data alongside static data integration and usage.

Within the **organisation**, complexity increases with the number of stakeholders involved, process integration and regulatory requirements: while the Basic DPP is assigned to a few roles and embedded in existing processes, the Integrated DPP requires cross-departmental coordination and embedding in central business processes. Finally, the Enhanced DPP brings about profound changes, including international coordination, complex change management and differentiated regulatory requirements based on market and product specifics.

The choice of approach depends heavily on a company's digital maturity, strategic goals and regulatory impact. The definition of different levels of complexity in the dimensions of data, infrastructure and organisation makes it clear that DPPs should not be understood as isolated IT projects, but as strategic elements of the organisation's digital and sustainable transformation.

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Outlook

The presented complexity model offers companies a structured basis for classifying and implementing DPPs. It illustrates that DPPs require not only technical but also organisational and strategic adjustments. The differentiated approaches help to make the complexity of DPPs tangible and to plan initiatives in a targeted manner. The model thus supports companies in understanding DPPs not as isolated IT projects, but as an integral part of a digital and sustainable transformation. The systemic consideration of key corporate dimensions makes it possible to navigate the dynamic and not yet fully defined regulatory environment and to develop viable implementation strategies in this uncertain environment.

The model is currently being implemented and tested in ongoing industry projects and is being continuously developed and specified based on the requirements identified in this context. As technical and regulatory developments progress, the focus is shifting in particular to interoperability, the future AI readiness of DPP systems and the use of data-based business models.



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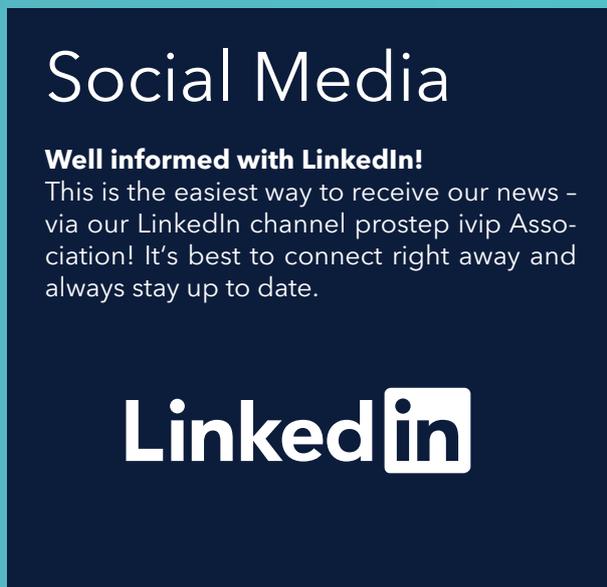
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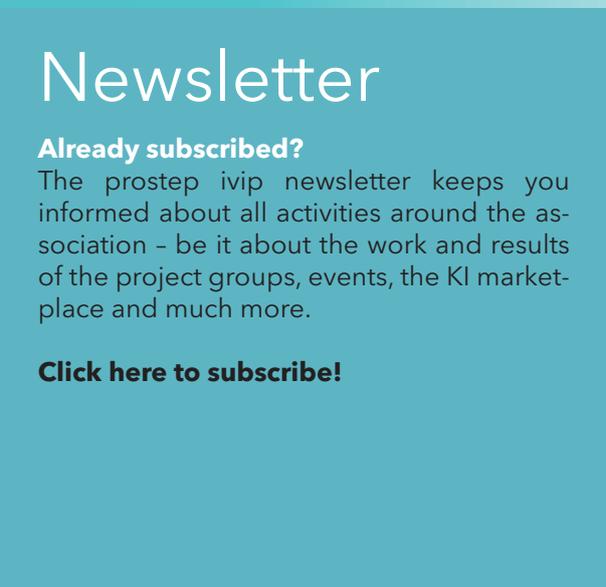
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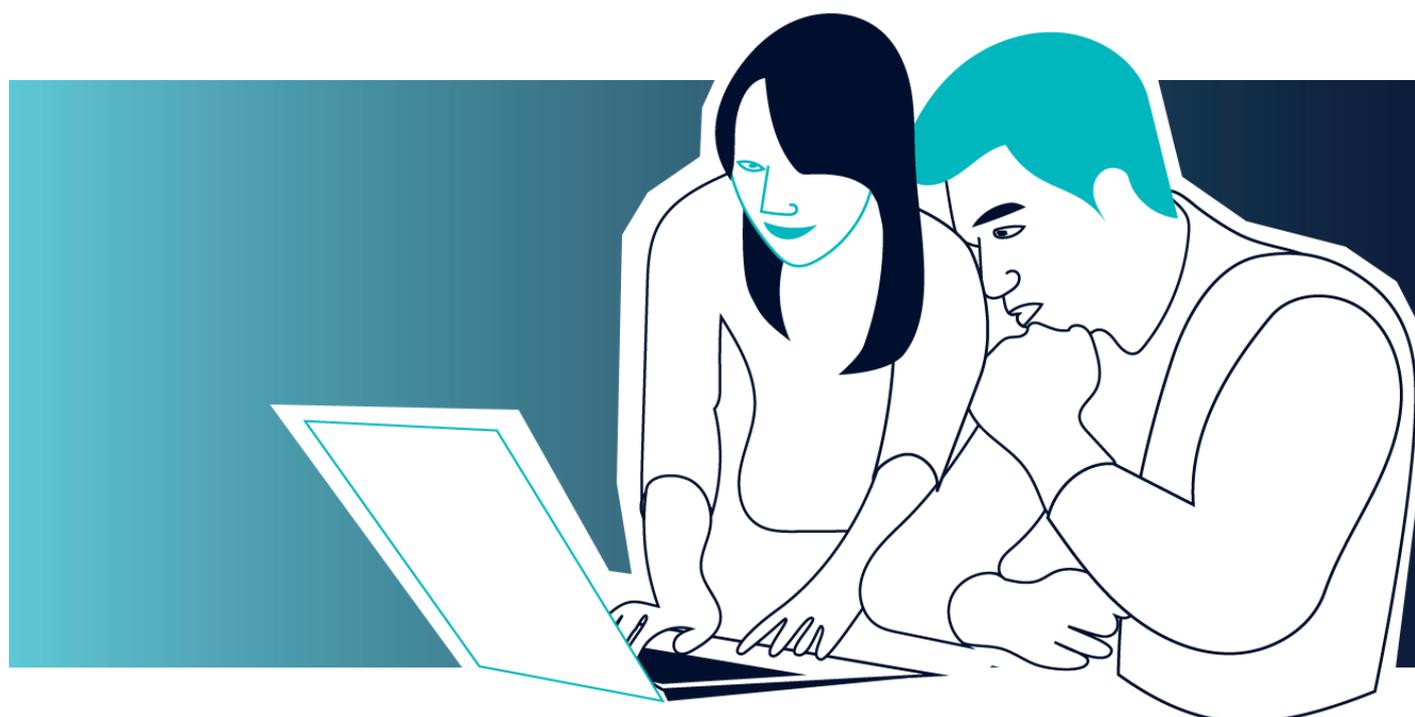
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