IIWH

Innovation Initiative Wire Harness

Results of Phase 2.1

(July 2020 to June 2021)

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www.arena2036.de/en/innovation-initiative-wire-harness

ARENA2036

Foreword ARENA2036

Professor Peter Middendorf

Speaker of the Research Directorate ARENA2036

Head of the Institute for Aircraft Design (IFB) at the University of Stuttgart

Dear Readers,

ARENA2036 is one of nine research campuses funded by the Federal Ministry of Education and Research (BMBF). Its mandate and goal is nothing less than to contribute to technological sovereignty in the field of key technologies. In this respect, ARENA2036 is focused of the field of automobile production.

The wire harness is a key component in cars that is facing constantly rising demands, particularly in production. Increasingly complex electrics and electronics, autonomous driving, functional safety and the electrification of the drive train – just to name a few drivers – require new paradigms in the automation and digitisation of the entire value chain in the medium-term.

As part of the University of Stuttgart campus, the partners of the Innovation Initiative Wire Harness benefit from the expertise and the geographic proximity to numerous institutes. Apart from working together with the Institute of Human Factors and Technology Management (IAT), collaboration has also been established with the Institute for Control Engineering of Machine Tools and Manufacturing Units (ISW). The involvement of the Institute of Mechanical Handling and Logistics (IFT) now adds a third institute at the University of Stuttgart.

The IIWH represents an innovative approach with great potential. The partners exchange specific scientific know-how according to their needs and use their collaboration as a precompetitive lever for developing new production paradigms. This company-driven approach to collaboration with research institutes constitutes a relevant expansion of our innovation system that benefits the partners of the Innovation Initiative Wire Harness as well as the involved institutes – all in accord with the research campus concept of ARENA2036.

Foreword ARENA2036

Dear Readers,

The Innovation Initiative Wire Harness is entering its third year. A total of 19 partners and over 100 experts are now working on the largest project at the ARENA2036 research campus – all despite the difficult fact that conditions over the past year were anything but easy.

The results of the second year of the Innovation Initiative Wire Harness speak for themselves. While the focus was initially still on ‘quick wins’, the consortium has now increasingly turned its focus to the ‘big wins’. The quality and intensity of the collaboration is reflected, in particular, in the development of the draft for a DIN standard based on the IIWH results in about six months as part of the DIN working group.

A key success factor in this respect was the model of fully self-financing all project costs. It enables the areas of focus to be decided and set completely independently in an annual cycle. This agility ensures that the entire project is closely aligned to requirements. The continuous addition of new partners who enrich the range of expertise is also a favourable development.

This confirms the great importance of automating the entire wire harness value chain for the industry as well as the successful functioning of the precompetitive collaboration on disruptive innovations in ARENA2036. The Innovation Initiative Wire Harness can continue to rely on this support.

Contents

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1 Partner viewpoints

IIWH partners in phase 2.1

APTIV	BMW GROUP	BOSCH
Coroplast group	DRÄXLMAIER	GG
komax	KOSTAL	KROSCHU KROMBERG & SCHUBERT
KUKA	Mercedes-Benz	Nexans autoelectric
Rosenberger	SCHÄFER	Schleuniger
schunk	SIEMENS	

Viewpoints BMW

Peter Doubek

Head of Wire Harness

BMW Group

The Innovation Initiative Wire Harness is advancing the automation of the wire harness, which will profoundly change the wire harness industry. This is a huge task that can only be successfully tackled with numerous partners across all stages of the value chain and through continuity in the development of solutions.

Phase 2.1 with the results in the various sub-projects and fields of activity ranging from design rules through to concepts, processes and quality as well as digital continuity shows the ongoing commitment of all participants in this field of innovation.

The automated production of wire harnesses has been discussed for many years but has never gained any meaningful traction. An important enabler for future development in this direction is an industry-wide standard that defines all the relevant parameters. In Phase 2.1, the results of the IIWH project to date were reviewed and established as a standard in DIN 72036. The publication for public commentary took place as part of VDA AK51 and was received with great interest. This is a fantastic success for the project and all involved.

Phase 2.2 will add further topics and sub-projects concerning production and logistics processes as well as sustainability. We will continue to advance the technical content and make additions to the standard.

Viewpoints Bosch

Dr Thomas Kaiser

Director Engineering Area Connectors, Powertrain Solutions, Business Unit Components and Connector

Robert Bosch GmbH

The overarching trend in E/E architecture with the switch from domain to zone architecture has continued to gather momentum through the progressive electrification of the drive train as well as other factors, such as autonomous driving in all its facets and development stages. The increasing complexity in the wire harness and the greater demands on durability and functional safety require a reconceptualisation of the previously largely manual production towards fully-automatic production in the final stage. Closer collaboration between OEMs, control unit and component manufacturers as well as manufacturers of plug connectors and assemblers is a fundamental requirement in this respect. From an organisational perspective, many participants in the value chain have already prepared themselves for this, and the Innovation Initiative Wire Harness in ARENA2036 offers an ideal platform for precompetitive collaboration.

In various sub-projects, phase 2.1 made important progress in reducing the complexity in the wire harness, the digital description and its automated production. In a first stage, the results will be integrated into DIN 72036 to make them available to the entire industry. The described standardisations mark an important first step towards harmonisation, which is necessary for automation. The approaches identified following rounds of intense discussions continue to enable technical differentiation in the competition between component manufacturers, which the OEMs consider to be an essential requirement to continue to allow competitive and innovative products to be purchased in future.

In phase 2.2, it is important to expand the standardisation activities in order to consider the high-current applications in the electric drive train and also involve automotive Ethernet, which will become increasingly important in the wire harness together with the classic bus systems. Bosch will continue to contribute its expertise in the layout of electrical interfaces to components and control units as well as its know-how in plug connectors.

Viewpoints Coroplast

Jens Kaufmann

Global Head of Sales

Coroplast Fritz Müller GmbH & Co. KG

The automotive industry and, in particular, the wire harness industry, are a key focus of the Coroplast Group's three business units Coroplast Tape, WeWire and Coroflex. Coroplast largely operates as a tier 2 with its cable and wire components as well as wire harness tapes. The WeWire business unit develops and produces specific wire harnesses as tier 1 or even as tier 2. As the Coroplast Group has been successfully implementing automation solutions in various business units for many years, we decided to share our experience in the area of component and wire harness production in the IIWH.

In phase 2.1 of the IIWH, the focus was on developing design rules as well as formulating the new DIN 72036 standard for automated wire harness production. We, too, consider the associated reduction in complexity to be a necessary condition to successfully implement automation solutions. While the topics of automation, digitisation and sustainability are key issues for the IIWH, the aim will also be to keep all the other functionality and safety requirements for wire harnesses in mind and ensure their continued development.

We believe that our extensive experience places us in a good position in this respect, and we look forward to working on joint concepts and practical solutions together with the other partners within the IIWH. The coordination and documentation of the results by the Project Office is highly professional and focussed.

Viewpoints Dräxlmaier

Dr rer. nat. Karsten Rüter

Concept Design Harness Systems

DEE Dräxlmaier Elektrik- und Elektroniksysteme GmbH

The automation project in wire harness production has a direct impact on assemblers, as they are the ones that implement the automation in their plant. The success of this project will depend on its technical feasibility as well as the economic viability. In relation to both aspects of success, assembler must rely on the cooperation of the OEMs, the component manufacturers and the machine manufacturers.

The constantly increasing level of electrification in vehicles due to new or enhanced safety and comfort functions increases the demands on the central power and data distribution systems. These thus become the complexity drivers for the physical on-board electrical system. Any further increase in electrical functions while maintaining the same installation space also requires further miniaturisation, especially of the plug connectors. With manual production, both can only be achieved – if at all – with considerable additional effort. Increasing the degree of automation in the production of vehicle electrical systems is therefore a key factor in meeting these increasing requirements.

The targeted automation is made more difficult, or better put, impeded by the enormous number of different individual components that make up a wire harness these days, without the ability to process these wire harnesses with a standard toolset. It is therefore essential to reduce this high variance and to standardise components and/or tools and processes as much as possible. Only then can the technical and economic objective of automation in wire harness production be viably implemented.

All parties must work together to prepare the wire harness product and the associated production processes for efficient automation.

The IIWH provides a platform to drive this precompetitive standardisation of both physical products and virtual product descriptions and to define an industry standard. This creates investment security in automation technology for all those involved along the value chain, while still leaving enough scope to offer individual on the market that have been optimised relative to the standard. It also lays an important foundation for the automated – and thus cost-efficient and high-precision – production of wire harnesses.

Viewpoints
Gebauer & Griller

Dr Holger Fastabend

Managing Director (CSO/CTO)

Gebauer & Griller Kabelwerke Gesellschaft m.b.H.

The new vehicle generations require new and innovative solutions for the wire harness, in particular to guarantee high vehicle performance with the lowest possible weight and space requirements as well as low system costs. This demands new ideas and a high level of creativity in research and product development.

At the same time, the technical requirements (functional safety, technical cleanliness, etc.) and the strained situation on the labour market (staff shortage) require gradual automation in the process design and industrialisation. But the level of automation achieved is not only critical for a company's competitiveness, it is also increasingly playing a role in the freedom to consider various locations. This enables the optimisation of the industrial and carbon footprint.

In light of this, it is absolutely fundamental that the design be oriented around the criteria of a high automation level. This is where IIWH comes in, by developing a valuable foundation of design rules for all the elements of the wire harness. This was impressively evidenced by the first draft standard.

The companies along the value chain most assuredly already all work with design rules but can only ever have a limited influence on specific subareas, such as the number and design of the components, the interconnection, the level of interlinking, the integration and the structure of the wire harness. But as these play an important role in determining the possible degree of automation, individual companies often reach their limits in terms of 'design to manufacturing'.

The work results of the IIWH are gradually creating greater freedom for achieving the automation objectives and have also fostered a good culture of information exchange for quick problem-solving even when faced with controversial goals.

Digitisation will play a fundamental role in future implementation. This is another area in which the IIWH, as part of the 'Continuous digitisation' core project, has taken valuable steps forward to create the necessary conditions in all phases of development through to assembly.

The IIWH has constantly grown and been enriched with the addition of further partners, which enables other perspectives and expertise to be taken into account. We look forward to the next phase of the IIWH and to jointly shaping the future of the automation of wire harness production.

Viewpoints Komax

Beat Wicki

Vice President Automotive

Komax AG

The physical on-board electrical system carries out a key role within the vehicle. However, the previous strategy of manual production in countries with low labour costs is coming ever closer to its inevitable limits. A higher level of automation is vital in order to ensure reliable cable production and stable supply chains.

We regard the IIWH as a central platform for precompetitive cooperation between important representatives of the industry in the sub-projects and for joint discussion of various solution pathways. This is particularly important because frameworks have already been defined during the vehicle concept development phase, which have a direct impact on wire harness production.

Thus, when locating control units or selecting wire harness components, unexpected challenges may arise for subsequent automation.

Our cooperation in the IIWH has so far been very productive. The broad partner base allows expertise from all stages of the value chain to be combined. In our view, this integrated approach is essential in order to make significant progress towards automation of the wire harness. It is therefore desirable that other partners actively participate so that we can find viable solutions that are recognised throughout the industry.

Komax is committed to continuing in its role as a strong and reliable partner in the IIWH by contributing our extensive expertise from all group companies.

Viewpoints KOSTAL

Dr rer. nat. Jens Haun

Director Pre-Development

KOSTAL Kontakt Systeme GmbH

Plug connectors are central components of a wire harness. They represent the connection between the E/E components of the physical on-board electrical system and the cables. The demands being made on plug connector systems have increased steadily in recent years. Reduced installation space, higher power transmission as well as maximum reliability at reduced costs are just a few obvious goals. The requirements of the plug connectors are directly linked to the changing demands of the physical on-board electrical system. The sometimes revolutionary changes being made to the vehicle architecture, novel drive systems, digitisation and the desire for autonomous driving have fundamentally changed the on-board electrical system architecture and thus also the wire harness.

Conventional wire harness production in low-cost countries is reaching its limits. Political uncertainties, personnel fluctuations, high logistical costs and thus low sustainability require a higher degree of automation in wire harness production, which is making it feasible to bring production back closer to the OEM production sites again.

To be able to meet current and future requirements, a higher, more consistent level of automation in processing must be a central element in wire harness production. Plug connector production is already automated to a certain extent. And crimping processes are almost fully automated these days. With new plug connector systems, however, it is important to ensure good automation capability, high reliability and also the possibility of direct process testing during production.

To enable continued innovation, it is necessary to set standards and define industry-wide design rules. This will enable all process partners in the value chain to achieve a higher level of automation, which can then be realised by different automated machine manufacturers thanks to the clearly defined standards. KOSTAL Kontakt Systeme has extensive experience working with various automated machine manufacturers. Together with all our interdisciplinary partners within the IIWH project, we hope to define and standardise holistic design rules for future plug connector systems.

This is a challenge that can only be tackled by working together. We are happy to lend our support and would also like to encourage new partners to join this medium- to long-term goal.

Viewpoints Kromberg & Schubert

Dr Wolfgang Langhoff

Chief Development Officer

Kromberg & Schubert GmbH & Co. KG

The fundamental challenges for developing and producing on-board electrical systems were described in the mission for phase 1. Based on the (intermediate) results achieved on standardisation, it is worthwhile taking another close look at the basic production conditions in the precompetitive context. This means examining the installation of the wire harness in the vehicle, the necessary features of the on-board electrical system and their optimal implementation, etc.

It makes sense to analyse these steps across the entire value chain and to distinguish between necessary and optional attributes. The line between physical manifestation and digital image is becoming increasingly blurred, and the actual product can be created at short notice via simulation and digital assembly tests.

The topology and structure of the cable harness are currently receiving great attention in the industry. But it is also important to consider how the cable harness is actually built and the production steps involved. The use of flexible robotics allows the production sequences to be broken down. These days, several possible solutions can be selected for joining the contacts in the plug connector casings, but manual work still dominates the actual installation and bundling of the cables.

Significant potential exists in this area. It seems that only by unlocking this potential will it be possible to once again bring production closer to the OEM plants, as the remaining manual activities will then no longer dominate the selection of an appropriate production site.

Viewpoints KUKA

Christoph Hock

Business Development Manager

KUKA Systems GmbH

Automation in general, and robot-based automation in particular, is our focus in the IIWH. From a current perspective, we can still see a large number of manual processes along the 'on-board electrical system' or cable harness value chain. And this is entirely logical in view of the technical requirements. Only the dexterity of a worker can currently meet these requirements. The handling of flexible parts can essentially be managed in controlled channels and so be automated. But cable harnesses in the automotive sector have an almost infinite variety:

- Different lengths
- Different stiffnesses
- Different plugs (etc.)

The number and variations of these product requirements are virtually limitless. The need for an integrated approach to overcome the problem becomes clear, at the latest, in combination with the external framework conditions – which are specific to every car body.

The IIWH allows us to address and discuss these issues as well as develop outlines for solutions. This is effectively the only configuration in which it is possible to effect real product simplification. And this does not just involve simplified automation. Beyond the 'obvious' topics, we can also see an opportunity to put our own digitisation topics directly to the test. Besides the automation of wire harness assembly, we consider the exchange with assemblers to be extremely valuable. The earlier in the process that an automation-compatible product design occurs, the greater the chances of success in the actual installation.

Viewpoints Mercedes-Benz

Dr Rainer König

Senior Manager Wire Harness and DMU

Mercedes-Benz AG

After two extremely successful phases, the Innovation Initiative Wire Harness has arrived at its third year and has become a firm presence in the wire harness industry. The acceptance as a competent precompetitive driver for automation and standardisation is reflected in the constantly growing network of partners involved in the IIWH.

Experts from partners at all stages of the value chain have transformed the vision of the automated production of wire harnesses into specific premises and rules to be established as a generally available standard. The publication of this standard represents a milestone on the path towards the broader automation of the production of wire harnesses in the automotive industry.

This paradigm shift in production can only be brought to a successful conclusion if the necessary accompanying processes are also upgraded. The automated production of wire harnesses requires the continuous digitisation of the process chain and appropriate data models. The IIWH has already tackled these topics and will now flesh these out in phase 2.2.

The positive response from the industry shows how important it was to launch the IIWH and how important it is to ensure that it is consistently advanced.

This reaffirms our decision to head down the path towards automation, and we look forward to continuing our collaboration to drive this transformation forward as a member and partner of ARENA2036 and, in particular, the IIWH.

Viewpoints Nexans

Claudius Grüner

Head of Product Development

Nexans autoelectric GmbH

Improvements in the safe and cost-effective production of future on-board electrical systems is unthinkable without automation and digitisation in all of the important process steps – along with all the associated issues, such as standardisation, modularisation and reducing the variety of parts and components. This is the only way to combine the sometimes contradictory requirements, such as process reliability and miniaturisation, a high level of flexibility and automation, complexity and short process times.

Nexans autoelectric began semi-automated production of motor wire harnesses back in 2010 and developed the necessary processes for a safe and economical manufacturing process in pilot projects together with machine manufacturers and parts suppliers. We have consistently pursued this path for many years. The successful automated production of wire harnesses, especially under the aspect of increasing complexity and safety requirements, strongly depends on the quality of the preceding and accompanying process steps. While we have always worked on the modularisation and optimisation of designs for automated machines as well as reducing the variance of parts and wires, we have been intensifying the automation of our engineering and logistics process for several years using in-house software solutions plus individually adapted and customised applications. Strict design rules as well as the goal of reducing the complexity of component and cable diversity play a significant role. Bearing in mind our aim of reducing end-of-line testing to a minimum, the selection of robust components and processes as well as consistent process documentation are coming into ever sharper focus.

The IIWH's orientation in ARENA2036 spans the respective submodules, takes the aforementioned requirements into account and focusses on the key drivers of reduced complexity, variance, digitisation, assembly and process to achieve maximum automation.

Important objectives, such as describing the necessary design rules, producing digital product description and defining the necessary standardisation across all sub-projects, have already been achieved by the end of phase 2.1.

A first draft for translating this content into a DIN standard clearly shows the significant progress of many submodules as well as the cross-sectoral nature of the standardisation.

Viewpoints Rosenberger

Martin Zebhauser

Vice President Product Management & Design Business Area Automotive

Rosenberger Hochfrequenztechnik GmbH & Co. KG

Working together to shape the future of the on-board electrical system.

The ‘Innovation Initiative Wire Harness’ (IIWH) provides a framework for close collaboration between automobile manufacturers and companies across the entire supply chain for wire harnesses in vehicles. The initiative has succeeded in bringing together expertise, fostering creative and constructive discussions and compiling a DIN draft standard as a first step. This is expected to form the global foundation for an automatable on-board electrical system.

Creating a model to analyse the automation capability of wire harness components established a reference that can be used as a benchmark for early evaluation by component manufacturers as well as upstream and downstream companies along the value chain.

Working groups discuss innovative approaches and possibilities, which are then planned in the form of prototypes. The working groups allow all experts to contribute ideas, bundle their strengths and identify potential risks in advance. This makes the topics tangible and measurable. As a next step, the insights could be applied to future developments in the form of globally available standardisation.

The requirements for flexible, innovative as well as local and highly-automated production in the various automobile production regions are increasing. Taking such an approach allows risks in the supply chain to be reduced and quality to be increased even further. With this goal in mind, partners are involved in an intensive exchange of ideas in order to develop standardised and modular solutions.

At Rosenberger, we are pleased to be part of the team and to be able to contribute our expertise in the field of highly-automated data and high-voltage connectors in production and assembly.

Viewpoints Schleuniger

Martin Stier

Head of Business Development

Schleuniger GmbH

The electrified, self-driving and interconnected car of the future requires a change in the on-board electrical system. Manufacturers of these complex, highly flexible, sequential and largely manually manufactured products are faced with new requirements by the OEMs: the on-board electrical system is becoming a safety-critical and quality-driven, strategic purchased part.

On-board electrical systems have become the balancing element of the ‘electrical/electronic architecture’. Once the production of control units or other electronics starts, changes can usually only be made in the on-board electrical system. As long as this dependency remains and carry-over parts play a major role in the design, the current production processes will continue to dominate. De facto around 80 percent of all work steps for on-board electrical system production are still being performed manually. But C.A.S.E. and the associated rise in requirements on the overall wire harness plus the increasing complexity and the new requirements for traceability no longer permit any scaling of the current production methods without major changes. In future, the architecture and the component diversity and design will have to follow the automation requirements of the tier 1 suppliers and machine manufacturers. Processes that are individually aligned to the fit-out of the vehicle can rarely be efficiently automated. For instance, clips, cable ducts, taping, protective hoses, braided tubing and similar components have the lowest level of automation. The design rules for automation developed as part of the collaboration can change this. The focus is shifting to the digitisation of production (‘track & trace’). This requires a consistent interlinking of the production systems across all the current production steps, which will extend across the phases of the development and production of the on-board electrical system as well as the OEM installation.

The IIWH offers a unique global opportunity for precompetitive collaboration, and Schleuniger is pleased to do its part as a technology and system supplier since the company is already supporting its customers with cable processing, testing equipment and software solutions across large sections of the value creation and production processes.

Viewpoints Schunk Sonosystems

Udo Wagenbach

Head of Sales – Terminal Applications & Tube Sealers, authorised signatory

Schunk Sonosystems GmbH

Sebastian Rühl

Head of Development

Schunk Sonosystems GmbH

The automation of the wire harness is an extremely relevant topic in the industry. Various working groups have already made a number of attempts in this respect in the past. But this has so far resulted in, at best, partially-automated solutions. The IIWH intends to comprehensively tackle this task: it will examine the entire production chain, and the entire process will be automated to the greatest possible extent. As has already been demonstrated, this is an ambitious project.

Flexible parts with their undefined states and a variety of individual components that need to be attached across the entire vehicle are just some of the challenges faced on the path towards wire harness automation. In addition, the developed solutions must be viable from a structural perspective – no mean feat, given the declining size of the installation spaces in the vehicle and the aspect of the weight optimisation. On the other hand, efficiency of implementation must also be taken into account.

The IIWH brings together a range of stakeholders from different fields with a full spectrum of knowledge, viewpoints and expertise in a single project with the goal of finding end-to-end solutions for the entire chain. The automation of individual segments is a realistic possibility in the short-term, while comprehensive automation is expected in the medium- to longer-term. As a specialist in system solutions for ultrasonic metal welding in wire harness production, Schunk Sonosystems intends to actively support and shape the continued development of the wire harness and also contribute its experience from current wire harness production to the project.

Viewpoints Siemens

Michael Richter

Market Development Director – IES

Siemens Electronic Design Automation GmbH

The industry is facing enormous change. Trend researchers believe that digital transformation may lead to the biggest change in 100 years.

The continuous digitisation of the value chain and the representation of the physical product along the value chain using a comprehensive digital twin (including all sub-products) presents an enormous challenge. Silos within companies and secure inter-company data transfer to cover the entire chain are additional challenges to be overcome.

If you look at the history of the development of on-board electrical systems and their largely manual production, you will see that there have been very few really ground-breaking innovations in the overall process chain in recent years.

The joint activities in ARENA2036 and the IIWH surrounding standardisation of the requirements for automating wire harness production reflect great interest in this topic by a relevant group of companies operating in the field of on-board electrical system development. This trend towards a reduction of the manual activities, large-scale automation and the associated need for complete and traceable data gives further impetus to this transformation.

The rapidly rising complexity of the products, new requirements for completeness, traceability, digital change management, data-driven release processes as well as validation and verification opportunities established by these efforts to increase automation mean that the use of model based systems engineering (MBSE) approaches and the corresponding software tools will be critical for implementing this transformation.

In particular, the inherent ability of such approaches to reproducibly create the data required along the value chain through synthesis rather than manual activities makes them the perfect complement to digital transformation processes.

At Siemens, we are looking forward to contributing our expertise and products to actively support this transformation of the on-board electrical system industry and continuing to advance the constructive work together with the ARENA2036 partners.

2 The ARENA2036 Innovation Initiative Wire Harness

2.1 An overview of the Innovation Initiative Wire Harness

The Innovation Initiative Wire Harness is a joint push by automobile manufacturers, assemblers, component manufacturers as well as machine manufacturers and toolmakers towards automation across the entire value chain. At its core, the partners are focussed on working together to address the general automation challenges in a precompetitive framework. The spectrum is diverse. In addition to automation-optimised design, it also includes:

- Approaches for automated module manufacturing
- Measures of the optimised automation of components
- Automation of inline quality control
- Concepts for automating the wire harness production itself
- Feasibility studies for automated installation in the car body

Added to all this is the digital description of the wire harness components.

At the time the IIWH was established in July 2019, 11 partners initially came together to work on these topics. One year later, this had increased to 13 partners, and now – at the end of the second year – 16 partners are advancing these topics. The challenges are not new. Numerous contributions at the Ludwigsburg Automotive Wire Harness Conference over several years have shown what companies in the industry are working on and what successes they have achieved. These efforts also make clear that key challenges in the switch from largely manual production to an automated production paradigm can only be overcome together.

The initial spark behind the IIWH was the Automotive Wire Harness Conference held in March 2019. The programme committee came up with the idea to join forces to pave the way towards automation. From the very beginning, it was made clear that this would involve open and transparent collaboration on a precompetitive basis. ARENA2036 provided a neutral innovation platform, and it took just 3 months to move from initial contact to the requirements analysis and then launching of the IIWH with 8 sub-projects at the time.

Today, this summary provides a report on the IIWH's results from its second year. This clearly shows that the IIWH is addressing a fundamental need for transformation of one of the most expensive components of a car. It would have been hard to imagine more difficult conditions to those under which the partners planned and decided to continue the project in April and May 2019. The fact that the Innovation Initiative Wire Harness remained on track – not to mention the addition of further partners – reflects the relevance of the initiative as well as the effectiveness and efficiency of the collaboration. The Project Office would like to extend a big thank you for this commitment by the partners!

This publication gives the IIWH partners a chance to share an overview of their work to date. The majority of the results are flowing into the draft DIN standard 72036, which the IIWH partners are working on together with other industry representatives. This standard represents a milestone that establishes a basis for a key automation requirement: the reusability of the investments of all stakeholders in the value chain across multiple orders.

The IIWH remains open to new partners who are prepared to get involved and provide their own ideas and contribute to the success of this major transformation task.

2.2 IIWH roadmap and collaboration

The development of the Innovation Initiative Wire Harness follows the logic that the requirements analysis (phase 0) and conceptual planning (phase 1 – see website for results) are now followed by the implementation (phase 2). The implementation phase itself is comprised of several annual tranches, resulting in the use of the terminology ‘phase 2.1’, ‘phase 2.2’, etc. The following figure shows the course of the IIWH to date and highlights the period covered by this report:

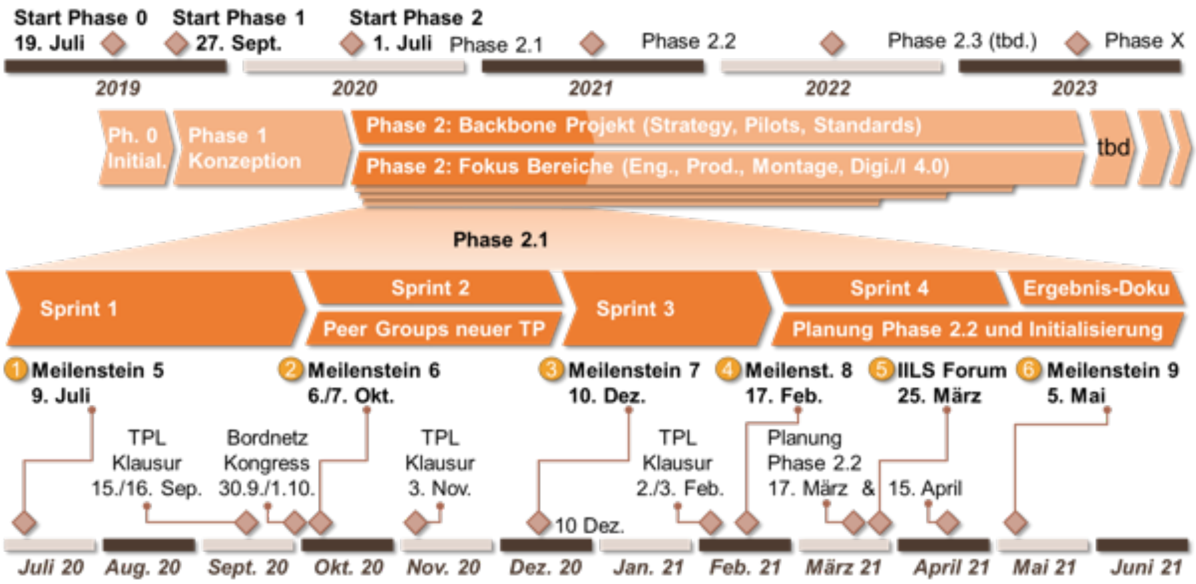


Figure 1: Roadmap of the Innovation Initiative Wire Harness

The roadmap shows the backbone of the Innovation Initiative Wire Harness: The partners come together every 2 to 3 months as part of milestone meetings. These milestone meetings include management representatives and the sub-project heads. The Project Office, the sub-project heads and the appointed researchers and consultants report on the current status of their work. Together with the management representatives, they reflect on the progress made and set priorities for the next steps.

Periods of 2 to 3 months have proven to be a good rhythm for the overall project work. The evaluation sessions of the sub-project heads also provide the opportunity to coordinate general content in greater detail at a technical level and coordinate the work processes. The evaluation session meetings are supplemented by one-hour coordination sessions every 3 weeks. What’s more, the planning for the next annual phase took place at the same time as the last sprint. The plans of the sub-projects enter into this planning, while new topics that were developed as a priority during phase 2.1 are also addressed.

This content planning for the next phase 2.2 is based on a budget that is defined by the partners. Every partner bears an equal share of the costs of the Innovation Initiative Wire Harness; these funds primarily finance the Project Office, scientific support as well as consultants. This simple and flexible governance model is possible because the Innovation Initiative Wire Harness operates without public funding. The initiative is operated by ARENA2036, and its structure is particularly suited to integrating new partners quickly. The legal basis comprises the

ARENA2036 Articles of Association, the IIWH Antitrust Law Guidelines and the IIWH Cooperation Agreement, which has been signed by all partners and to which new partners accede.

2.3 The course of phase 2.1

The start of phase 2 marked the first step in a multi-year implementation of the preliminary conceptual work from phase 1. How long this implementation will take is not certain. Hence the breakdown into phase 2.1, 2.2, etc. One thing is clear: the implementation will require considerable perseverance. And it is also clear that the path will continue to take shape as we travel along it. New possibilities, new priorities and adjustments shaped the path in phase 1. At the start of phase 2.1, a range of structural adjustments were made that were identified at the end of phase 1.

Overall, the Innovation Initiative Wire Harness was structured based on four focus topics: development, production and assembly of wire harnesses plus continuous digitisation. The sub-projects were organised around these focus topics. The focus of phase 1 in the area of development was subsequently balanced with increased activities in the other focus areas.

The following sub-projects were realigned and renamed by their managers:

- The ‘Wire harness component library’ sub-project was renamed ‘**Digital product description**’ to emphasize the effort to determine the necessary data requirements that are derived from the design rules.
- The ‘Wire harness architecture of the future’ sub-project was renamed ‘**Wire harness concepts**’ to establish the foundation for greater freedom in the development of the conceptual foundations.
- The ‘Establishment of a quality seal for wire harness components optimised for automated machines’ sub-project was renamed ‘**Automation index**’, which refers to an index that tracks how well components are optimised for automation.
- The ‘Reasons for automation’ sub-project has successfully completed its work and presented the motivating factors for the automation of the entire value chain in a comprehensive outcome document. This brochure is also freely available on the website.[1]

The following sub-projects were prepared during the course of phase 2.1:

- Production equipment and processes for automating wire harness production: This delves into the fundamental concepts for automation of production by the assembler.
- Automation of indirect processes: This focuses on packaging and logistics as well as all other handling requirements between the assembler and the OEM’s assembly line.
- End-to-end digital process chain and continuous digitisation of change management

Preparation as a separate sub-project initially took place as a peer group: During this preparatory phase, the focus was on specifying the topics and translating these into a work plan. The peer groups were staffed by interested partner representatives who had a direct stake in the respective topic. All three peer groups were able to specify their topic to such an extent that a decision was made to convert these peer groups to sub-projects as part of milestones 8 and

[1] See: www.arena2036.de/iils

9. The ‘Digitisation’ sub-project commenced its activities immediately after the milestone 9 meeting. The associated report is therefore included in the following presentation of results. The ‘Production’ and ‘Logistics’ sub-projects will commence at the start of phase 2.2.

Another adjustment at the start of phase 2.1 was the effort to bundle and systematically interlink the results of the sub-projects. In this respect, the design rules in particular demonstrated their role as an integrative link. As a result, the design rules also serve as a linchpin in the DIN standard. The physical demonstration vehicle will also play an integrative role across several sub-projects; however, its construction had to be postponed to phase 2.2 due to the pandemic. Digitisation may potentially also play this kind of role in future and will be looked at in greater detail in phase 2.2.

This leads to the overall challenge of aggregating various partial results. While the apparent connections between the individual results may still differ, the objective is to continue to establish interconnections and, in particular, to adjust the individual results to establish a mutual fit.

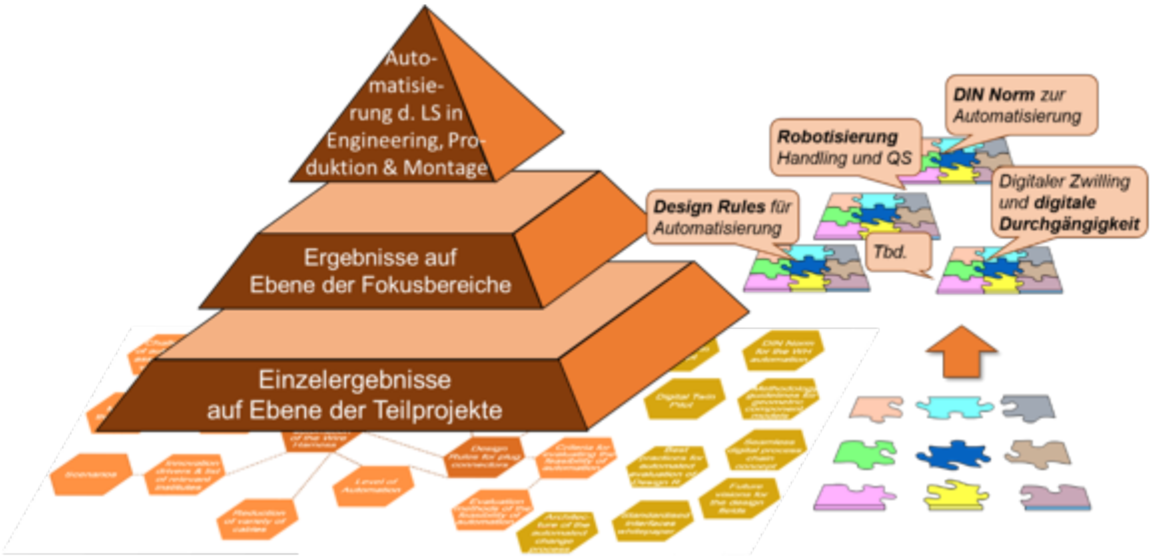


Figure 2: Results portfolio of phase 2.1

This figure shows that individual results at the level of the sub-projects are bundled at the level of the focus topics so that the overarching automation objective is based on several foundations that are laid by the contributions of various sub-projects.

Another flanking measure, whose beginnings extend back to phase 1, was the derivation of overarching scenarios by the Institute of Human Factors and Technology Management at the University of Stuttgart. The objective was to develop target visions for the focus areas based on a methodical scenario management approach for deriving macro- and micro-scenarios that, in turn, supplied the basis for a comprehensive identification of innovation drivers. The results were presented to the partners in extensive documents in the spring of 2021. The following figure shows a layer model of the innovation drivers:

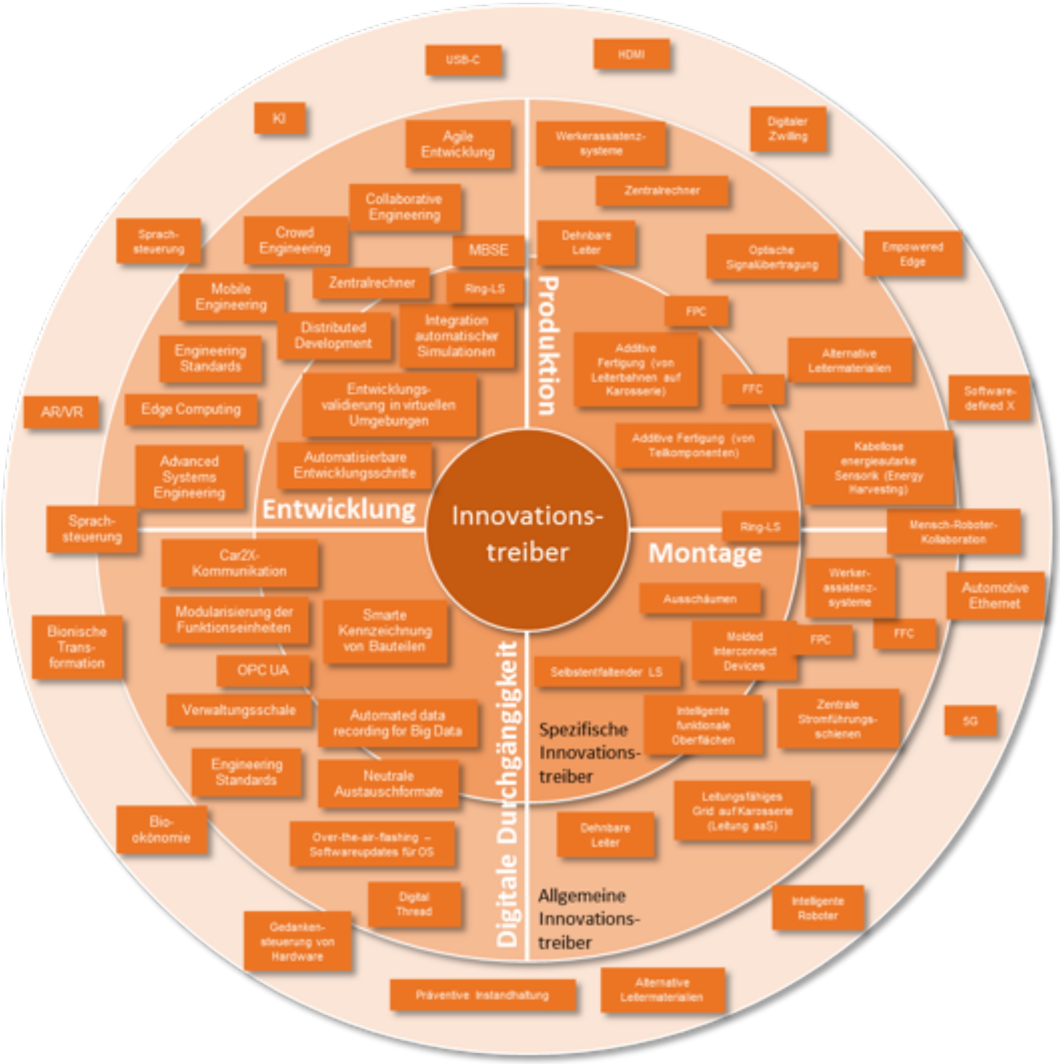


Figure 3: Innovation drivers (source: IAT)

The innovation drivers represent a map in the broadest sense, whose layers are arranged by direct and indirect reference to the wire harness. In particular, the list of direct innovation drivers could be expanded significantly, but the list was not intended to be exhaustive. Nevertheless, both the process of collaboration between partner experts and the results themselves provided inspiration that each of the partners assessed differently.

Additional motivation was generated from the collaboration with the Institute for Control Engineering of Machine Tools and Manufacturing Units (ISW) at the University of Stuttgart. In this case, approaches for using optics and sensors to support the robotic handling of flexible parts were trialled. A potential analysis laid the foundation for a more extensive feasibility study, which is being successfully advanced together with Kuka. This work is taking place as part of sub-project 8.

At the start of phase 2.1, the federal government launched an economic package, with part 35c intended to benefit the automotive industry. The associated funding measure, with a particular focus on value chains in the automotive supply industry, opened up additional development possibilities for the Innovation Initiative Wire Harness. As part of the milestone 8 meeting held on 17 February 2021, the Federal Ministry for Economic Affairs and Energy

(BMWi) 'Kopa35c' programme[2] was personally presented to the IIWH partners by the head of the responsible 'Digitalisation, Industry 4.0' department, Mr Stöckl-Pukall. Following this presentation, the 'digitisation' peer group established a task force that developed a project outline for this funding initiative in March 2021. And with success: the project outline received a positive evaluation, and the task force was invited to submit a full proposal.

Although the final funding approval is still pending, the result of phase 2.1 makes it clear that the Innovation Initiative Wire Harness has the means to establish itself in the long-term. Despite all the fears, the commitment by the partners has held firm even under extremely difficult conditions. The results are impressive.

The IIWH partners are publishing this results report in an effort to openly and transparently present the findings and results of phase 2.1. It is therefore an important element of the transfer of results by the IIWH. Additional elements are contained in the report by the IIWH partners presented at the Automotive Wire Harness Conference in Ludwigsburg. This was held on 30 September 2020 and was the first major public appearance in the wire harness industry. The next transfer milestone was the IIWH Forum on 25 March 2021. This one-day virtual event organised by the IIWH received a great response with over 80 participants. It was a fantastic opportunity to find out more about the activities and results of the sub-projects and enter into discussion with the sub-project heads.

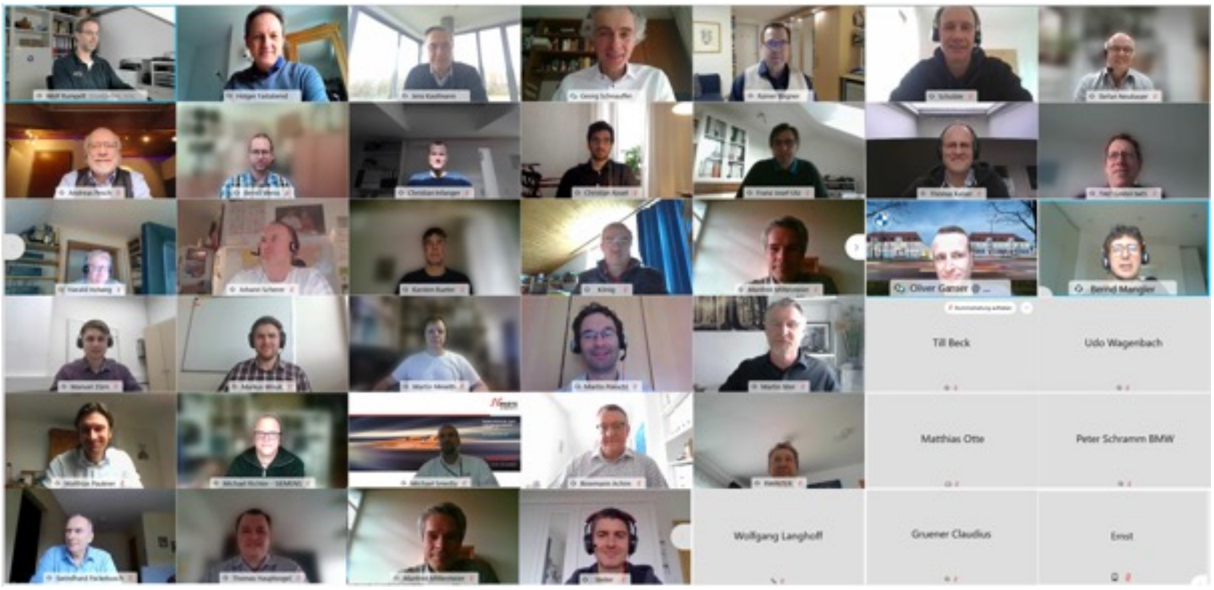


Figure 4:Milestone meetings in the era of coronavirus, here: Milestone 8 meeting on 17 February 2021

[2] See: www.kopa35c.de

3 IIWH sub-projects

3.1 Overview of the sub-projects

The foundation for establishing the sub-projects was laid in 2019 with the definition of the topics relevant for automation of the wire harness from the perspective of the companies and based on a requirements analysis. Of the numerous influencing factors, eight core topics were identified, which then led to the establishment of sub-projects in November 2019.

Sub-project heads were appointed from the ranks of the partners for each sub-project, who were responsible for managing the partners involved in the project. The start of the sub-projects also marked the beginning of 'Phase 1' of the IIWH. The purpose of this was to further specify the most urgent challenges facing the industry with regard to the automation of the wire harness and to lay the foundation for phase 2.

In the subsequent 'Phase 2.1', starting in July 2020, more extensive work on content was tackled with the overriding aim of creating standards that can lead to standardisation.

After the sub-project teams were formed in phase 1 and it was clear that they were pursuing the topics with a great deal of motivation and commitment, at the start of phase 2.1, the IIWH compared the topics already addressed to the backlog from the requirements analysis. This process identified additional highly relevant topics, which were set up as sub-projects during phase 2.1. SP 0 – 'DIN standard for the wire harness' was added in January 2021 and TP 11 – 'Digital twin, process chain and change management' in February 2021.

Rumpfprojekt	Strategische Ausrichtung, Normung & Standards, Gesamtdemonstrator								
Fokusprojekte		Entwicklung				Produktion	Montage	Durchgänige Digitalisierung	
Teilprojekt / Partner	0 DIN-Norm für Leitungssatz	1 Design Rules Leitungssatz	2 Design Rules Steckverbinder	3 Konzepte Leitungssatz	4 Automatisierungskennzahl	5 Automat. Qualitätsprüfung	8 Automat. Montage im Fahrzeug	10 Digitale Produktbeschreibung	11 Digitaler Zwilling, Prozesskette, Änderungsmgt.
Aptiv	x	x	x	x					
BMW	x	x	x	x	TPL	x	TPL	TPL	
Bosch	x		x	x					
Coroplast	x	x	x	x					
Dräxlmaier	x	x	x	TPL		x	x	x	x
G&G	x	x	x	x	x			x	x
Komax	x	TPL		x		Co-TPL		x	x
KOSTAL	x	x	TPL	x	x			x	
Kroschu	x	x	x	x			x		x
Kuka	x	x	x				Co-TPL		
Mercedes-Benz	x	Co-TPL	x	x	x	x	x	x	Co-TPL
Nexans	x	x		x		x		x	
Rosenberger	x		Co-TPL	x	x	x	x		
Schäfer		x				x			x
Schleuniger	x	x	x		x	x		x	x
Schunk Sonosvs.	x	x	x						
Siemens	x	x		x				Co-TPL	TPL

Figure 5: Organisational chart in phase 2.1 as of 30 June 2021

The development of content for a DIN standard was a challenge that could only be approached by setting up a separate sub-project (SP 0) staffed by standardisation experts dispatched by all partners in the Innovation Initiative Wire Harness. The partners in the Innovation Initiative Wire Harness also established a separate working group in the Automobile standardisation committee, which is focussed on VDA as well as DIN. The working group, called 'Automation of the wire harness NA 052-00-32-51 AK' was created in January 2021 and consists of 16 IIWH partners as well as 8 additional members. In addition to establishing the substantive basis, the IIWH was also responsible for managing the working group as well as project management.

This was the necessary to ensure that the ambitious timeframe could be met, with the submission of the draft standard in August 2021 to allow the publication of the DIN standard in the first half of 2022. Above all, this sub-project showed the high level of commitment and collaboration between the partners in the IIWH. The development of the draft standard for DIN 72036 within just over six months was only possible thanks to the exceptional dedication shown by the partners as well as sharing of the IIWH's preliminary work on the standard so that this could be discussed and coordinated in the respective working group. 'I have never experienced anything like it,' reported one of the experts of the external participants in the working group as several full-day meetings were sometimes held per week during June and July.

As part of the strategic refinement of the topics, the IIWH was structured by focus areas (see figure below). This includes the focus on development, production and assembly as well as continuous digitisation. Once the sub-projects had been delineated, it was possible to identify gaps and additional topics of strategic relevance to automation of the wire harness. This structuring established the basis for setting up further sub-projects to join the others.

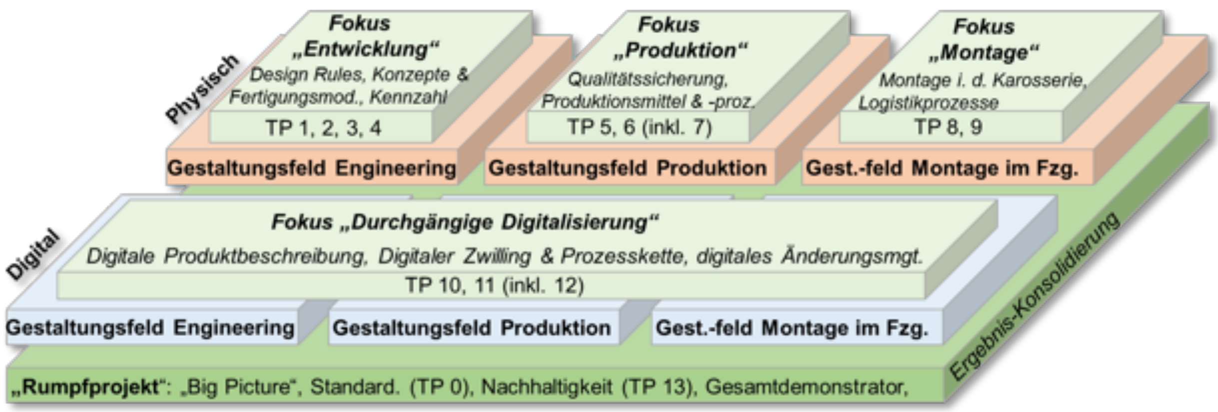


Figure 6: Classification of the sub-projects in focus areas

This chapter now provides an overview of the sub-projects in phase 2.1. The focus is not only on the motivation for the respective sub-project but also on the approach and the results developed from it.

It gives the sub-project heads who were interviewed about the objectives of their sub-projects a chance to have their say. In these discussions, they explain the background and necessities resulting from automation in more detail and point out the main stumbling blocks in the ongoing development of the topics. As this format had already been used in the results brochure in phase 1, it enables an interesting comparison of the statements from the various project phases and allows the development and direction of the activities in the sub-projects to be tracked.

It also provides an overview of the companies involved in the respective sub-projects, the timeline and the coordination meetings held within the framework of the sub-projects. These show how comprehensive discussions have taken place in all of the sub-projects, which have included very different aspects due to the participation of companies from all stages of the value chain. The following figure, which contains the work meetings of the sub-projects as well as other coordination meetings (such as the sub-project Head rule communication and networking as well as milestone meetings), provides an impression of the number of meetings and the associated intensity of the work on the topics.

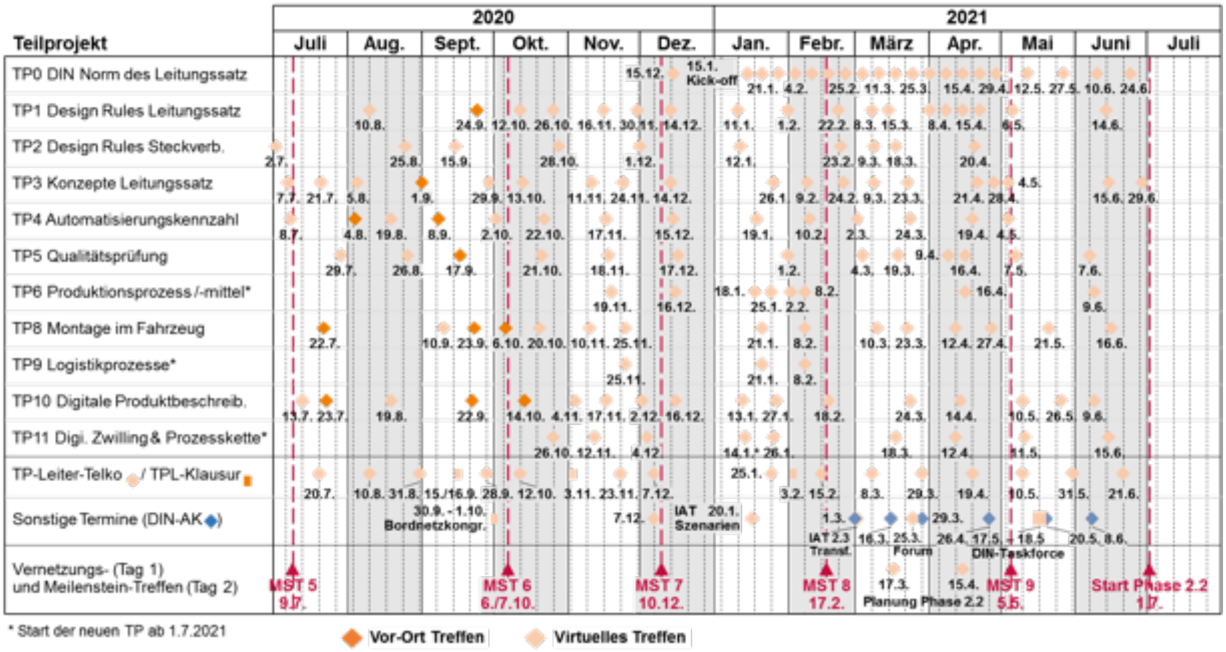
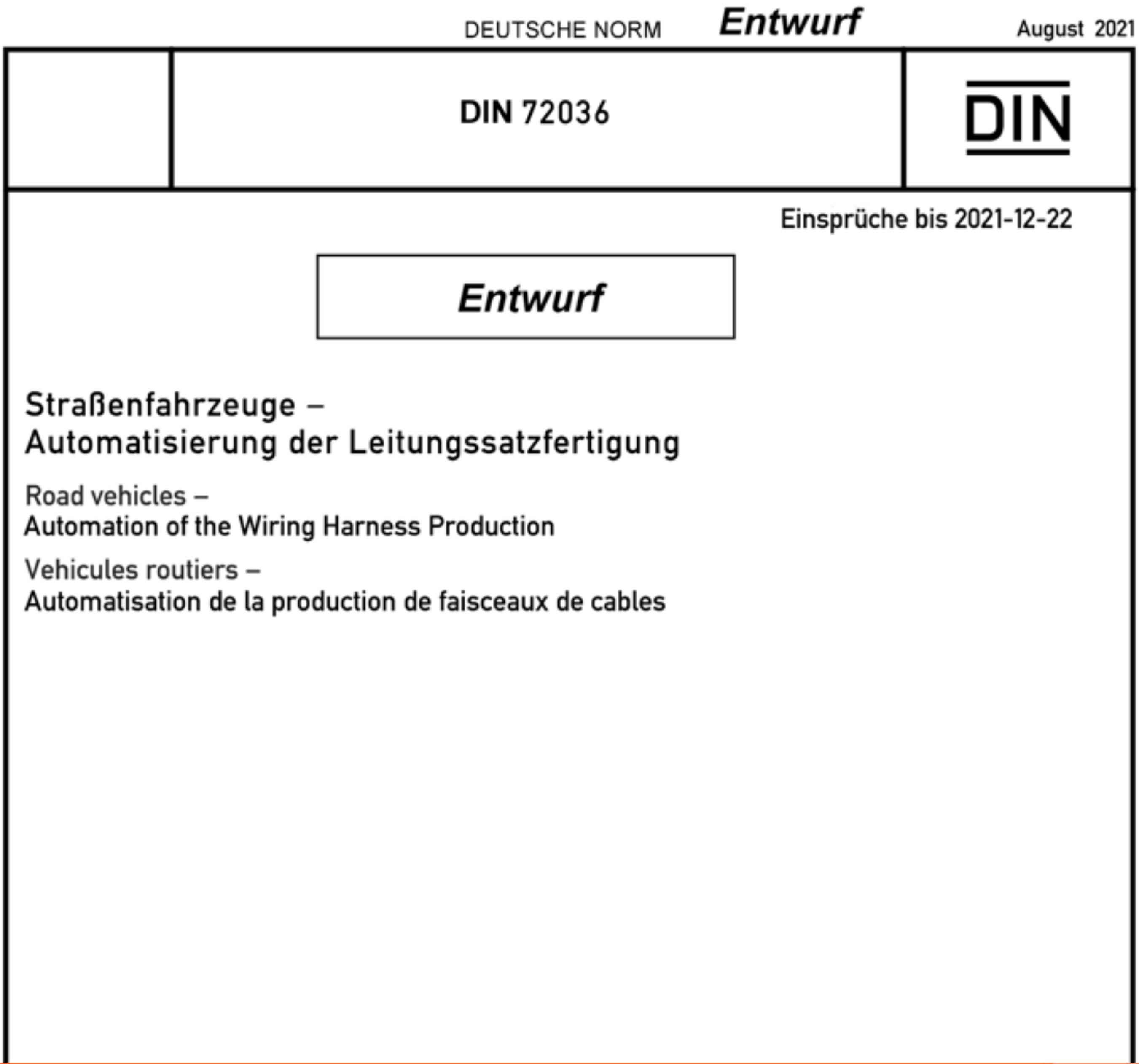


Figure 7: Meetings of the Innovation Initiative Wire Harness in phase 2.1

The descriptions of the sub-projects are rounded off by a brief preview of phase 2.2 and the resulting ongoing thematic orientation in the development of the sub-projects.



DEUTSCHE NORM **Entwurf** August 2021

DIN 72036

DIN

Einsprüche bis 2021-12-22

Entwurf

Straßenfahrzeuge –
Automatisierung der Leitungssatzfertigung

Road vehicles –
Automation of the Wiring Harness Production

Vehicules routiers –
Automatisation de la production de faisceaux de cables

Sub-project 0
DIN standard for the wire harness

3.2 Sub-project 0
DIN standard for the wire harness

3.2.1 Participants

Dr Carsten Kübler (Sub-project Head)

TWT

Peter Schramm (Joint Sub-project Head)

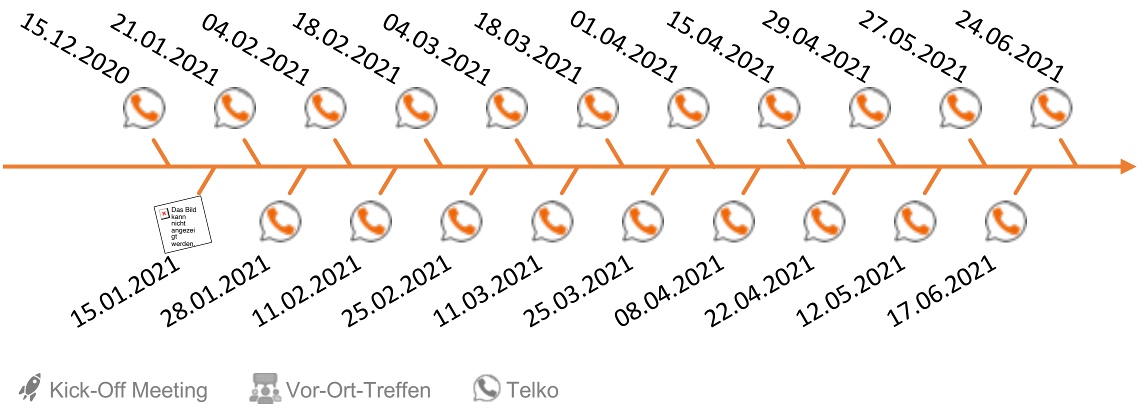
BMW

Bernd Weiß (Joint Sub-project Head)

Mercedes-Benz

Harald Holweg	**Kurt Herrmann**	**Hermann Schötz**
Aptiv	*Gebauer & Griller*	*Mercedes-Benz*
Dr Martin Pöschl	**Christian Infanger**	**Manfred Mittermeier**
BMW	*Komax*	*Rosenberger*
Stephan Fahrnbauer	**Matthias Otte**	**Martin Stier**
BMW	*Komax*	*Schleuniger*
Rainer Bogner	**Dr rer. nat. Jens Haun**	**Heiko Strobel**
BogCon	*KOSTAL*	*Schunk Sonosystems*
Andreas Vogt	**Till Beck**	**Michael Richter**
Bosch	*Kromberg & Schubert*	*Siemens*
Jens Kaufmann	**Matthias Paukner**	
Coroplast	*Kuka*	
Helmut Wichmann	**Stefan Olbrich**	
Coroplast	*Mercedes-Benz*	
Michael Wortberg	**Jerome Trommnau**	
Dräxlmaier	*Mercedes-Benz*	

3.2.2 Project timeline



3.2.3 Starting point/motivation

At the moment, specifications for the wire harness design and wire harness production are coordinated between OEMs (original equipment manufacturers) and suppliers. These can vary slightly depending on the OEM and supplier and are in line with best practices in this field, which have established themselves over time and which permit a significant amount of manual process steps. Any adjustment to these specifications was previously not subject to a centrally coordinated process able to take account of the state of the art and encourage automation. The standardisation of the requirements via a standardisation organisation such as DIN can change this.

To start off with, the requirements for the concept, design and production phase as well as the components for automation were defined. In addition, a definition of data profiles for wire harnesses aligned to the requirements enables model-based, consistent and transparent development. These data profiles address the safety and quality objectives and enable a continuous use of the data across the entire process in the IT toolchain. Standardisation of the requirements for automation-compatible wire harness production via the DIN supports an open, guided and transparent development of automation that is also subject to a process of continuous further development. All members of the IIWH had the opportunity to involve experts in the standardisation from the beginning. Moreover, any market participant can follow this development and constructively contribute to the standardisation by submitting proposals.

The constant growth in E/E components and functions in the vehicle is placing greater demands in terms of more complex quality assurance measures for the wire harness in order to achieve a consistent quality level. Moreover, the wire harness is now fulfilling new functions that ensure a high level of safety. In addition, error-free and precise traceability of the components and their creation process can only be achieved through an increase in wire harness automation. What's more, automation reduces human factors, which also encourages the production of wire harnesses close to the point where they are fitted into the vehicle.

Before launching SP0, every established SP compiled its existing preliminary work, which it believed should be included in the draft standard. This preliminary work was bundled in SP0 and proposed to the DIN for standardisation via the VDA. At the DIN, these topics were submitted to working group 51 'Automation of the wire harness' in the 'E/E components and general system requirements' segment under the 'Automotive engineering' DIN standardisation committee, and the working group was commissioned to create DIN 72036 as a project.

This working group involved experts from all the SPs and all IIWH companies as well as 8 others.

3.2.4 Objective

Sub-project 0 is focussed on bringing together the fundamentals, methods, processes and specifications developed by the sub-projects into an inherently consistent standard. One important aspect of this is to gradually standardise the complex field of automation, starting with the requirements for the concept and development phase, and also to simplify the complex wire harnesses for production. This unbundling enables automation-compatible handling and can be realised by modular component systems, among other things. The automation indices aim to enable an assessment and comparison of concepts, designs and production methods for wire harnesses.

In addition, the rules for digital interoperability will be developed in relation to the requirements for automation-compatible wire harnesses for the toolchains. The standard uses the KBL (wire harness list) and VEC (vehicle electric container) data formats as a basis and defines binding rules for implementing the requirements by applying and, where applicable, extending the data formats.

The standard currently targets developers of wire harnesses for automobiles at OEMs, the wire harness assemblers, component manufacturers and the manufacturers of automation solutions for wire harnesses. It is also hoped that the standard will provide the requisite impetus for innovation.

The aim of SP0 is to ensure an optimal compilation of the results of the IIWH SPs as complete and comprehensive proposals for the DIN working group and their presentation to the DIN working group. The appointment of Dr Kübler to manage the DIN 72036 project in the working group also enables the efficient and unbiased creation of the draft standard by all experts involved in the working group. The proposals will then be fleshed out in workshops in the working group, assessed by the various companies and, in some cases, expanded before they are finalised in the draft standard.

3.2.5 Results of project phase 2.1

Project phase 2.1 was focussed on standardising specifications to achieve the automated production of low-voltage (LV) wire harnesses for automobiles (‘design rules’) to be able to control the components and processes in automation and enable an inherently consistent standardisation of these aspects. This is the first step necessary to standardise the automation of the wire harness.

One of the results of the project phase was the development of a method for the uniform description of the requirements in design rules. These design rules define specifications to reduce the complexity in wire harness production well before production, to enable automation during wire harness production and to automatically fulfil the quality requirements after production. Design rules were defined for the phases of concept development, design development, production and components. Every design rule contains, among other things, specifications for target values for the requirements in the design rule, the digital description of the requirements as well as the background to the requirements.

<table>
<tr>
<td>Identifikationsnummer
Eineindeutige Identifikationsnummer, die zum Referenzieren dieser Gestaltungsrichtlinie dient.</td>
<td rowspan="2">Leitungssatzebene
☐ Bordnetz, ☐ 150 % LS, ☐ LS, ☐ Teilumfang
Komponente(n)
adressierte Komponente
Prozess
adressierte(r) Prozess(e) der Komponente oder der Instanz der Leitungssatzebene
Applikationsebene
☐ Niedervolt</td>
<td>Kategorie
☐ Komponentenvorgaben
☐ LS-Konzept
☐ LS-Design
☐ LS-Fertigung</td>
</tr>
<tr>
<td>Verbindlichkeit
☐ Regel
☐ Empfehlung</td>
<td>Motivation
☐ Komplexität reduzieren
☐ Automation begünstigen
☐ Qualität sicherstellen</td>
</tr>
<tr>
<td colspan="3">Gestaltungsrichtlinie
Prägnante Beschreibung der Gestaltungsrichtlinie mit Verweis auf die Anforderungen und den Zielwerten.</td>
</tr>
<tr>
<td colspan="3">Bebilderung
Optional grafische Darstellung der Situation zum besseren Verständnis mit der Einstufung, ob die Darstellung „in Ordnung", das heißt konform zu dieser Gestaltungsrichtlinie, oder „nicht in Ordnung", das heißt nicht konform zu dieser Gestaltungsrichtlinie, ist.</td>
</tr>
<tr>
<td colspan="3">Hintergrund
Motivation der Automatisierung und das Potential der Optimierung durch die Gestaltungsrichtlinie oder den Grund des Ausschlusses.</td>
</tr>
<tr>
<td colspan="3">Anforderungen als Zielwert
Liste aller Anforderungen als konkrete Zielwerte, anhand deren die Einhaltung einer Gestaltungsrichtlinie überprüft wird.</td>
</tr>
<tr>
<td colspan="3">Messkriterium
Attribute, anhand derer die Anforderungen beziehungsweise die definierten Zielwerte überprüft werden können, oder die digitale Produktbeschreibung der Gestaltungsrichtlinie (siehe Abschnitt 6.2) mit den Bedarfen digitale Komponentenbeschreibung (DKOB) oder digitale Leitungssatzbeschreibung (DLSB).</td>
</tr>
<tr>
<td colspan="3">Ausblick
Möglichkeiten der Innovationsentwicklung unter anderem in Bezug auf die <Anforderungen als Zielwert>.</td>
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<tr>
<td colspan="3">Verweise
Verweis auf weiterführende Informationen wie zum Beispiel Normen oder Gestaltungsrichtlinien.</td>
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<tr>
<td colspan="3">ANMERKUNG 1: Legende: Kursive Texte beschreiben den Inhalt der Tabellenzelle</td>
</tr>
</table>

Figure 8: Template for design rules

In addition, the requirements for the digital description and their implementation in the KBL and VEC data formats are defined for every design rule. An extension of the data formats was requested in SP10 to cover missing attributes needed for implementation of the requirements so that these open data formats can be used for implementing the standard.

The compilation of all SP work results necessary for the standard in SP0 meant that the results were uniformly formulated as design rules and the design rules were supplemented by the necessary aspects of all the SPs. This resulted in 60 design rules extending across all of the SPs as a first collection of automation requirements. For the digital description of the design rules, 17 data records were defined for wire harness data, 31 for component data and 1 for wire harness and component data. Each design rule guideline and its requirements together with the necessary scope of data were supported by all companies involved in the working group.

A new collaborative approach was established for the creation of the draft standard that allowed all experts in the working group to work on the contents in parallel and transparently track the progress. This new approach for DIN working groups enabled very close coordination and rapid development of the draft standard, despite the fact that using a collaboration platform presented new challenges for the collaboration and technology, which called for continuous refinement and optimisation of the process during the creation of the standard.

3.2.6 Outlook for project phase 2.2

In the next project phase, sub-project 0 deals with the expansion of the current draft standard for the timely publication of a second version and plans to standardise further topics as requirements with additional design rules as well as further automation topics in a new version of the standard or family of standards. In future, low-voltage wire harnesses will be joined by high-voltage and high-frequency wire harnesses, among others. In addition, design rules with a greater complexity of requirements will be developed so that additional topics support automation at a higher level, e.g. through quality requirements, unbundling methods or quantification via an automation index. What's more, all sub-projects will be given the opportunity to contribute their content to the standard.

3.2.7 Interview with sub-project head Dr Carsten Kübler and the head of DIN working group 51, Rainer Bogner

Dr Carsten Kübler, TWT

Rainer Bogner, BogCon

ARENA2036: *Dr Kübler, the 'Standardisation' sub-project, which you are managing, enables great visibility and the establishment of a binding national standard based on the results of the IIWH sub-projects. What is the current state of standardisation?*

Kübler: In project phase 2.1, the first draft standard was developed with the cooperation of all sub-projects. The preliminary work by the sub-projects in the previous phases meant that the important topics for the draft standard were well-prepared. The great challenge was cohesively bringing together this preliminary work by the individual sub-projects and linking the topics. These results were then handed over to DIN WG51 so that these proposals could be coordinated and generalised together with other experts.

ARENA2036: *Were all the results of the sub-projects able to be included in the first version of the draft standard?*

Kübler: To start off with, a large number of topics from the sub-projects that could potentially enter into the standard were identified. These were presented to the DIN working group. The aim of developing a high-quality draft standard and ensuring its prompt publication meant that the first version of the draft standard was reduced in scope and focussed on the key topics of automation requirements and the digital description of these requirements.

ARENA2036: *Why was it so important to publish the draft standard within a year, when a period of up to three years is provided for creating a draft standard?*

Kübler: First of all, activities looking at how guidelines for automation could be defined and uniformly specified have already occurred in the past. What's more, the sub-projects have been working on standardising the requirements since the start of the IIWH activities. So the only remaining challenge was to develop methods for defining the design rules and to uniformly and describe the previously developed requirements in a comparable way using these methods.

We restricted ourselves to this core to ensure that we could create a stand-alone, comprehensive draft standard. We were able to draw on the momentum supplied by the IIWH without risking a collapse of the project due to the diversity and complexity of all the topics. It was also clear from the start that the IIWH did not consider standardisation to be a one-off project; the goal was rather to continuously advance the topic of wire harness automation.

ARENA2036: *You were not able to include all of the topics from the sub-projects in the first version of the draft standard. Does this negatively affect the quality of the first version of the standard?*

Kübler: The task of sub-project 0 was to select which results would enter into the draft standard. For the draft standard, it was important that the topics it contained were consistent in themselves and all-encompassing, even if the requirements were developed by different sub-projects. The focus on these selected topics for the draft standard allowed this consistency and completeness to be ensured.

This enabled an important foundation for the automation of the wire harness to be achieved, which can now continue to be developed in the coming phases. So we achieved our goal of creating a high-quality and comprehensive standard without merely scratching the surface of various topics. Focussing on certain topics also benefitted the collaboration and a coherent view of the sub-projects.

ARENA2036: *What was the collaboration with the DIN working group like?*

Kübler: The collaboration with the DIN WG 51 initiated by the IIWH was very good. All experts involved in the working group had the same common goal of creating this draft standard using a new, agile collaboration model. All of the experts professionally complemented each other and were able to establish a mode of operation that led to the targeted and collaborative development of the draft standard. This newly established mode of operation will now also enable other DIN WGs to implement their standards faster and with greater agility.

ARENA2036: *Mr Bogner, as the head of WG 51, what did you think of the collaboration between WG 51 and the IIWH?*

Bogner: The collaboration was extremely constructive. Even though companies along the entire wire harness production value chain are represented, the discussion was focussed on content with the common goal of creating DIN 72036. WG 51 first met on 1 March 2021 and then every four weeks. The draft version was released by the working group on 16 August 2021, so the basis for the first version of the DIN was established in less than six months. I can only express my great respect for all involved, who managed to work on this in addition to their daily business.

ARENA2036: *What influence will this draft standard have on the industry?*

Bogner: This DIN will revolutionise the industry once it is applied by car makers. In some cases, the contents have been under discussion over the past 10 years. Every OEM and every tier X has formulated their individual ideas and implemented them to some extent. This has led to the creation of isolated solutions, which often were not cost-effective due to the lack of market penetration.

The application of the standard will change this. In the medium-term, the design of wire harnesses in connection with new architectures will be completely different for vehicle projects starting in 2026. But the formulated design rules for the on-board electrical system do not just require action from on-board electrical system developers.

To achieve the goal of automated production, exchange with the control unit manufacturers must take place in the early concept phases in order to design the PIN layout accordingly. This is already happening today in some cases, but it must become a milestone in the project sequence controlled by the OEM. Only a binding network encompassing both electronics architecture and on-board electrical system design will enable vehicles with level 4 autonomous mode and higher to be produced safely.

ARENA2036: *How can the relevance of the standard be increased for this industry?*

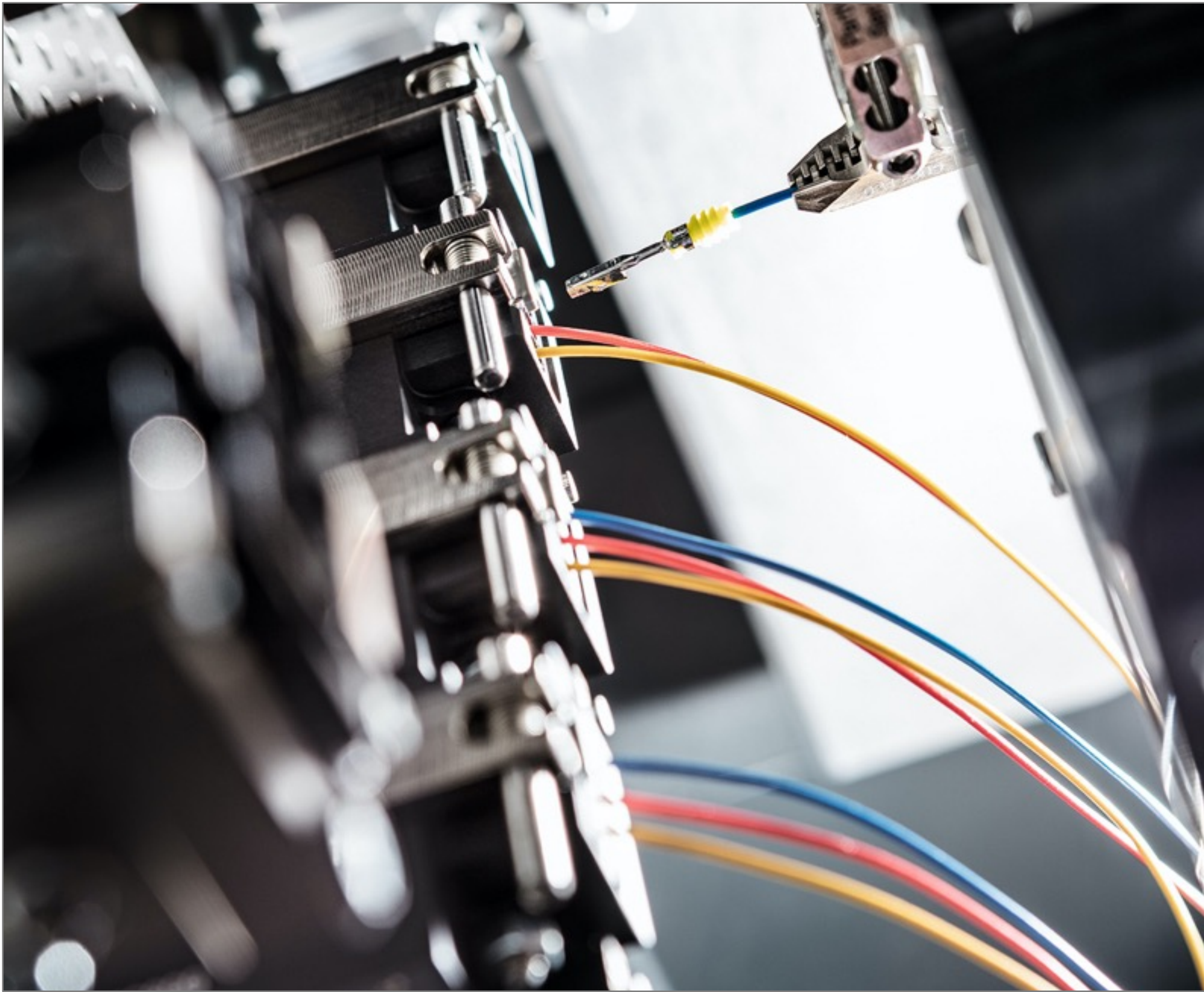
Bogner: The first version lays the foundation. A number of important and highly complex topics were not included in this version. All involved partners will work on the coming version from Q4 2021. The focus will be on new topics and the consistency of the current document. The relevance of this standard is determined by the technical quality of the document and by the application as part of new vehicle projects.

ARENA2036: *All that remains is to congratulate you on the draft standard.*

Bogner: Thank you. I will happily pass this on to all those involved for their exceptional commitment, sometimes even working late into the night

Kübler: Thank you to all the experts working both outside and inside the IIWH for their fantastic commitment and collaboration in creating the draft standard. Also, I would like to thank the working group and Mr Bogner for their trust and confidence in appointing me as the head of the draft standard project in the working group.

ARENA2036: *We wish you every success in the future with the timely publication of the standard and the ongoing standardisation activities.*



Sub-project 1
Design rules for the automation of the wire harness

3.3 Sub-project 1
Design rules for the automation of the wire harness

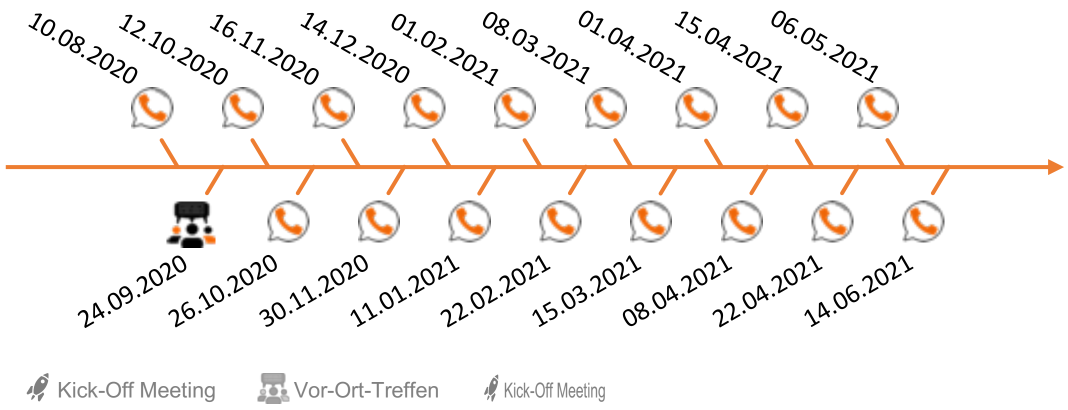
3.3.1 Participants

Christian Infanger (Sub-project Head)
Komax

Bernd Weiß (Joint Sub-project Head)
Mercedes-Benz

Achim Rosemann *Aptiv*	**Andreas Müller** *KOSTAL*	**Martin Stier** *Schleuniger*
Swindhard Packebusch *Aptiv*	**Wolfgang Kölbl** *Kromberg & Schubert*	**Sebastian Rühl** *Schunk Sonosystems*
Stephan Fahrnbauer *BMW*	**Carsten Schubert** *Kromberg & Schubert*	**Udo Wagenbach** *Schunk Sonosystems*
Dr Christoph Frigge *Coroplast*	**Matthias Paukner** *Kuka*	**Siva Arumugam** *Siemens*
Stephan Wuth *Coroplast*	**Jerome Trommnau** *Mercedes-Benz*	**Pavel Nosek** *Siemens*
Helmut Wichmann *Coroplast*	**Ulrich Döllinger** *Nexans*	
Dr rer. nat. Karsten Rüter *Dräxlmaier*	**Michael Smedla** *Nexans*	
Kurt Herrmann *Gebauer & Griller*	**Stefan Neubauer** *Schäfer*	
Gottfried Fleischer *Gebauer & Griller*	**Carmelo Messina** *Schleuniger*	

3.3.2 Project timeline



3.3.3 Starting point/motivation

The manufacturing process of a wire harness runs through various disciplines from development to installation in the vehicle. The value creation itself is presented and implemented so that it is optimised for the respective field of action in every company. Maintaining a holistic view of the value chain is therefore an essential factor in enabling more efficient wire harness production. The various motivations and experiences are to be incorporated into the early stages of wire harness development through close coordination between the individual companies.

3.3.4 Objective

Sub-project 1 is developing the design rules that lead to automation-compatible wire harness designs. Important indicators here are the number of different components, the complexity of the processing procedures and the actual structure of the wire harness. ‘Hard’ rules (compliance with which can be digitally evaluated) as well as recommendations of a less binding nature are being formulated. The design rules are standardised in DIN 72036. The content is deliberately set above and beyond the current state of the art. A look ahead at possible advances in machinery and equipment is ensured.

We want to project the impact on the wire harness of technology decisions made at the early concept stages. This allows obstacles to automation to be prevented and enables cost-effective automation.

3.3.5 Results of project phase 2.1

The activities in phase 2.1 were focussed on developing design rules for DIN 72036, which were discussed and adopted in the Automotive Engineering standardisation committee/Working Group 51, with the involvement of numerous parties. As this task is extremely varied, we have attempted to create a guiding framework for readers. The following system was developed for structuring the design rules:

- **Binding nature** includes recommendations as well as, in particular, rules with a clear target value and defined data basis.

- **Category** distinguishes between component specifications and design rules for wire harness concepts, wire harness design and wire harness production.
- **Range of topics** details the affected processes and components as well as the application and wire harness level. The latter relates to the entire on-board electrical system, a (150%) wire harness or a certain scope of parts.
- **Motivation** indicates the primary effect targeted by a design rule guideline – ensure quality, reduce complexity or enable automation.

This foundation was used to classify, describe, illustrate and assign target values to 60 design rules. Measurement criteria were defined for every target value, which were used to check compliance with these targets. Sub-project 10 specified the necessary data basis.

What is important is that these design rules can now be consulted in various project phases, for instance, when new components are developed or the automation-compatibility of existing components is to be assessed. The same applies for phases in which the wire harness concepts or the specific wire harness design are developed. The reference to the target audience is established by the specific design rules.

This analogy can now be continued in the area of wire harness production. This is because the interaction between components, the wire harness and the available automation technology once again becomes clear: individual components that appear suitable from a stand-alone consideration may make the production of a wire harness design impossible in combination with the rest.

3.3.6 Outlook for project phase 2.2

Sub-project 1 aims to raise awareness of the highly automated production of wire harnesses. The existing low-voltage design rules will therefore be expanded and enhanced. In addition, topics such as high voltage, high frequency and the assembly of partial wire harnesses and purchased parts are included for consideration. The target format is selected analogous to phase 2.1 to enable the expansion of DIN 72036.

The practical application of the design rules is a key concern of the project team. A video demonstrator will be used to show examples of how the design rules can be integrated into standard industry software systems. To encourage innovation, a stress test will be used to identify where the standard stipulates requirements that cannot currently be implemented.

3.3.7 Interview with sub-project head Christian Infanger

Christian Infanger, Komax

ARENA2036: *The design rules are being published as a key component of DIN 72036. One might think that this marks the end of your task. How do you see the future of the 'Design rules for the automation of the wire harness' sub-project?*

Infanger: The publication of the standard is certainly an important milestone. But there is still a long way to go to reach our goal.

ARENA2036: *Are you referring to topics such as high voltage, high frequency and the final assembly area?*

Infanger: In part, yes. Without a doubt, those are important aspects that need to be looked at. But we also need to take a closer look at the low-voltage area. Wire harnesses are extremely diverse and the picture that we have today is not yet complete.

ARENA2036: *What effect do you believe that these design rules will have on wire harness production?*

Infanger: I am hoping for two positive effects. Firstly, the simplification of the diversity of wire harness components and process technology. Secondly, the continued simplification of the structure of the wire harness. Both will significantly benefit automation. In saying that, I naturally don't mean that technical solutions for these challenges are currently not conceivable, merely that they are not cost-effective.

ARENA2036: *In what kind of timeframe will these positive effects be seen?*

Infanger: I think the changes will be implemented gradually. New zone calculators provide the opportunity to provide automation-compatible connector systems with optimised pin assignment and contact part diversity. On the other hand, carry-over parts are a reality. They set the guidelines that we will not be able to break free from in the coming years. At worst, they even prevent the unbundling of the wire harness.

ARENA2036: *What success factors will you build on to tackle these challenges?*

Infanger: The broad partner base in the IIWH lets us address various stages of the value chain. We also continue to work closely together with other sub-projects to identify and integrate overarching interrelationships.

ARENA2036: *We wish you every success! Thank you for the interview.*

Infanger: Thank you.

Sub-project 2
Design rules for plug connectors

3.4 Sub-project 2 Design rules for plug connectors

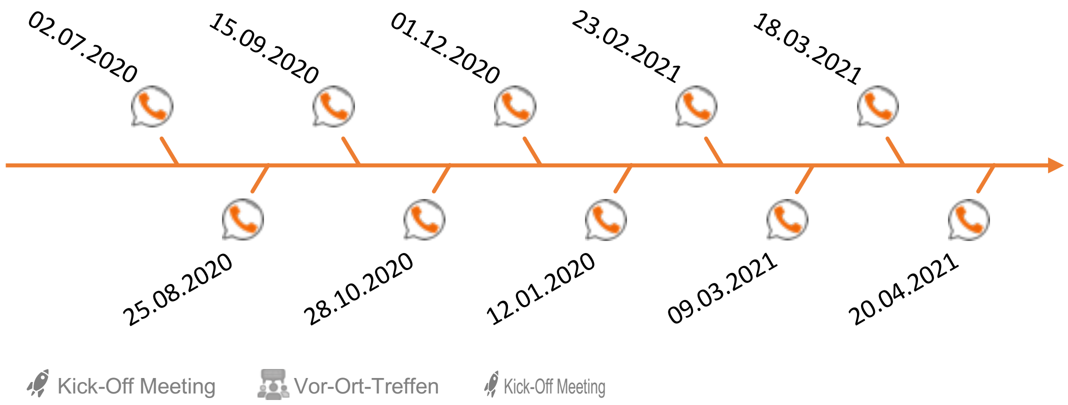
3.4.1 Participants

Dr rer. nat. Jens Haun (Sub-project Head)
KOSTAL

Manfred Mittermeier (Joint Sub-project Head)
Rosenberger

Franz Pacher *Aptiv*	**Gottfried Fleischer** *Gebauer & Griller*	**Carmelo Messina** *Schleuniger*
Jörg Beinersdorf *BMW*	**Andreas Müller** *KOSTAL*	**Sebastian Rühl** *Schunk Sonosystems*
Dr Thomas Kaiser *Bosch*	**Andreas Pesch** *KOSTAL*	**Udo Wagenbach** *Schunk Sonosystems*
Andreas Vogt *Bosch*	**Michael Knödler** *Kromberg & Schubert*	
Klaus Döpper *Coroplast*	**Matthias Paukner** *Kuka*	
Norbert Sickau *Dräxlmaier*	**Marco Schweizer** *Mercedes-Benz*	
Kurt Herrmann *Gebauer & Griller*	**Ulrich Thelen** *Mercedes-Benz*	

3.4.2 Project timeline



3.4.3 Starting point/motivation

Today, plug connectors are mainly assembled manually or semi-automatically. This type of standard connector is shown in Figure 9. The crimping process is already automated. Process monitoring is implemented by means of crimp force monitoring.

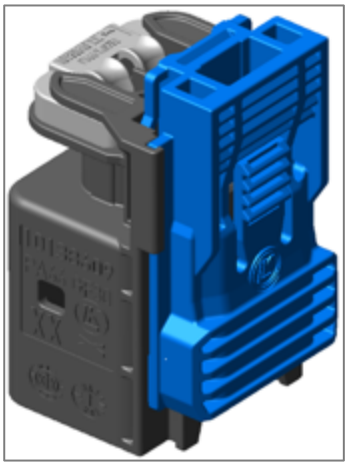


Figure 9: Standard connector

Depending on the type of wire harness – low-voltage, data, high-voltage – there are very different degrees of automation in wire harness production. The degree of automation is generally higher for low-voltage wire harnesses than for data or high-voltage wire harnesses. The proportion of manual production is highest for customer-specific wire harnesses.

However, the fact remains that fully automated assembly of all existing plug connectors is currently not possible. There is no industry-wide design rule for plug connectors that would facilitate automation.

3.4.4 Objective

After design rules for low-voltage plug connectors were developed and documented in a VDA/DIN standard in phase 1, the focus in phase 2 is on high-voltage and high-frequency plug connectors. In contrast to low-voltage plug connectors, high-voltage connectors are characterised by their greater diversity. The flurry of development in the field of e-mobility in recent years has led to the creation of different high-voltage and high-current plug connectors. One particular challenge will now be to define generalised and precompetitive standards. But it should be noted that many plug connector systems developed in recent times already consider automation capability.

High-frequency plug connectors have been established longer. The smaller installation space for physical reasons, the associated smaller dimensions, the necessary lower tolerances and the more durable, often rotationally symmetrical structure usually require automated assembly. Design standards are therefore generally defined and ‘merely’ need to be documented.

However, it must also be possible to depict future design changes. In addition, the design rule must be consistent with the other sub-projects. The design rules for plug connectors are based on the structure from sub-project 1, into which they are also integrated.

3.4.5 Results of project phase 2.1

In phases 1 and 2.1, the focus was on formulating design rules for low-voltage plug connectors. The design rules were formulated and the target values for measurability defined in consideration of established guidelines used by assemblers and plug connector manufacturers alongside the requirements of the OEMs as well as safety aspects. An example of a design rule is shown in Figure 10.

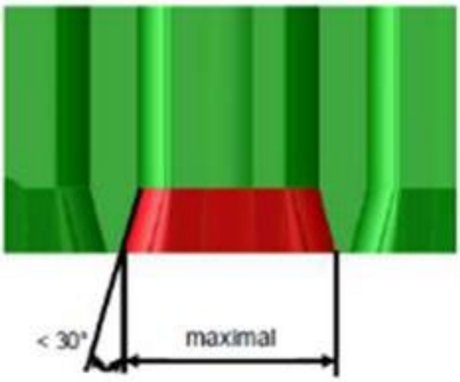


Figure 10: Example of lead-in chamfers into a chamber

Particular attention was paid to the input provided by assemblers. The mandatory and optional design requirements during assembly were compiled and categorised in a separate document. Some of the requirements were classified as mandatory, others as optional. Subsequent discussions led to the classification of some requests as unfeasible, as this would affect other specifications and requirements for the plug connectors. The essential requirements were included in the design rules and are part of the VDA/DIN draft standard.

To ensure that all plug connector manufacturers could be included, an additional channel was opened up. KOSTAL Kontakt Systeme GmbH coordinated a dialogue with the German Electrical and Electronic Manufacturers’ Association (ZVEI) working group ‘Requirements for the validation and processing of contacts’ so that the various design rules of the contact part manufacturers could be taken into account.

The Covid-19 pandemic rules prevented face-to-face meetings. So almost all discussions were held online. This proved to be a viable option and can – at least in part – serve as a model for future work.

3.4.6 Outlook for project phase 2.2

Phase 2 targets the development of design rules for high-voltage and high-frequency plug connectors. The experiences from the discussions on low-voltage plug connectors will be taken into account and will help shorten the coordination process.
As already planned at the start of the IIWH, the design features will now be visibly demonstrated based on sample parts. To do so, sample parts will be created using 3D printing processes, see Figure 11. For example, the benefits of gripping and clamping surfaces will be demonstrated as part of sub-project 8. The installation of a wire harness in a car body, for instance, can be shown. In addition, sub-project 1 will simulate the possible automation of the wire harness.

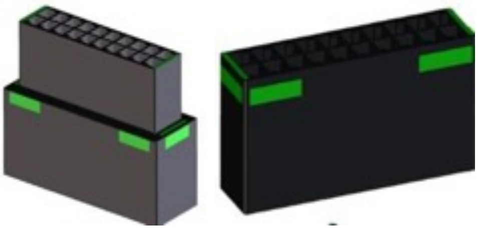


Figure 11: Examples of gripping surfaces

Phase 2 will also once again look at the design features of current plug connectors that could be removed with the fully-automated processing across the entire process chain. This includes servicing instances where the replacement of wire harness parts is to be preferred in future over repair, even purely from a safety perspective. Some of the design features necessary for manual assembly, see Figure 12, could be eliminated with fully-automated processing, which would make the plug connector systems simpler and cheaper. This approach gets to the very heart of one of the key questions being tackled by the IIWH.

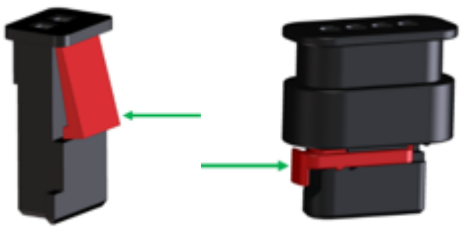


Figure 12: Examples of designs with more favourable force application for the automated actuation of the secondary locking mechanism

In addition, the work on the existing draft standard will continue, and updates will be prepared for a second version.

3.4.7 Interview with sub-project head Dr rer. nat. Jens Haun

Dr rer. nat. Jens Haun, KOSTAL

ARENA2036: *The topic of 'Design rules for plug connectors' is nothing new in the industry. What is new in this project?*

Haun: Indeed, there are already design rules that have been drawn up by some plug connector manufacturers that allow automation to a certain degree. These design rules are specified in the design rules of the contact and plug connector manufacturers. They are based on the specifications of the machine manufacturers.

We should also mention the widely used Komax Design Guideline. The innovation driver Bayern Innovativ set up a project about 10 years ago with the aim of working out optimisations and also with an eye to drawing up design rules. The results achieved there, together with the guidelines established in the market, were analysed and updated as part of our sub-project.

ARENA2036: *Wouldn't general design rules lead to reluctance on the part of plug connector manufacturers, as their unique selling points could disappear?*

Haun: I do not see this as a danger. On the contrary, standardised design rules will lead to more participation in this topic. The unique selling points do not concern the automation of production but rather other aspects of plug connectors.

Automation is increasingly becoming a trend. Requirements relating to the road safety of vehicles have not led to fewer car manufacturers on the market. Rather, road safety is merely a prerequisite for participation in road transport.

ARENA2036: *What influence does e-mobility have on the design rules of plug connectors?*

Haun: There is no impact on plug connectors for the low-voltage and high-frequency area. These plug connector systems have been established for years and are well-suited to meeting the high demands on reliability and durability. Automated processability does not depend on a vehicle's drive type. High-voltage plug connectors suitable for automotive applications have only been developed in recent years. In most cases, the automation capability has been taken into account from the very beginning.

ARENA2036: *Has the interest of the partners in this sub-project changed over time?*

Haun: The interest of partners in the topic of design rules for plug connectors has only grown over the previous project period. While discussions initially revolved around formats and exploring existing guidelines, interest subsequently increased as a result of the specification on the one hand and the extension of tasks on the other. This is reflected in the new additional partners, which is very pleasing.

And we have also received positive feedback from outside parties. The activities of the IIWH have already attracted great interest on the other side of the Atlantic, where the results are being followed and have also been integrated.

ARENA2036: *What challenges do you foresee with regard to the automation requirements for high-current plug connectors?*

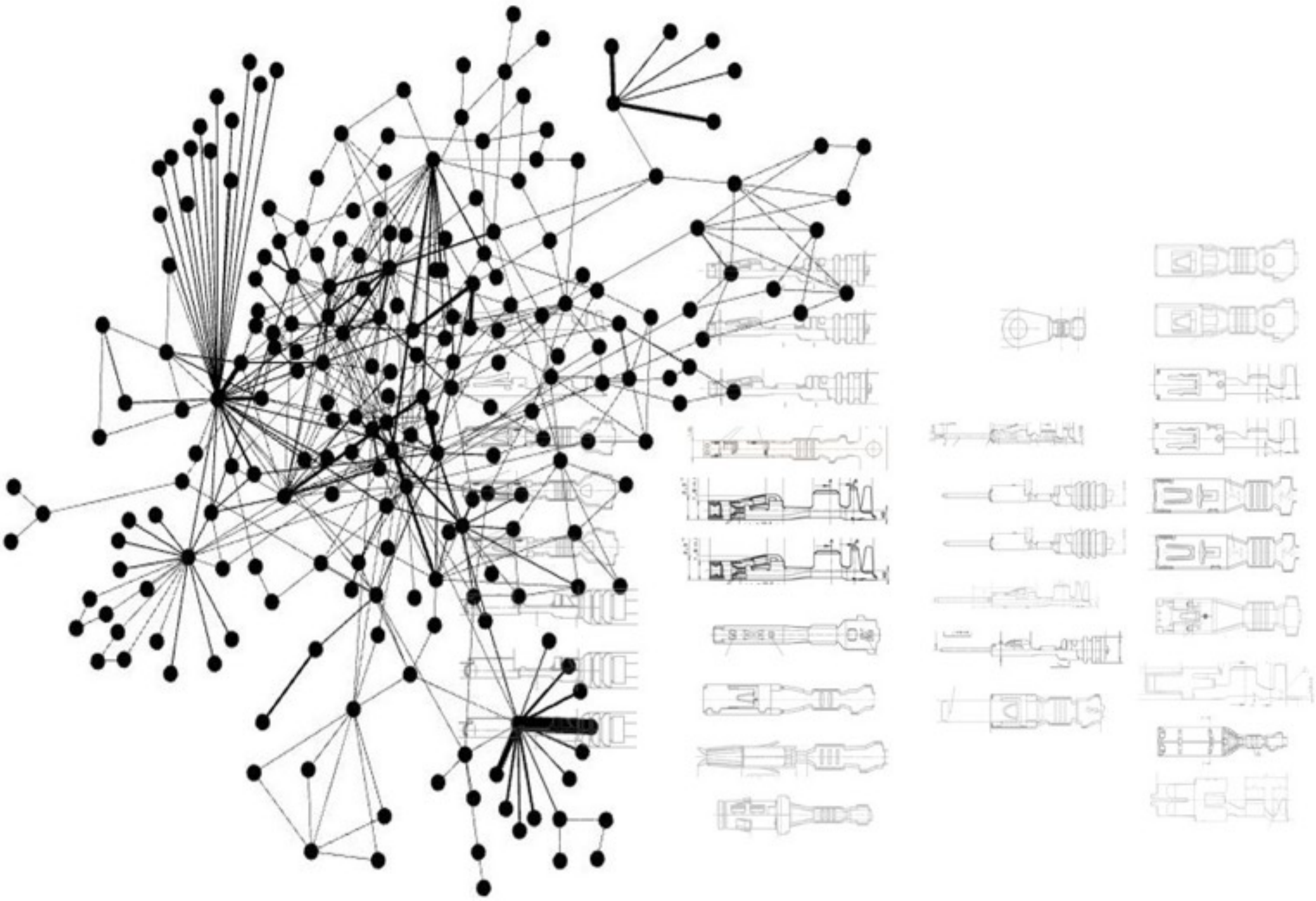
Haun: High-current plug connectors need to be able to transmit very high currents. The resulting high electromagnetic radiation caused by inverters means that these connections often need to be well shielded. Both require a high number of individual components and involve the risk that unfavourable designs will unnecessarily complicate the automation process. In this case, less is often more. But the designs currently available on the market already allow appropriate design rules to be derived, which can be applied in a precompetitive environment.

ARENA2036: *How will the design rules be presented?*

Haun: Straightforward and clear communication of the design rules is important for establishment in the market. Two paths will be taken simultaneously. Firstly, the design rules will be compiled in a uniform and clear format. This is then also how they will be documented in the standard. We have made sure that the format for all design rules from different sub-projects is the same. Secondly, a demonstration vehicle will be set up to provide a practical demonstration of the installation of a cable harness and the attached plug connectors. Short video sequences will be used to present the installation process and the design features used by way of example.

ARENA2036: *Dr Haun, thank you very much for the interesting interview.*

Haun: My pleasure.



Sub-project 3
Wire harness concepts

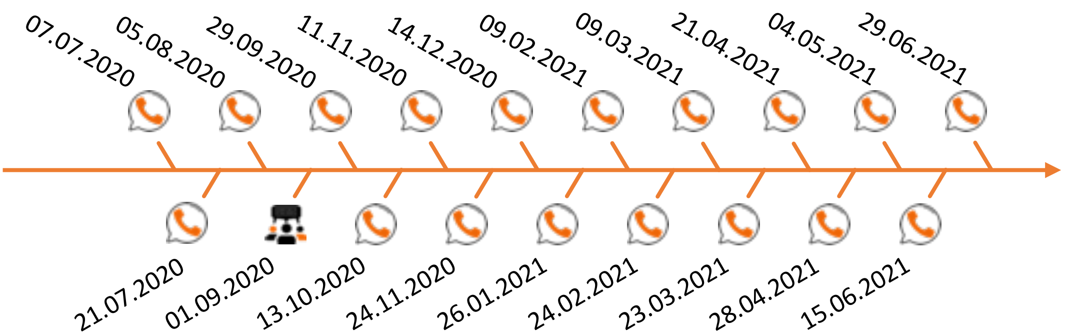
3.5 Sub-project 3
Wire harness concepts

3.5.1 Participants

Michael Wortberg (Sub-project Head)
Dräxlmaier

Swindhard Packebusch *Aptiv*	**Volker Clemens** *Gebauer & Griller*	**Dr Helmut Steinberg** *Nexans*
Martin Hager *Bosch*	**Christian Infanger** *Komax*	**Manfred Mittermeier** *Rosenberger*
Felix Moos *Bosch*	**Andreas Müller** *KOSTAL*	**Siva Arumugam** *Siemens*
Richard Schöttle *Bosch*	**Andreas Pesch** *KOSTAL*	
Dr Christoph Frigge *Coroplast*	**Uwe Hessler** *Kromberg & Schubert*	
Stephan Wuth *Coroplast*	**Klaus-Michael Schaible** *Mercedes-Benz*	
Richard Böhm *Gebauer & Griller*	**Ulrich Döllinger** *Nexans*	

3.5.2 Project timeline



Kick-Off Meeting Vor-Ort-Treffen Kick-Off Meeting

3.5.3 Starting point/motivation

The production of a wire harness by an assembler is a complicated process of assembling numerous components into a complex product. The use of automation-compatible components is just one sub-aspect of automation. The automation of wire harness production ultimately needs to be implemented by the assembler. As a result, it is important to understand and work through the assembler's requirements for automated production.

3.5.4 Objective

The 'Wire harness concepts' sub-project originated from the 'Wire harness architectures' sub-project. This name change reflects the recognition that the wire harness as such is not 'architecture' and that E/E architectural aspects are only indirectly associated with automation capability in wire harness production.

The objective of the 'Wire harness concepts' sub-project is to develop the structural requirements for automation feasibility. In addition, it is important to first understand the structural stumbling blocks that have previously prevented automation (as a direct cause). The structural analyses relate to the wire harness as an assembly of numerous components. The automation capability of components is assumed and is not the focus of this sub-project.

New and innovative approaches for physical connections in the vehicle are generally taken into account, but the initial focus is on conducting a structural analysis. Only this foundation enables the formulation of design scopes for successful innovative approaches.

3.5.5 Results of project phase 2.1

The structure of a conventional wire harness is defined in the development process. The system relationship between the connector socket of the on-board electrical system unit (e.g. control unit) and the wire harness connector is clearly specified. While the specific 'external' interfaces to the on-board electrical system units – the control units, sensors, motors, etc. – are clearly defined from the perspective of the wire harness, the internal connection or, better put, interlinking structure of the wire harness is not a development objective per se. Rather, this is effectively incidental.

The complex interlinking structure of a main wire harness, as shown in Figure 13, can be analysed using graph theory. This shows that a wire harness is a large, interconnected, non-planar multigraph that is not divided into partitions. Partitioning in terms of graph theory is the division of a large graph (the wire harness connections) into self-contained individual graphs (partial scopes) without needing to break connections.

There is no trivial solution to the partitioning problem. As a result, the wire harness cannot simply be broken down into partial wire harnesses, whose size and interlinking as a production module (partial scope) would allow it to be manufactured on an automatic machine in a discrete manufacturing process.

Figure 13: Interlinking, extract from a typical main wire harness
Source: C. Infanger, Komax

The latter point, the impossibility of automation in discrete manufacturing steps, leads to the root cause of the lack of automation to date. A discrete manufacturing step in this respect is a stand-alone manufacturing sub-process with preliminary products as the input and finished intermediate products as the output. These discrete manufacturing processes can be sequenced or run in parallel for automation.

Conventional wire harness production already has a high degree of automation provided that discrete manufacturing processes can be applied. This applies to the cutting machinery, with automated cutting, stripping and attaching of contact parts.

If block loading as a process step for the complete fitting of all plugs is then anticipated as the next manufacturing step, it quickly becomes apparent that this could not be implemented as a discrete manufacturing process. The output of this type of process step would be so complex that it would be impossible to remove from an automatic machine and subsequently transfer to a building board for shaping. This clearly shows that, in conventional manufacturing, the following processes can only be carried out gradually in small, alternating and intermeshed individual steps:

- Fitting of the contacts in connector chambers
- Shaping on a building board
- Threading, e.g. through bushings
- Winding

This circumstance – together with the aforementioned de facto incidental structure of the wire harness – means that these process steps can currently only be implemented manually.

The following objective can thus be formulated: the physical on-board electrical system connection must be partitioned such that these connection partitions can be automatically manufactured in discrete manufacturing process steps (as partial wire harnesses).

There is no trivial solution for achieving the above objective for the partitioning problem of a conventional wire harness. For example, a trivial solution would be achieved if only point-to-point connections from one plug to another plug in the on-board electrical system existed. The unit – consisting of a plug, wires and another plug – would be a stand-alone unit and could be extracted from the on-board electrical system connections as a no longer intermeshed part and produced in discrete manufacturing steps.

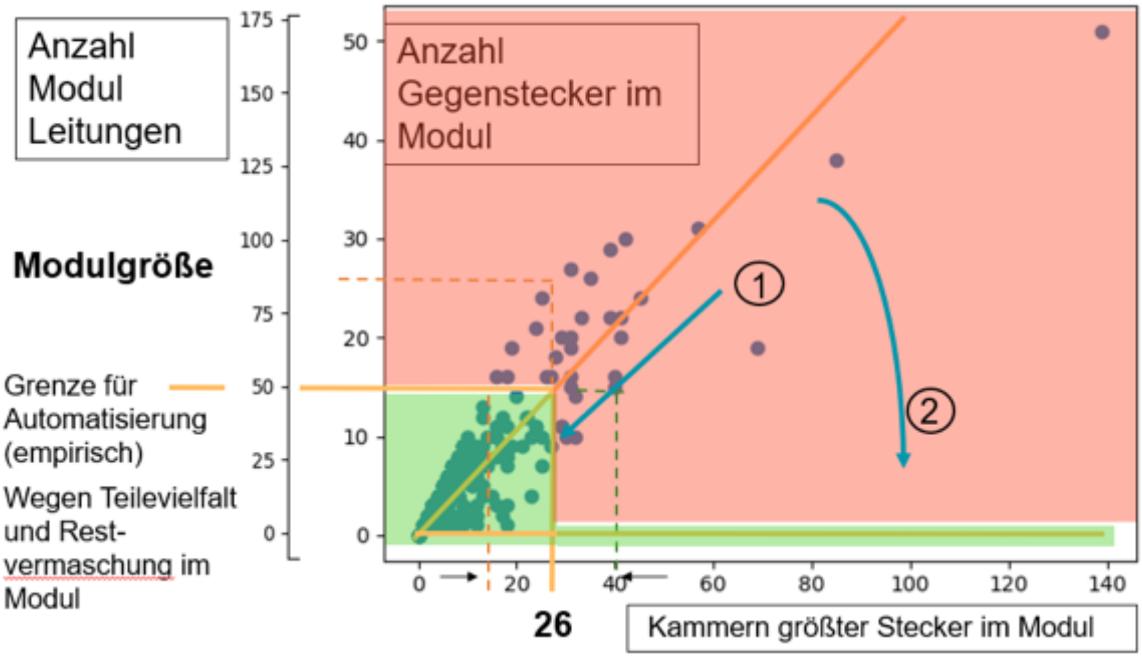


Figure 14: Scatter plot of plug sizes (number of chambers) versus number of mating connectors
Source: M. Wortberg DRÄXLMAIER Group

The scatter plot in Figure 14 shows that only a small number of point-to-point connections from a plug to a mating plug are present in a vehicle on-board electrical system. Point-to-point connections lie on the horizontal line, parallel to the X-axis. Rather, the plot indicates that, for example, a 140-pin plug is connected to up to 50 mating connectors via individual wires. The production module with this plug would therefore have to include at least 51 plugs. This magnitude that could not be implemented with block loading.

Experience suggests a feasibility limit of 15 mating connectors with a median of 50 cables in total. These 15 mating connectors project themselves to a maximum permitted median of 26 chambers of the largest plug in the production partition. So large plugs lead to interlinking in the on-board electrical system that prevents partitioning into production modules for discrete manufacturing steps.

The arrows in Figure 14 show two possible paths for reaching the green area for automation feasibility:

Option 1: Reduction of the number of chambers in the insulators

Possible implementations are:

- Exclusive use of adequately small plugs in the on-board electrical system, or
- Use of modular plugs and plug assemblies with a maximum of 26 chambers. The pinning of the control units must support the partitioning in the wire harness across the

plug modules. This would then require a pinning convention for the wire harness and control unit fraction.

Option 2: Transition to point-to-point connections

Based on an initial analysis, the transition to exclusively point-to-point leads to a significant increase in the number of single wires and so to an increase in costs in the physical on-board electrical system as well as for the control units.

The exclusive use of adequately small plugs, as described in option 1, is diametrically opposed to the requirements of control unit developers to use the largest possible connectors in order to meet the miniaturisation requirements while simultaneously increasing the functionality of the control units.

For a modular plug, the implementation in design and the scope of any possible standardisation is still unclear and no consensus has yet been reached. As a result, this approach was not considered in DIN 72036.

Another structural problem of a conventional wire harness is the diversity of the parts. A typical conventional wire harness uses up to 120 different contacts in a cross-sectional area of up to 2.5 mm² of relevance for automation, with each contact requiring a dedicated tool on an automatic machine.

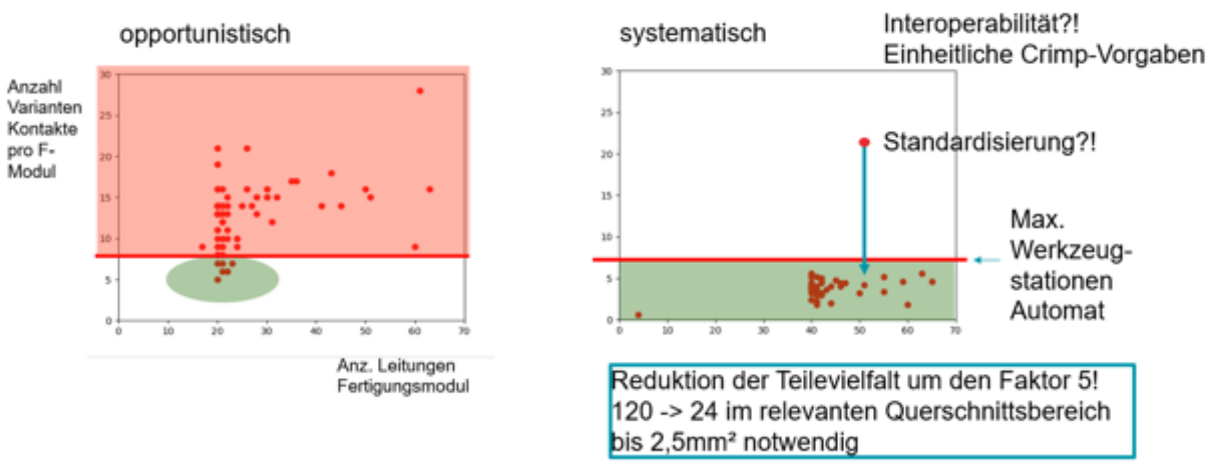


Figure 15: Scatter plot of the number of cables in a manufacturing partition versus the number of different contact parts or the necessary number of tool stations in an automatic machine
Source: M. Wortberg DRÄXLMAIER Group

If it were possible to break down the physical connections of an on-board electrical system into partitions for automated production, any automation based on the existing situation would fail for over 80% of these partitions (partial wire harnesses) due to the diversity of the parts. As shown in Figure 15, on the left, a maximum number of eight tool stations is assumed for 120 different contact parts, each with their own tools. This could not be called systematic automation feasibility; at best, a small number could be opportunistically automated.

The scatter plot on the right in Figure 15 shows that the diversity of parts would have to be reduced by a factor of five to expect systematic automation feasibility.

An alternative to a global reduction in the diversity of parts by a factor of five would be to define a separate, restricted set of contact parts for every production partition. However, this approach would be impacted by the determination of optimal production partitions, which could differ depending on the automation technology used. At this point, a more detailed look at the considerations is necessary.

3.5.6 Outlook for project phase 2.2

The results of phase 2.1 show that the approach of a modular plug can be used to tackle the direct structural obstacles:

- Interlinking
- Diversity of parts
- Pinning

Phase 2.2 will now work together with sub-projects SP1 and SP2 to develop a solution to the following challenges:

- Design rules for modular plugs
- Pinning convention with control unit manufacturers

Our vision is to establish the modular plugs as a standardised interface of a physical on-board electrical system.

3.5.7 Interview with sub-project head Michael Wortberg

Michael Wortberg, Dräxlmaier

ARENA2036: *What were your expectations at the start of the 'Wire harness concepts' sub-project?*

Wortberg: The sub-project's original name was 'Wire harness architectures'. I got involved because I specialised in energy/on-board electrical system architectures and came across the zonal on-board electrical system architecture approach.

ARENA2036: *Are architecture approaches the enablers for automated wire harness production?*

Wortberg: I am initially sceptical about linking the automation capability of the wire harness to an architectural approach. After all, this would imply that only one architecture could exist for uniform automation capability, which would then have to be adopted by all OEMs.

I believe that the on-board electrical system architecture must focus on the efficient implementation of customer functions and not the automation capability of the wire harness. What's more, I am convinced that an exclusive focus on new and 'fancy' architectures obscures the real causes of previous failed automation attempts.

ARENA2036: *So you believe there is no connection between the automation capability of wire harness production and on-board electrical system architecture?*

Wortberg: No, there is a connection: If an on-board electrical system architecture requires a small number of physical connections, the wire harness becomes smaller and less complex, making automation is easier.

But this connection is trivial; it can be documented in a single sentence and then we would effectively be done. In that case there would be no further need for the IIWH. But it's worth drilling deeper. To date, even the production of smaller wire harnesses, such as the cockpit wire harness, is not automated.

ARENA2036: *So where do the road-blocks to automation feasibility lie? Is it in the lack of automation-capable components?*

Wortberg: You obviously need automation-capable components, such as contacts and connector housings. But these have existed in the past, and the production of autonomous wire harnesses, such as motor wire harnesses, has already been largely automated.

ARENA2036: *But the main wire harness has evaded automation to date. Is this the focus of SP3?*

Wortberg: Yes, the focus of SP3 is to view the wire harness as a complex assembly of a large number of components. And it is precisely this perspective which shows that the challenges are *structural*.

Our analyses have shown that the structural road-blocks are:

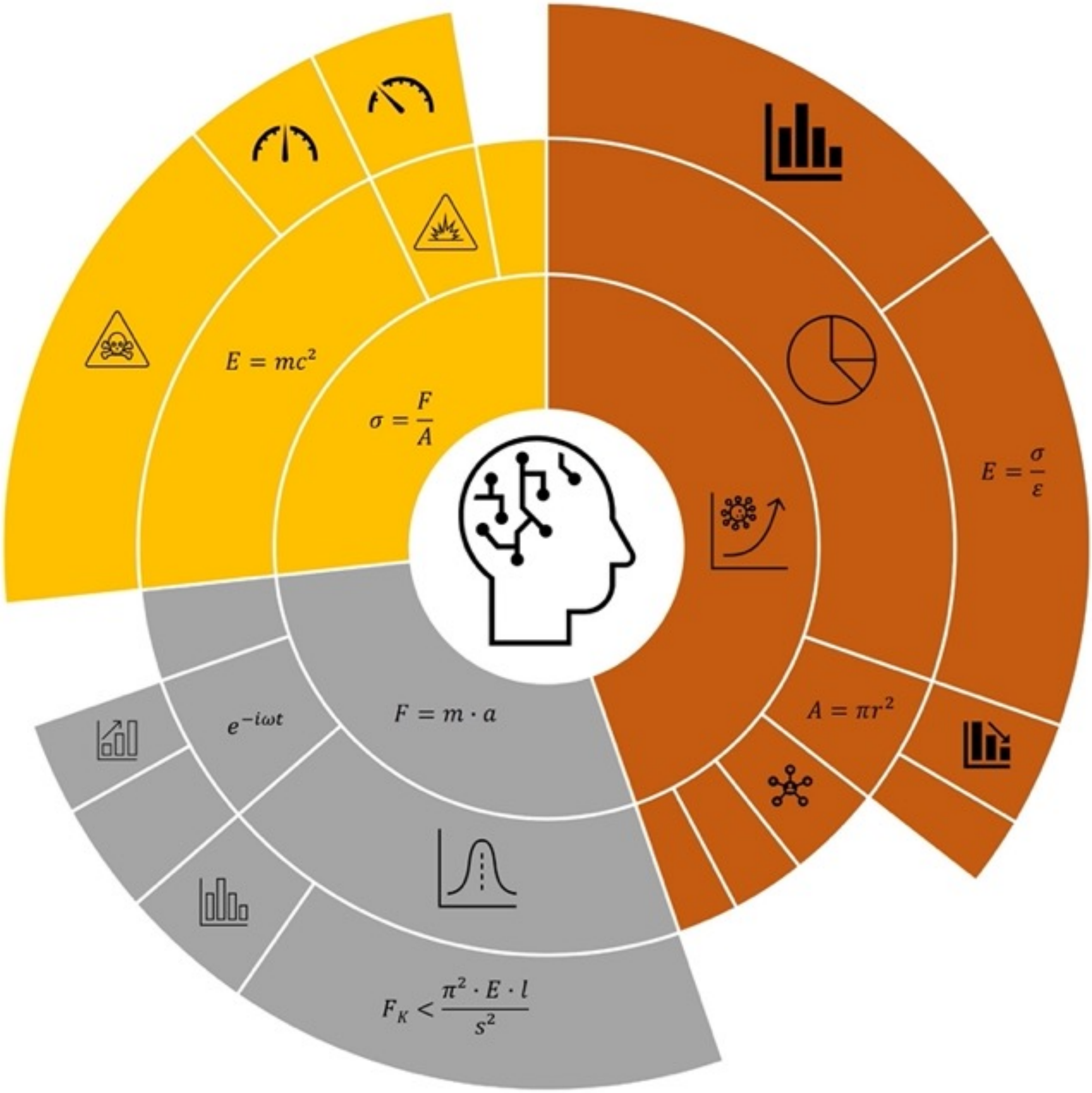
1. Interlinking
2. Diversity of parts
3. Lack of pinning conventions

ARENA2036: *Structural challenges; that sounds like fundamental changes are necessary.*

Wortberg: It looks as if we will have to get right to the heart of the problem because everyone will have to make changes. The wire harness as the ‘problem solver’ that somehow connects everything as it is, regardless of the level of diversity and with frequent changes will no longer exist for an automated and digitalised design of the future.

ARENA2036: *What do you believe is the top priority as a next step for the necessary change?*

Wortberg: A modular plug/interface convention can best answer the three structural challenges. It won’t work without a plug/interface convention.



Sub-project 4
Automation index

3.6 Sub-project 4 Automation index

3.6.1 Participants

Stephan Fahrnbauer (Sub-project Head)
BMW

Manuel Heindl
Gebauer & Griller

Andreas Pesch
KOSTAL

Henning Winkelhardt
Schleuniger

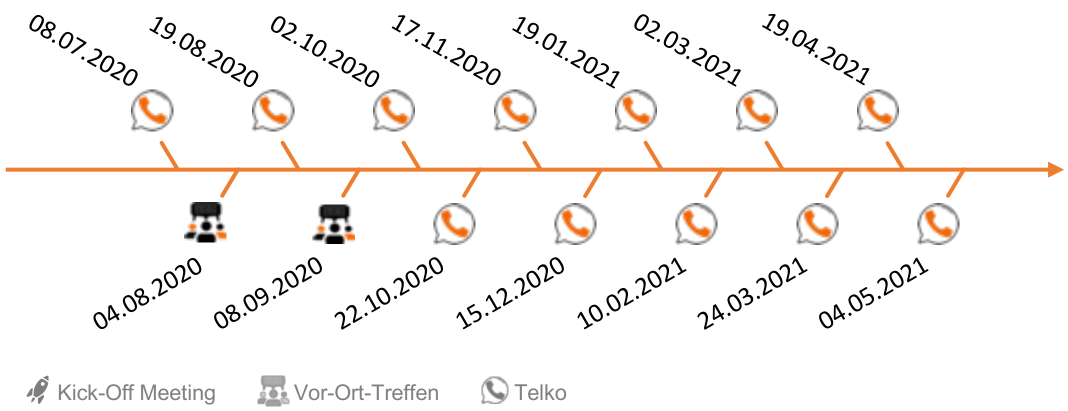
Bernhard Meyer
Gebauer & Griller

Stefan Olbrich
Mercedes-Benz

Andreas Müller
KOSTAL

Manfred Mittermeier
Rosenberger

3.6.2 Project timeline



3.6.3 Starting point/motivation

A component's product characteristics have a major influence on the automation properties within the component's assembly. As a result, the automation capability of components assembly must already be taken into account, based on relevant product- and process-specific criteria, when selecting wire harness components or in the development of new wire harness components.

A range of methods for evaluating ease of assembly already exist. These fall in the categories of methods and rules for assembly-oriented product design, methods for analysing the production process and methods for assembly planning. What is common to all of these is that the application of these methods is too general in the field of wire harness assembly and often is not applicable to the specific area of application. As a result, application of these methods does not enable adequate differentiation. This sub-project was therefore focussed on describing a general process model to identify the relevant product- and process-specific evaluation criteria for the application to determine the automation index. This involves the implementation of elements and findings from established methods in the process model.

3.6.4 Objective

To be able to consider the subsequent assembly requirements early in the product development process, the automation index must be determined as early as possible. This should generally be performed by the responsible component developer.

The aim of the automation index is to ensure that the user looks into the assembly requirements and that conflicting goals are discussed during the development of components. The result of this approach is a reproducible decision-making basis. The automation index must be determined by an interdisciplinary team within the company, headed by an appropriate moderator. It should take into account the experiences (in the form of evaluation criteria to be defined) of as many stakeholders as possible, and the industry knowledge should flow together in the form of the automation index.

Finally, there is also a need to clarify how this process is to be maintained and updated. For example, in case the technological advancements develop such that evaluation criteria determined based on the process model change at some point in time. This could be necessary, for instance, if new technologies are used that contain previously unknown individual processes. As a result, various scenarios need to be looked at to consider which organisation will continue and manage this sub-project under the aspect of solution-neutrality.

Another medium-term goal is the implementation of a detailed description of the universal process model in a DIN standard.

3.6.5 Results of project phase 2.1

As indicated by the results from phase 1, this sub-project continued to develop a process model for the technical evaluation of the automation effort in assembling HV wire harness connectors.

As a reminder: the cost-benefit analysis forms the basis for determining an automation index. This is able to check the plausibility of complex problems by quantifying the target with a utility value. This enables a statement to be made on the quality of a technical solution with regard to the technical automation effort. A cost-benefit analysis involves defining evaluation criteria are defined and assigning characteristics to them in order to determine their influence on the utility value in the form of a criteria weighting[3].

To support further definition and validation of the process model described above, a decision was made at the start of phase 2 to investigate this based on an additional component class. Besides the HV connector systems, it was decided to take a closer look at various low-voltage

[3] Also refer to the article ATZproduktion 3-4/2020 – Stefan Olbrich, Lab Hang Ren: Bestimmung des technischen Automatisierungsaufwandes [Determination of the technical automation effort]

components as an additional component class since their design and dimensions differ significantly from the HV components, but they have a large amount of overlap in the individual assembly processes. The basic idea was to check whether the application of the process model can be implemented based on the previously developed results without excessive effort. But it soon became clear that simply transferring the previously developed results is not appropriate, despite an identical process description, as the large dimensional difference of the two component classes require other characteristics to be considered.

For a utility value to be determined for the selected component class, the process model presented in phase 1 was gradually adapted based on two comparison components. When selecting the components, the use of identical and therefore comparable properties and assembly guidelines was ensured. The selection was made for a sealed contact system built by two different manufacturers. As shown in Figure 16, manufacturer A uses single-wire seals (SWS) in a cylindrical form (type 1) in its design, while manufacturer B has a rectangular design (type 2).

Figure 16: Single-wire seals of two manufacturers, cylindrical type 1 by manufacturer A on the left and rectangular type 2 by manufacturer B on the right

After inspecting all the individual process steps from the respective processing specifications, the next step was to define the evaluation criteria, followed by assignment of characteristics and weighting of the criteria based on a known approach. During these activities, the results from sub-project 1 (Design rules for the automation of the wire harness) and sub-project 2 (Design rules for plug connectors) were taken into account to identify relevant evaluation criteria.

As only the process step ‘fit single-wire seal on cable’ differed in this component comparison, this result report focuses exclusively on this individual process. As shown in the matrix in Figure 17, the result indicates the determined criteria with characteristic and weighting to arrive at a comparable utility value:

Prozessschritt: Dichtung Aufschieben

Einzeloderabdichtung auf Leitung montieren

Bewertungskriterien	Ausprägung				Gewichtung
Verfügbarkeit von Greif-/ Spannflächen an ELA	Formschluss innen	Formschluss außen	Kraftschluss		17,24 %
Werkstücksteifigkeit der Leitung	Biegung der Leitung i.O.		Biegung der Leitung n.i.O		6,9 %
Werkstückabmessungen der ELA	Länge/Wandstärke > Grenzwert		Länge/Wandstärke < Grenzwert		3,45 %
Werkstückempfindlichkeit der ELA	Materialeigenschaften ≤ Silikon		Materialeigenschaften > Silikon		20,69 %
Aufschiebbarkeit der ELA	Funktioniert -> Nachweis erbracht		Funktioniert nicht -> Nachweis erbracht		24,14 %
Verfügbarkeit von Fügehilfen	An Leitung und ELA	Nur an der ELA	Nur an Leitung	keine	13,79 %
Einzuhaltende Fügetoleranzen	Standardtoleranzen		Kleiner Standardtoleranzen		6,9 %
Toleranz der ELA in Endposition	Standardtoleranzen		Kleiner Standardtoleranzen		6,9 %

Figure 17: Evaluation criteria, characteristic and weighting for the ‘slide on seal’ process step

To determine the relevant total utility value of a process step, experts were surveyed for each evaluation criterion to determine the characteristic up to which a low automation effort can be realised. The relevant characteristic was then multiplied by the associated weighting to define a partial utility value, where the total utility value is the sum of all of the partial utility values. As indicated in the results table in Figure 18, SWS type 1 has a lower total utility value than SWS type 2. The 'fit single wire seal on cable' process step is therefore easier to automate with SWS type 1, which can also be confirmed from practical experience.

Prozessschritt: Dichtung Aufschieben

Einzeladerabdichtung auf Leitung montieren

Bewertungskriterien	Gewichtung	Merkmale ELA Typ 1	Ausprägung	Teil-nutzwert	Merkmale ELA Typ 2	Ausprägung	Teil-nutzwert
Verfügbarkeit von Greif-/ Spannflächen an ELA	17,24 %	Formschluss innen	1	0,1724	Formschluss innen	1	0,1724
Werkstücksteifigkeit der Leitung	6,9 %	Biegung der Leitung i.O.	2	0,1379	Biegung der Leitung i.O.	2	0,1379
Werkstückabmessungen der ELA	3,45 %	Länge/Wandstärke > Grenzwert	***2***	0,069	Länge/Wandstärke < Grenzwert	***4***	0,1379
Werkstückempfindlichkeit der ELA	20,69 %	Materialeigenschaften: Silikon	2	0,4138	Materialeigenschaften: Silikon	2	0,4138
Aufschiebbarkeit der ELA	24,14 %	Funktioniert -> Nachweis erbracht	2	0,4828	Funktioniert -> Nachweis erbracht	2	0,4828
Verfügbarkeit von Fügehilfen	13,79 %	Nur an der ELA	***2***	0,2759	keine	***4***	0,5517
Einzuhaltende Fügetoleranzen	6,9 %	Standardtoleranzen	2	0,1379	Standardtoleranzen	2	0,1379
Toleranz der ELA in Endposition	6,9 %	Standardtoleranzen	2	0,1379	Standardtoleranzen	2	0,1379
				1,8276			2,1724

Gesamtnutzwert

Figure 18: Comparison of the total utility values between SWS type 1 and type 2

In a next step, a threshold was determined based on the same principle with the intent of assessing the current state of the art. This time, various machine manufacturers were asked which characteristics can be achieved using today's machines. The thresholds for every machine manufacturer were also calculated using the same approach as in the previous step. The result for the threshold is shown in Figure 19.

Prozessschritt: Dichtung Aufschieben

Einzeladerabdichtung auf Leitung montieren

						Maschinenhersteller A		Maschinenhersteller B	
Bewertungskriterien	Gewichtung	Ausprägung	Teil-nutzwert	Ausprägung	Teil-nutzwert	Ausprägung	Teil-schwellenwert	Ausprägung	Teil-schwellenwert
Verfügbarkeit von Greif-/ Spannflächen an ELA	17,24 %	1	0,1724	1	0,1724	1	0,1724	1	0,1724
Werkstücksteifigkeit der Leitung	6,9 %	2	0,1379	2	0,1379	2	0,1379	2	0,1379
Werkstückabmessungen der ELA	3,45 %	2	0,069	4	0,1379	2	0,069	2	0,069
Werkstückempfindlichkeit der ELA	20,69 %	2	0,4138	2	0,4138	2	0,4138	2	0,4138
Aufschiebbarkeit der ELA	24,14 %	2	0,4828	2	0,4828	2	0,4828	2	0,4828
Verfügbarkeit von Fügehilfen	13,79 %	2	0,2759	4	0,5517	2	0,2759	4	0,5517
Einzuhaltende Fügetoleranzen	6,9 %	2	0,1379	2	0,1379	4	0,2759	4	0,2759
Toleranz der ELA in Endposition	6,9 %	2	0,1379	2	0,1379	2	0,1379	4	0,2759
			1,8276		2,1724		1,9655		2,3793

Gesamtnutzwert Schwellenwert

Figure 19: Threshold of automation feasibility for two machine manufacturers by way of comparison

In a final evaluation step, the comparison between the total utility value and the threshold provides information on the automation feasibility of the evaluated process step. If the calculated overall utility value is below the threshold, it can be assumed that the process step for this component can be automated with low effort. For a component with a utility value above the threshold, automation of the process step is not feasible with a reasonable amount of effort. The results were once confirmed based on practical experience as both sealing elements have already been successfully fitted with automation.

3.6.6 Outlook for project phase 2.2

The next steps are to further validate the process model for the evaluation of an automation index by addressing additional components from different component classes. Due to the high complexity of the process model and the resulting considerable expenditure of time, the evaluation process needs to be streamlined to a minimum. One possible approach would be to perform a comparison to find out how the principle of an FMEA can be used to evaluate an automation index in consideration of the previously developed findings.

To achieve certainty on the quality of the results developed to date, the process will be evaluated with the assistance of the IIWH partners at the end of phase 2. The question posed to the various sectors of the wire harness industry is whether an automation index based on the concept defined by this sub-project can be implemented using the developed procedural instructions. The planned demonstration vehicle in ARENA2036 could potentially assist in this respect.

At the end of phase 2, the intention is to provide a complete description of the procedural instructions for the process model to evaluate an automation index for wire harness components. The aim is to be able to integrate a version coordinated with all the IIWH participants in a DIN standard. This description will also be made available to users as a guideline.

3.6.7 Interview with sub-project head Stephan Farnbauer

Stephan Fahrnbauer, BMW

***ARENA2036:** Just over a year has passed since the last interview. How has your sub-project developed in the most recent project phase?*

Fahrnbauer: The team has been able to achieve a really good result in the last phase. We managed to use a neutral comparison of two example components to make a quantifiable statement on the automation effort for these components.

***ARENA2036:** What would you say was the most important finding in your sub-project in the last project phase and what can you learn from it?*

Fahrnbauer: We were able to confirm all seven steps of the process model presented in phase 1, starting with the definition of the system limits through to determining thresholds. Despite the success, we observed a high level of complexity and a corresponding expenditure of time in working through the model, which may stand in the way of an industrial implementation. To counter this, we will intensify our focus on simplifying the mechanisms for determining the automation index in the coming phase. The principle of an FMEA could be a good approach in this respect.

***ARENA2036:** In recent months, a significant amount of energy has been spent on the 'DIN standard' sub-project. What did you and your team contribute?*

Fahrnbauer: Together with the DIN working group, we set ourselves a very challenging schedule to complete the draft standard by mid-August, a period of only around eight months. To meet this milestone, the team in the sub-project decided that we would focus more on commenting on and developing the topic blocks in the document. As a team, we intensified and prioritised our activities during the final phase in the last three months through to the submission of the draft standard.

***ARENA2036:** Was the effort worthwhile? The submission date could simply have been postponed.*

Fahrnbauer: The huge effort paid off. We managed to achieve the set milestone with a huge amount of commitment and outstanding team performance. Given the central role that the standard plays in the shift towards automated wire harness production, timely completion was extremely important. In my opinion, a postponement would just have shifted rather than relaxed the situation. More time does not automatically lead to higher quality.

***ARENA2036:** Many thanks for your time and the interesting conversation.*

Sub-project 5
Automation of quality control

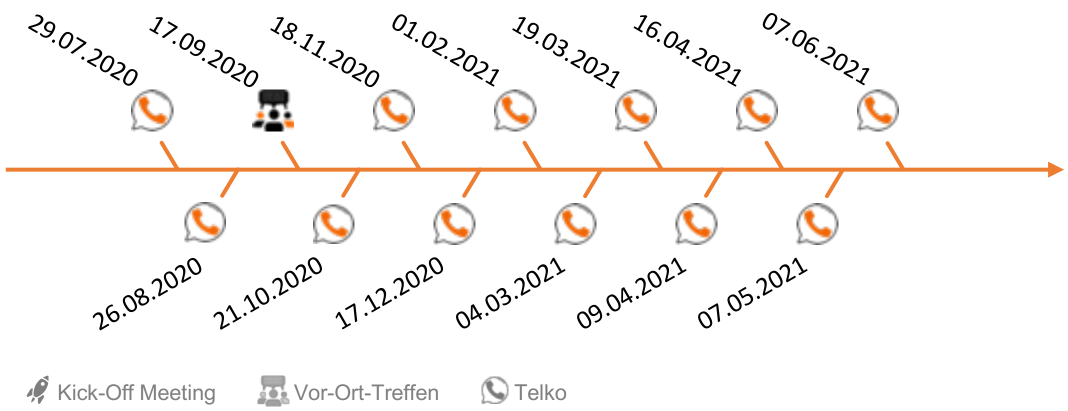
3.7 Sub-project 5 Automation of quality control

3.7.1 Participants

Matthias Otte (Sub-project Head)
Komax

Peter Marks *BMW*	**Marco Schweizer** *Mercedes-Benz*	**Stefan Neubauer** *Schäfer*
Johann Scherer *BMW*	**Hermann Schötz** *Nexans*	
Robert Schneider *Dräxlmaier*	**Manfred Mittermeier** *Rosenberger*	

3.7.2 Project timeline



3.7.3 Starting point/motivation

The envisaged quality of a finished product is usually ensured in wire harness production by an end-of-line test (EOL) on an electrical test table (ETT).

In upstream sub-processes, such as cutting and crimping, state-of-the-art in-line process monitoring is possible. The quality data collected here are usually documented in relation to batch sizes. However, any existing quality features, such as the assembly alignment and positioning of components, are checked again in the end-of-line test.

Increasing miniaturisation poses a great challenge for workers, both physically and mentally. Complex reworking due to possible sequential errors requires manual removal and repositioning during the end-of-line test, which places mechanical stress on the wire harness.

By translating 100% consistently documented and automated test steps into corresponding production steps, it is possible to create the technical basis for carrying out quality assurance in the intermediate steps of the ongoing production process.

This review was conducted for the production of wire harnesses in the low-voltage application case and will be expanded to include the high-voltage application segment.

In addition, another approach involves supplying the management shell with the data generated by the process to prevent duplicate checks in the value chain and its interconnected steps.

3.7.4 Objective

The aim of the sub-project was to investigate the extent to which it is possible to move away from the requirement of a mandatory 100% end-of-line inspection in automated production and to what degree the desired automation of inspections can already be achieved during the production process. Possibilities were identified for seamless quality assurance through automatic monitoring and documentation of the individual production and testing steps.

This was accompanied by a quantification of the potentials arising from the elimination of quality assurance measures in manual production up to and including the elimination of final inspections.

In addition to the aspects of technical feasibility, it was equally important to consider and demonstrate the associated cost implications on an abstract basis.

The design rules were updated (establishment of premises) and reviewed in this respect to ensure that they can be implemented with the manufacturing technology in the automation machinery. Moreover, a white paper was drafted, which establishes the framework for the future testing requirements and test development.

3.7.5 Results of project phase 2.1

The features of components and assemblies of a wire harness were considered with regard to the test criteria, test methodology and implementation. The necessity of an end-of-line test was also considered and whether the verification of the test results up to the component is necessary within the scope of traceability.

The goal of the sub-project is to reduce the scope of the end-of-line test. As a result, the necessary innovations and requirements with regard to the design of the wire harness and its components were defined and considered based on the automation of the wire harness.

Another focus of phase 2.1 was on transferring the developed results to design rules as contents for DIN 72036. As a first step, a system for structuring the design rules was developed and adopted in working group 51 of the standardisation committee.

This foundation was used to develop and assign target values to 18 design rules. Measurement criteria were defined for every target value, which were used to check compliance with these targets. Due to the significant amount of effort involved in harmonising the contents of all the design rules, three rules relating to quality were initially included in the first draft of DIN 72036.

3.7.6 Outlook for project phase 2.2

The design rules from phase 2.1 will gradually be expanded to include the high-voltage area for shielded and unshielded cables as well as charging sockets, high frequency for CAN FD and automotive Ethernet; the guidelines will then be transferred to DIN 72036. The approach follows the one developed in phase 2.1.

The automation of wire harness production and the associated digitisation of all information inflows is an important factor for success. The management shell is a promising approach within the scope of Industry 4.0, which is being pursued across all sub-projects and is consolidated in sub-project 11. The aim is to develop information models from the perspective of quality and allow these to flow into the management shell.

3.7.7 Interview with sub-project head Matthias Otte

Matthias Otte, Komax

ARENA2036: *How did the work in phase 2 of the sub-project change compared to phase 1?*

Otte: The 'Automation of quality control' sub-project was initially tasked with moving the automated quality control from the end-of-line test to the value creation point. The work on DIN 72036 shifted the focus from 'How specifically can this be implemented?' to the question of 'How should quality features be considered as part of automation?'.

ARENA2036: *You are referring to the design rules for DIN 72036. What effect do you believe these design rules will have on wire harness production?*

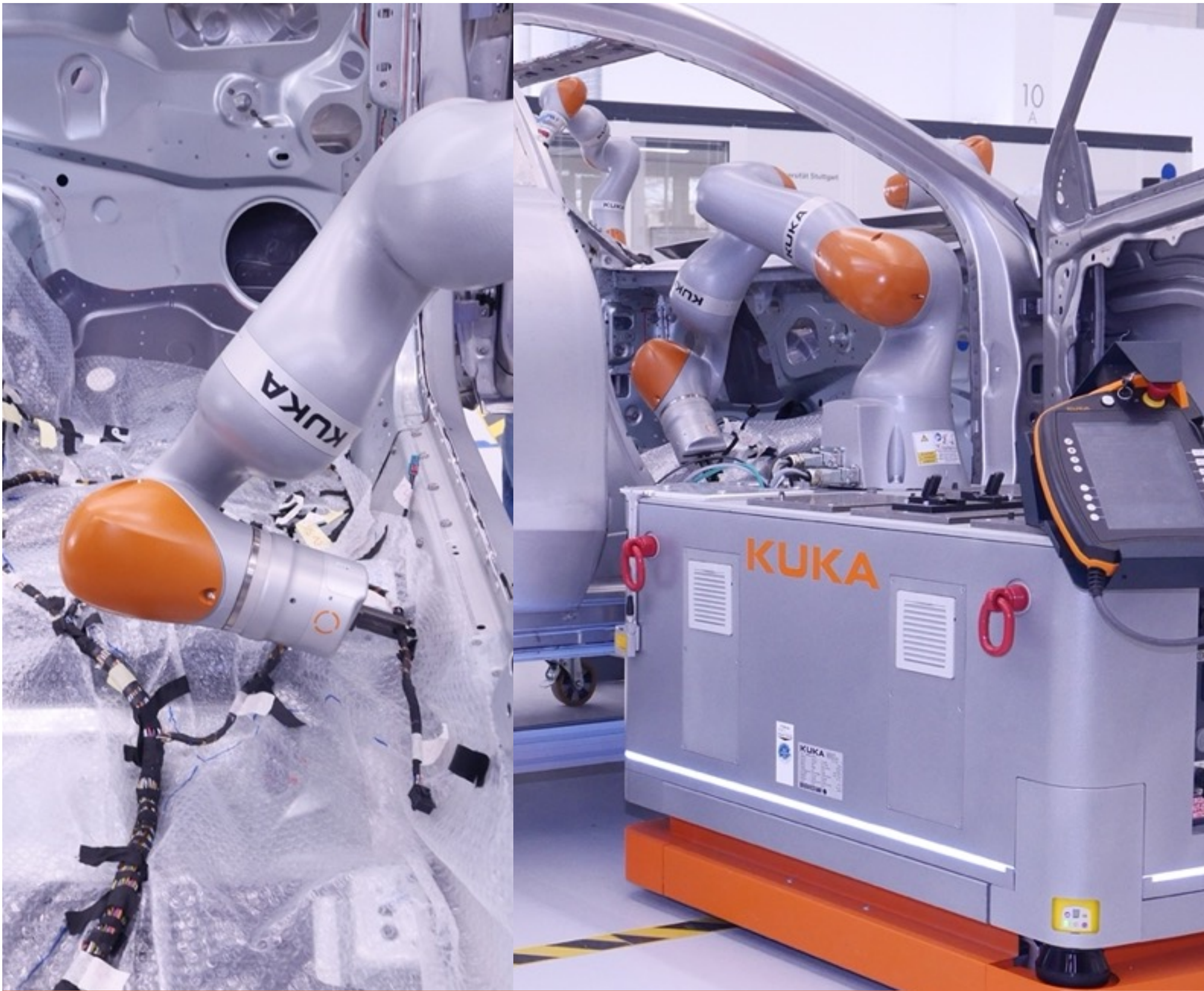
Otte: For one thing, the advancement of automation in wire harness production and the associated consistent implementation of DIN 72036 requires a consistent reduction of the component diversity together with a reduction in the wire harness structure. DIN 72036 provides a framework that enables this to be ensured from development through to assembly in the vehicle, thereby supporting the consistent advancement of automation.

ARENA2036: *What are the challenges in the 'Automation of quality control' sub-project?*

Otte: The sub-project will primarily pursue two objectives. Firstly, the high-voltage and high-frequency components need to be considered and corresponding design rules developed and assessed with regard to production. On the other hand, this sub-project will become increasingly digital with the integration into the management shell.

ARENA2036: *We wish you every success! Thank you for the interview.*

Otte: Thank you.



Sub-project 8
Automated assembly of the wire harness in the vehicle

3.8 Sub-project 8 Automated assembly of the wire harness in the vehicle

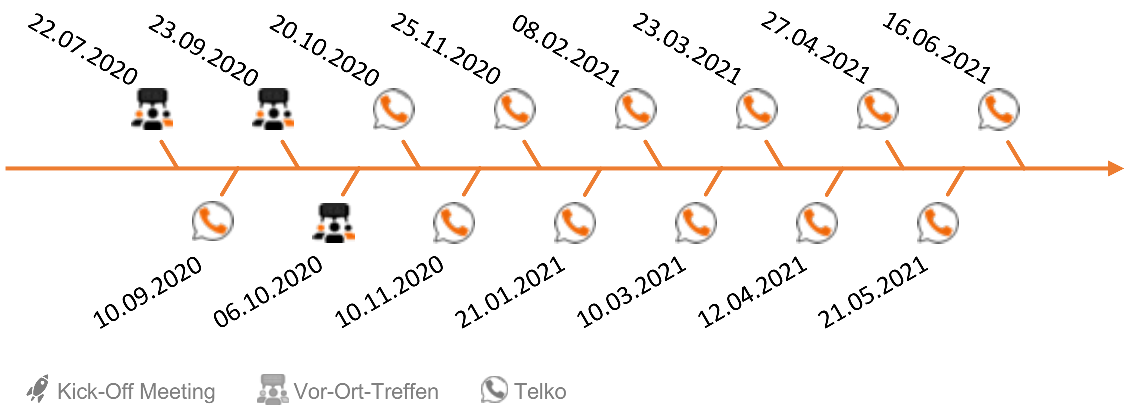
3.8.1 Participants

Christian Steiler (Sub-project Head)
BMW

Matthias Paukner (Joint Sub-project Head)
Kuka

Michael Wortberg *Dräxlmaier*	**Bernd Weiß** *Mercedes-Benz*
Uwe Hessler *Kromberg & Schubert*	**Manfred Mittermeier** *Rosenberger*
Michael Heinrichs *Kuka*	**Markus Wnuk** *ISW*
Jerome Trommnau *Mercedes-Benz*	**Manuel Zürn** *ISW*

3.8.2 Project timeline



3.8.3 Starting point/motivation

The assembly of wire harnesses in vehicles is a labour-intensive manual activity today. Due to the size and weight of the wire harness, it can easily be damaged. Manual installation also leads to variance in the exact laying of cables as well as to possible errors in the correct connection of the wire harness.

Last but not least, the great complexity of the wire harness binds up many cycles (time factor) in manual assembly because plugging in the large number of cable ends or connectors and fastenings, such as clips, is very labour- and time-intensive.

Since the wire harness is one of the first components to be installed in the vehicle, error correction at a later stage is very costly.

3.8.4 Objective

The assembly of the wire harness in the vehicle represents a relevant field of application for automation from an OEM perspective. This does not mean eliminating human labour from assembly per se. Rather, the aim is to use robotics to relieve the strain on the worker caused by unergonomic and/or monotonous activities as well as to identify possible applications for modern human-machine collaboration models. Furthermore, the aim is also to determine the assembly parameters, so that continuous quality recording, traceability and, if necessary, early reworking are made possible.

The assembly of the wire harness should therefore not necessarily become faster and more efficient; the aim is rather to increase quality in the assembly process and relieve the strain on the worker.

3.8.5 Results of project phase 2.1

A sample wire harness was defined back in phase 1, which is intended to representatively show all the features of a series-produced wire harness. But it also had to be more compact as well as neutral in terms of the supplier and vehicle. The four most common variants of retaining parts, pickups of varying thicknesses and lengths, different cable cross-sections and different windings were selected. Every fastening part and each pickup received a unique ID as shown in Figure 20.

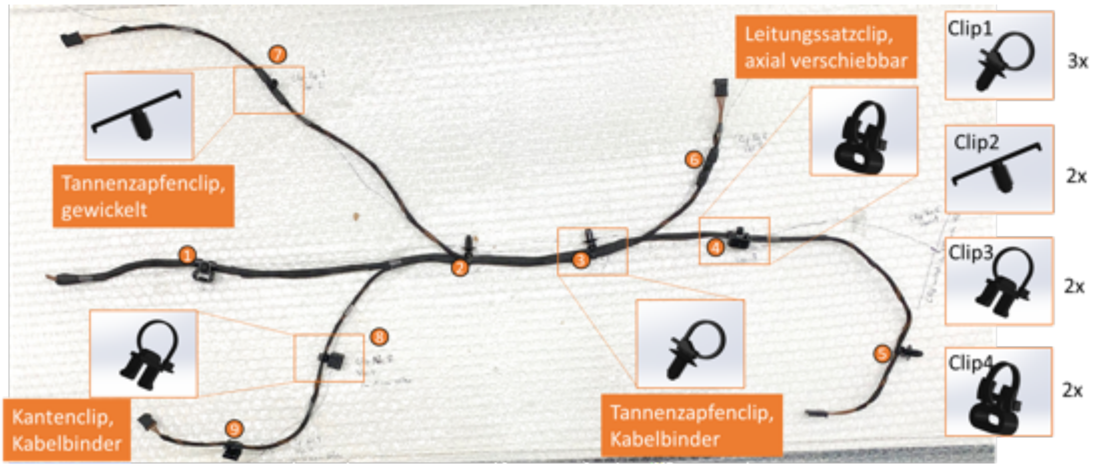


Figure 20: Sample wire harness from sub-project 8

Due to the effects of the coronavirus pandemic, the envisaged target area for installing the wire harness was recreated using a sample plate. This allowed the laboratories of the Institute for Control Engineering of Machine Tools and Manufacturing Units (ISW) at the University of Stuttgart (rough localisation) as well as the KUKA Systems Augsburg laboratories (fine localisation and assembly) to both work on the solution in parallel. To position the sample wire harness inside the car body and on the sample plate as precisely as possible, it was attached to a carrier foil using adhesive strips. The concept that was subsequently developed involved first identifying the position of the wire harness with camera-supported rough localisation. The positions of the clips to be fitted are then sent to the robot. In a next step, the precise position and orientation is defined (fine localisation) and the clip is picked up and fitted.

Rough localisation

The Institute for Control Engineering of Machine Tools and Manufacturing Units (ISW) at the University of Stuttgart was commissioned with the rough localisation given its broad expertise in the area. A centrally fastened stereo camera system determines the position of the wire harness using multibody simulation, as shown in Figure 21. Previously defined target points on the wire harness correspond to the position of the clips to be fitted and are transferred to the robot via an interface.

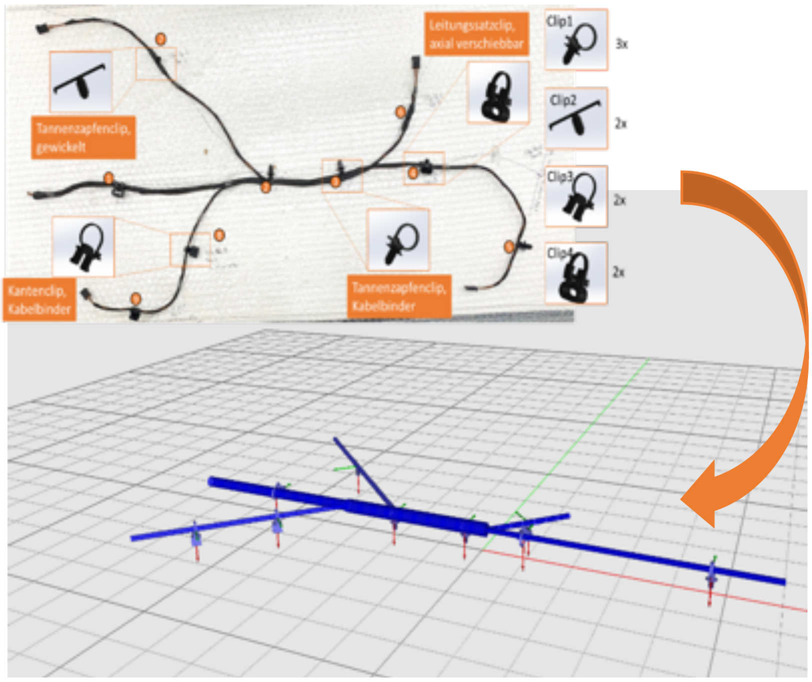


Figure 21: Rough localisation

As a one-off measure, the coordinate system of the rough localisation must be aligned with the robot, shown in Figure 22. This is performed by attaching a calibration pattern to the robot end effector.

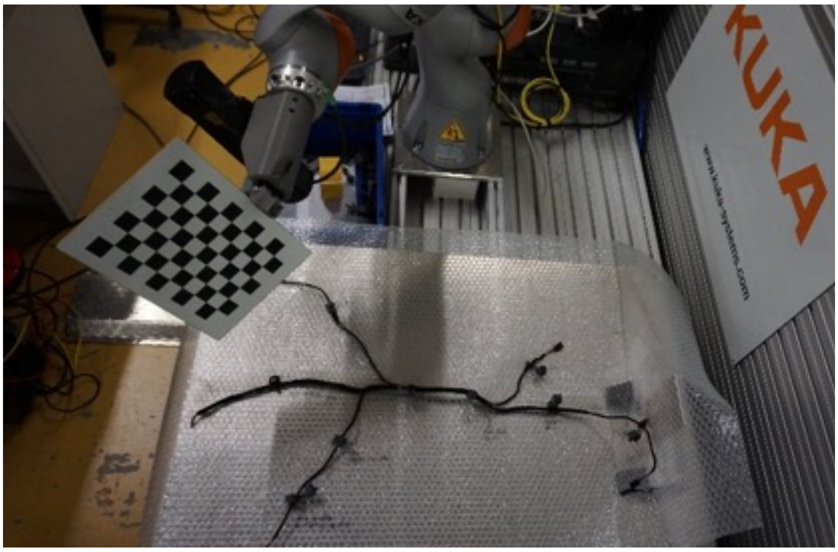


Figure 22: Calibration

Interface between rough and fine localisation

The interface was defined, programmed and successfully tested together with ISW employees during a 2-day workshop in the KUKA Augsburg laboratory. Agreement was reached on a client/server architecture for transferring the target position determined by the rough localisation to the industrial robot's control unit.

Fine localisation

A stereo camera fastened to the robot's gripper is used to localise the target object. As the mass-produced clips are neither reliably detected nor do they have a gripping surface for a parallel gripper, modified clips were drafted and manufactured using 3D printing. This took place using objects attached to the mass-produced clips, which have a distinct shape on all sides. They have parallel surfaces so that they can be reliably gripped by a robot gripper. The fine localisation starts at the target position supplied by the interface and returns the precise target position and orientation of the clip.

Gripping and fastening

The collaborative and sensitive lightweight robot LBR iiwa with 14 kg load capacity was selected as a robot. An electric parallel gripper was attached as well as a stereo camera system for fine localisation. The gripping jaws were designed especially for the adapted clips and produced by 3D printing. After transferring the target position, the clips are gripped (shown in Figure 23) and fitted in the defined hole in the target position, which is permanently programmed in the robot control.

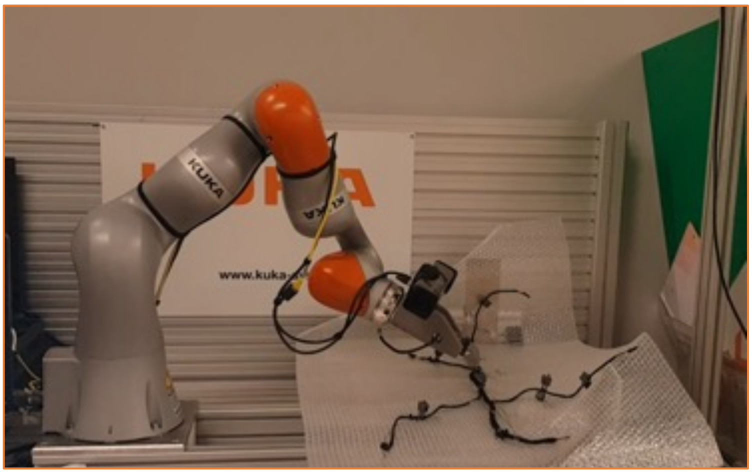


Figure 23: Gripping and fastening

3.8.6 Outlook for project phase 2.2

The demonstration vehicle is to be moved from the laboratory to ARENA2036. This means that a car body provided by an OEM will be used instead of the sample plate as described in the last chapter. The process for assembling the modified clips will be maintained for the time being and improved using the sensitivity of the robot as well as the gripper.

Practical investigation will be continued, and other concepts will also be assessed. For example, this may involve bringing the foil holding the wire harness into the car body.

The demonstration vehicle will also be made available to other sub-projects as a test device. This may, for example, be the automated assembly of modified plugs.

3.8.7 Interview with sub-project head Matthias Paukner

Matthias Paukner, Kuka

ARENA2036: *Mr Paukner, you work in the TecCenter at KUKA Systems. What were the greatest challenges in automating the assembly of the wire harness in the vehicle for you?*

Paukner: We initially focussed on detecting, gripping and connecting the clips. The biggest problem was that they did not have defined gripping surfaces and were difficult for a vision system to detect. So we designed clips to which a combined detection and gripping element was added. For the tests, we manufactured them on our 3D printers and were able to successfully test them.

ARENA2036: *These modified clips are more expensive due to the additional material and are certain to hamper installation in the body. How are you looking to solve this?*

Paukner: This can certainly not be the final solution and is merely intended to drive the development of a clip modification suitable for mass production. For example, the removal and recycling of the detection cube would be conceivable.

ARENA2036: *Why are you using a sensitive and collaborative lightweight robot without actually making full use of its abilities?*

Paukner: For the initial test with a fixed sample plate, we were able to do without the sensitivity. But any number of tolerances will be added once we position the clips in a car body. These can be compensated for by the robot and corrected in the direction of the hole axis. We also need the force sensors to improve the process reliability. This starts with detecting whether we have actually picked up the clip through to the OK criterion when joining the clip in the associated hole.

ARENA2036: *Thank you for the interesting insights.*

Sub-project 10
Digital product description

3.9 Sub-project 10
Digital product description

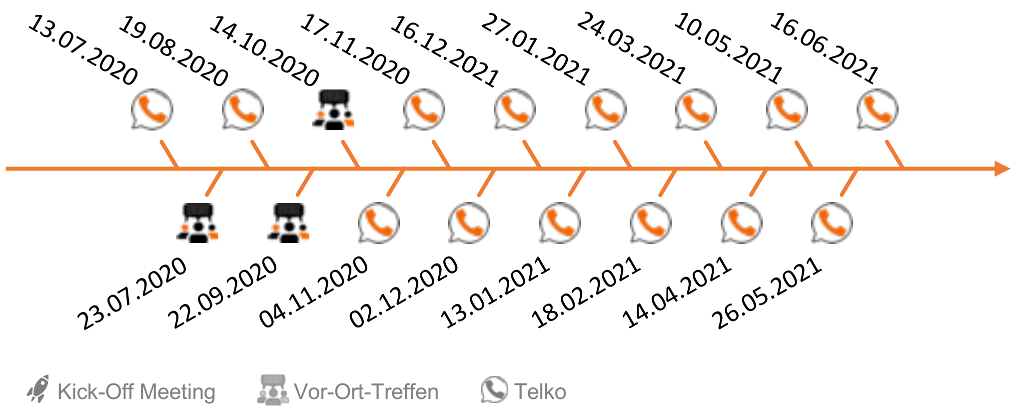
3.9.1 Participants

Dr Martin Pöschl (Sub-project Head)
BMW

Michael Richter (Joint Sub-project Head)
Siemens

Stefan Kreitmeier *BMW*	**Liane Michelsons** *KOSTAL*	**Bernd Jost** *Schleuniger*
Franz Stöckl *Dräxlmaier*	**Bernd Weiß** *Mercedes-Benz*	
Richard Böhm *Gebauer & Griller*	**Dr Helmut Steinberg** *Nexans*	
Matthias Otte *Komax*	**Hendrik Blei** *Schleuniger*	

3.9.2 Project timeline



3.9.3 Starting point/motivation

The general field of activity of sub-project 10 is to identify and leverage existing potential in the context of automated wire harness production based on the foundation of a digital product description.

To do so, the sub-project uses the open data format standards KBL and VEC as a basis, as these are specifically aligned to the digital description of wire harnesses and their components and are already being widely used, especially in the automotive industry. But the motivation behind specification of the KBL and VEC data formats as well as their use is not to evaluate the suitability of a wire harness specification or the contained components for automated production. Other aspects were critical in this respect, such as the opportunity to evaluate the technical design or the support of release, logistics and change processes.

This makes the sub-project the first known stakeholder to consider the KBL and VEC data formats within the scope of automated wire harness production. In light of this, the sub-project is looking at all questions that arise in both the specific application of the data formats as well as their specification.

3.9.4 Objective

The substance of sub-project 10 builds on the results of other sub-projects. The overarching goal is to identify how the KBL and VEC data formats are to be applied so that all of the wire harness design requirements established by the other sub-projects can be digitally evaluated. This is based on the conviction that digital evaluability will eventually be the key factor in effectively and efficiently considering the defined requirements in industrial application.

If a corresponding digital representation is fundamentally possible, sub-project 10 will use this as a basis to formulate formalised rules and recommendations for the digital product description. The background here is that the KBL and VEC data standards are generically specified in many respects. As a result, they do not establish enough hard specifications for the digital product description from the perspective of automated production. The sub-project therefore aims to define data profiles that contain the refined rules and recommendations.

If digital representation is not possible, sub-project 10 will submit corresponding requests to the responsible standardisation committees to extend the KBL and VEC data formats and will subsequently supervise the standardisation process.

3.9.5 Results of project phase 2.1

In project-phase 2.1, the sub-project was focussed on supporting the creation of the new DIN 72036. For the design rules contained in the standard, the sub-project derived as an initial result data requirements for the digital product description that are independent of the data format. The sub-project then projected these requirements onto the KBL and VEC data formats and ultimately defined three data profiles, as shown in Figure 24:

- VEC-based data profile for wire harness components
- VEC-based data profile for wire harnesses
- KBL-based data profile for wire harnesses

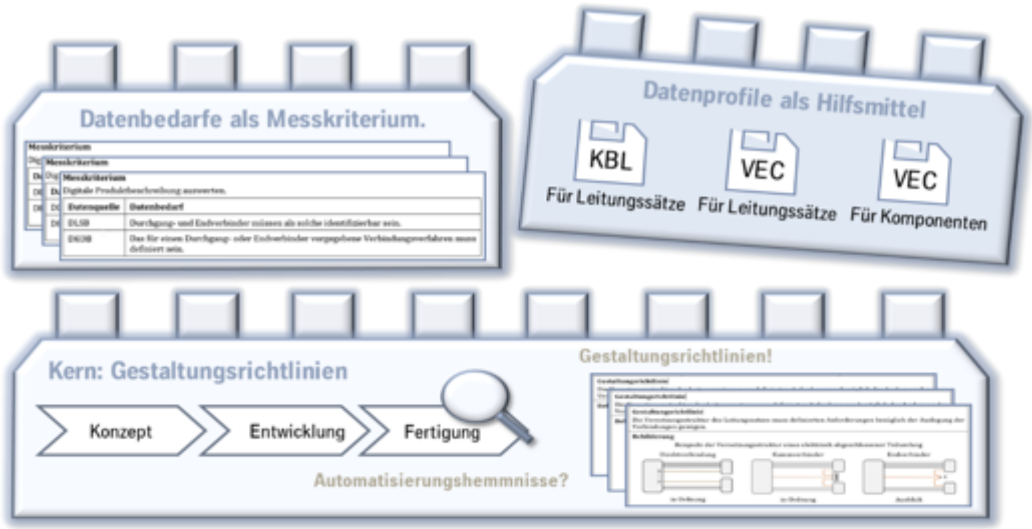


Figure 24: SP 10's contribution to the standard 72036: Data needs and data profiles

Figure 25 shows the specific content of the data profile definitions. For instance, the VEC-based data profile for wire harness components requires the digital representation on the master data side of whether the defined component rules are observed for all components of a wire harness addressed by standard 72036. This allows the data profile to ensure an evaluation of whether a wire harness contains non-compliant components.

VEC-basiertes Datenprofil für Leitungssatzkomponenten (VEC Für Komponenten)

Komponente	Dateninhalt	Standard VEC	Datenprofil
Übergreifend	Einhaltung der definierten Komponenten-Gestaltungsrichtlinien	Optional	Verpflichtend
Stecker	Position und Orientierung der Kammern	Optional (im VEC zu erweitern)	Verpflichtend (sobald verfügbar)
	Länge der Kammern	Optional (im VEC zu erweitern)	Verpflichtend (sobald verfügbar)
Elektr. Leitung	Farbe der Isolierungen	Optional	Verpflichtend
	Nennquerschnitt	Optional	Verpflichtend
	Leitungstyp	Optional	Verpflichtend
...	...	...	...

KBL und VEC basierte Datenprofile für Leitungssätze (KBL Für Leitungssätze, VEC Für Leitungssätze)

Dateninhalt		Standard KBL und VEC	Datenprofil
Verbinder	Ausführung Endverbinder oder Durchgangsverbinder	Optional	Verpflichtend
Leitung	DMU-Länge	Optional	Verpflichtend
	Bei verdrillten Leitungen die maximale Entdrilllänge	Optional (im VEC zu erweitern)	Verpflichtend (sobald verfügbar)
...	...	...	...

Figure 25: Object and content of the data profiles

The figure also shows why it was necessary to define multiple data profiles. The KBL data format exclusively targets the digital wire harness description. It is suitable for representing all relevant requirements in the context of automated wire harness production that affect the use of components in the wire harness and their interrelationship. Examples include the design of a connector or the cable length in the wire harness. The VEC data format additionally enables a digital description of the wire harness components, completely independent of the wire harness and in a high level of detail. As a result, a data profile for wire harness components is only defined in the standard for this data format.

The envisaged uses of the data profiles defined in the standard essentially extend to all stakeholders involved in development and production (see Figure 26). The reason for this is that the data profiles explicitly clarify which data are fundamentally needed in the process in the context of automated wire harness production and how they are digitally represented. This provides an orientation for all stakeholders, prevents unnecessary iteration loops and can support the development of useful tool solutions across the industry.

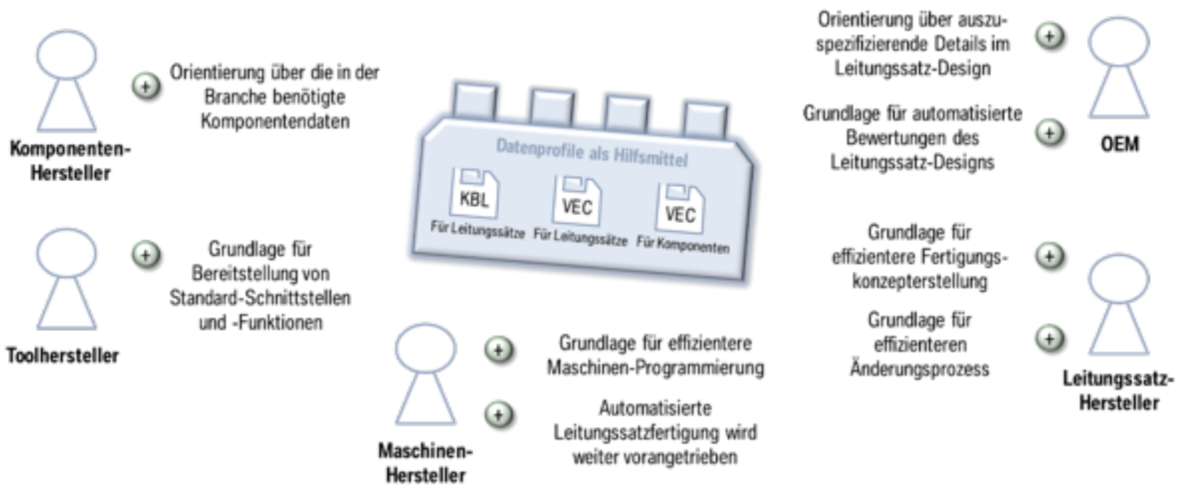


Figure 26: Envisaged uses of the data profiles

3.9.6 Outlook for project phase 2.2

Project phase 2.2 will now continue down the established path and update and expand the data profiles in coordination with the other sub-projects. This is based on all the activities for creating a new version of DIN 72036, such as the envisaged scope extension, e.g. to the high-voltage range, as well as all new topics, such as the introduction of an automation index.

3.9.7 Interview with sub-project head

Dr Martin Pöschl, BMW

ARENA2036: *Dr Pöschl, your sub-project has undergone an enormous transformation since phase 1. What were the reasons for this?*

Dr Pöschl: In fact, the sub-project was launched in 2019 under the name 'Wire harness component library'. The reason for this was the certainty that significantly more component data would be needed to evaluate the automation capability of a wire harness design. For example, we were already aware relatively early on that for every connector chamber we would need the geometric position of the entrance point in a digitally evaluable form. This is not currently supplied by the existing geometry models as well as the KBL and VEC data formats. But, over time, it became clear that the analogue situation also essentially exists at the level of the digital wire harness description. So the logical step was to expand the scope of the sub-project accordingly and also change its name.

ARENA2036: *It seems astounding that a 'Digital product description' sub-project would be needed in 2021. Does this mean that designs are still being developed using pen and paper?*

Dr Pöschl: No, of course not. The industry has been successfully using KBL and VEC for digital wire harness and component description for many years. But, in many cases, the product and component properties relevant for automated wire harness production are based on data that established processes and work methods have not required in digital form to date. So it is no surprise that the relevant digital data are not being generated and exchanged. And it is also no wonder that the KBL and VEC data formats need to be extended in a few areas.

In light of this, the 'Digital product description' sub-project has set itself the task of creating transparency concerning the required digital wire harness and component data for the context of automated wire harness production. And I think that we have been very successful with DIN 72036 and the defined data profiles. What's more, we looked at identifying existing gaps in the KBL and VEC standards and defining associated expansion requirements for standardisation.

ARENA2036: *You spoke about the sub-project's contribution to the new DIN 72036. I can imagine that the task was quite demanding, as the data profiles defined in the standard are highly dependent on the design rules also defined in the standard.*

Dr Pöschl: Yes, it was certainly not easy. At its peak, up to 20 authors were working on the document in parallel. This alone brings a whole range of challenges. For example, there was the matter of agreeing on uniform terms and ensuring that the terms had the same meaning for everyone. You wouldn't believe how many discussions were held for the term connector, for instance, whether this can or should also refer to a plug connector.

In this configuration, the content aspect effectively adds another dimension. The standard obviously had to be free of redundancies and contradictions – this was already a challenge within every chapter, but it also had to be ensured across the chapters. And the contents of the data profile definitions naturally depend on the design rules defined in the standard.

But the collaboration across all the stakeholders in the project was outstanding. What's more, I am convinced that the quality of the standard benefitted significantly from the discussions resulting from the content-related dependencies. The contribution made by the 'Digital product description' sub-project was to ensure that every design rule guideline was formulated based on clearly defined and digitally evaluable measurement criteria and targets. In addition, we also always checked whether this content is traditionally part of the wire harness design.

ARENA2036: *Did you enjoy the work?*

Dr Pöschl: It was an unbelievable experience – and yes, the work was really enjoyable. And I also think that it was worthwhile.

ARENA2036: *Dr Pöschl, can you give us a brief look into the future. What topic will your sub-project tackle next?*

Dr Pöschl: The sub-project will continue to focus on the standard. I believe that there is no doubt that an updated version, likely also with an extended scope, will be released in the foreseeable future. In this case, the 'Digital product design' sub-project will have the same tasks in the new, expanded context.

ARENA2036: *Dr Pöschl, many thanks for the interesting conversation.*

Dr Pöschl: Thank you.

Sub-project 11
Continuous digitisation

3.10 Sub-project 11
Continuous Digitisation Process Chain

3.10.1 Participants

Michael Richter (Sub-project Head)
Siemens

Bernd Weiß (Joint Sub-project Head)
Mercedes-Benz

Alexander Salinas
Dräxlmaier

Martin Widmaier
Kromberg & Schubert

Pavel Nosek
Siemens

Clemens Volker
Gebauer & Griller

Moritz Altner
Mercedes-Benz

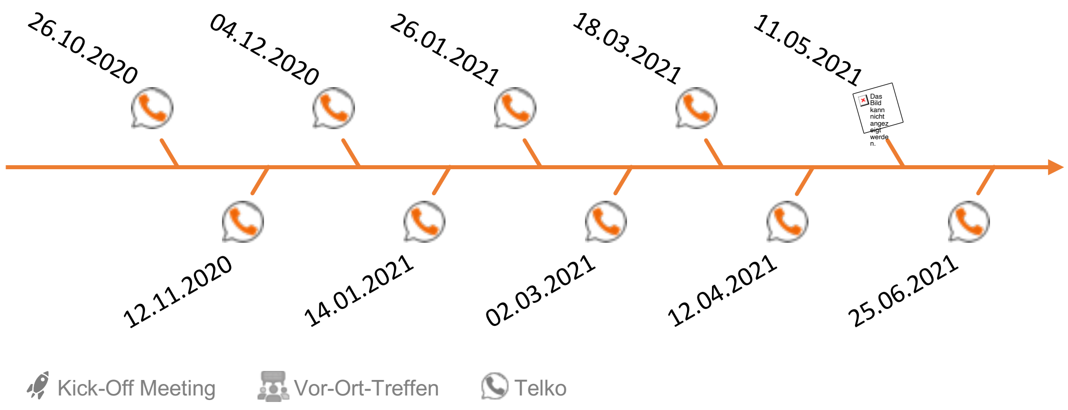
Phillipp Lauber
Komax

Hendrik Blei
Schleuniger

Miguel Rodriguez
Komax

Bernd Jost
Schleuniger

3.10.2 Project timeline



3.10.3 Starting point/motivation

The wire harness is one of the most expensive single components in today's automobiles.

Despite its enormous complexity, both the development processes and, in particular, the production processes involve a considerable amount of manual work and media discontinuity in the modification, approval and exchange of the individual fragments of its digital sub-twins.

In order to realise the continuous and cross-company representation of a holistic digital twin, a solution for managing and linking these fragments is required.

The management shell developed by the Industry 4.0 platform could represent a solution for this linkage for a mapping to the automotive wire harness value chain.

3.10.4 Objective

The goals were joint exploration of the topic and drafting of a white paper to present the current state of the art in relation to applying the management shell of the Industry 4.0 platform[4] to the value chain in automotive wire harness development.

3.10.5 Results of project phase 2.1

The outcome of project phase 2.1 is the white paper on the application of the management shell to the value chain.

The white paper describes 12 fields of action to be considered in future phases:

1. Information models
2. Product description (KBL, VEC, BOM, SBOM, BOP)
3. Means of production (equipment, plants, tools)
4. Implications for the conceptual integration of the management shell
5. Infrastructure, data infrastructure (Gaia-X)
6. Production control (OPC UA, SiOME, etc.)
7. Enrichment of the management shell in the product development process
8. Governance, roles, rights, scope, integrity
9. Relevant assets in the wire harness
10. List of potential cooperation partners and organisations
11. Overview of relevant available solutions/tools
12. Definition of demonstration/practical example(s)/field report

[4] See WG 1 'Reference architecture, standards and standardisation' of the Industry 4.0 platform www.plattform-i40.de

3.10.6 Outlook for project phase 2.2

In phase 2.2, the fields of action described in the white paper – shown in Figure 27 – are to be further specified and extended within the framework of several projects funded by project applications for the economic stimulus package 35c.

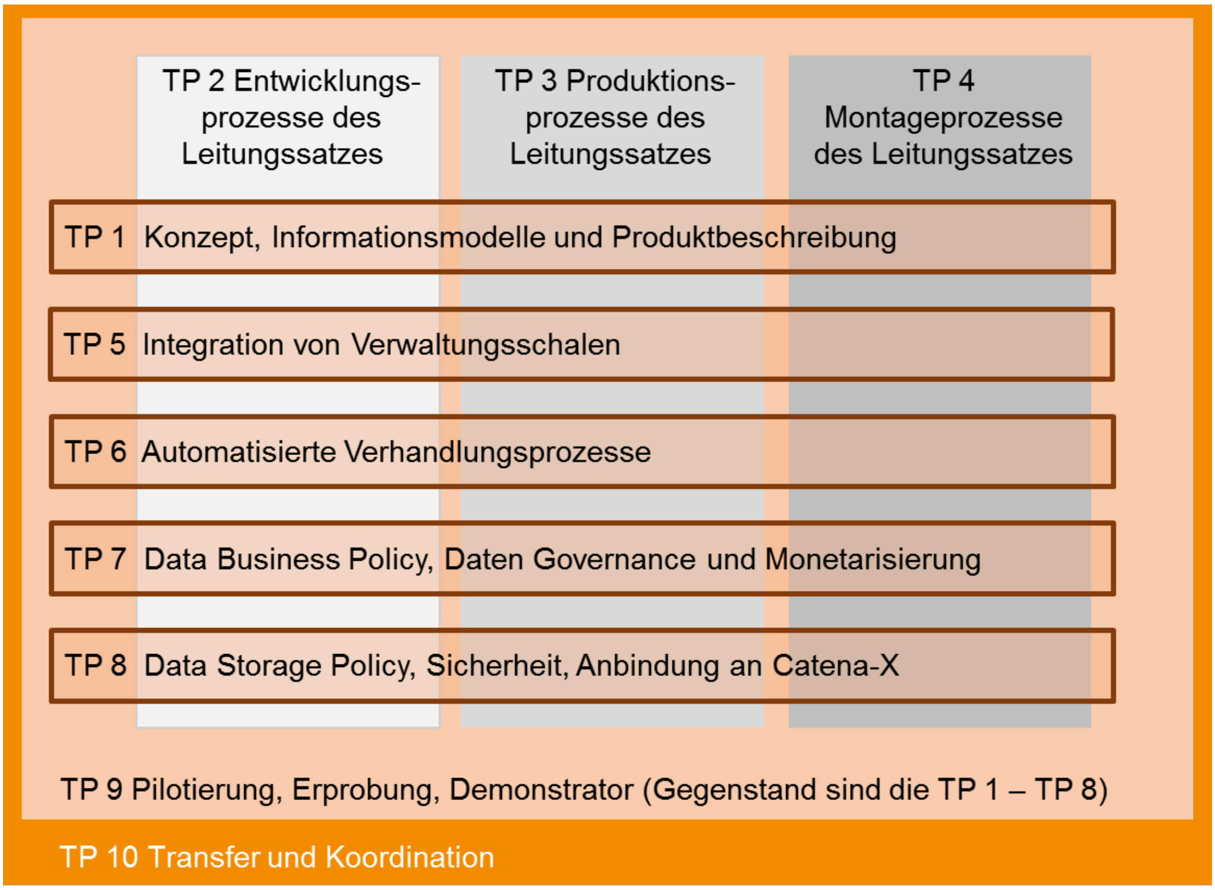


Figure 27: Project structure of the planned joint project 'VWS4LS' ('Management shell for wire harnesses')

Until the start of the 35c projects, sub-project 11 will be continued for transition to and organisation of the next steps.

3.10.7 Interview with sub-project head Michael Richter

Michael Richter, Siemens

ARENA2036: *Can you tell us a bit about your sub-project 11 'Digital process chain' and its goals?*

Richter: The goal of sub-project 11 was to draft a white paper on current approaches for mapping a continuous digital process chain to the value chain of the automotive on-board electrical system.

ARENA2036: *The automotive industry has obviously been successfully developing and producing wire harnesses for its vehicles for many years. What was the motivation behind tackling this topic?*

Richter: These days, electrical systems are developed in a range of processes and work steps, some of which occur in completely separate silos. In Germany, thanks to defined data exchange standards such as KBL and VEC, we at least have the possibility of exchanging the results of these steps electronically. However, there are often media discontinuities when transferring the data within the company, and particularly across companies, making a continuous link that spans the individual areas much more difficult, if not completely impossible.

ARENA2036: *You are referring to, for example, the data transfer from the OEM to the tier 1?*

Richter: Exactly. But there are a whole range of additional transfers that often don't take centre stage. What is important here, for example, is the interaction between the component suppliers and the tier 1 suppliers and OEMs as well as relationships between the production to the utilisation cycle of the product and its recycling.

ARENA2036: *Why is this problem so relevant now?*

Richter: The challenges have been discussed for a long time. But, in the past, many of these deficits could often be offset by the use of additional resources, manual steps and local solutions. Due to the continuously increasing complexity of the systems together with the rising requirements in relation to quality, verification, validation and continuous documentation, additional work will no longer be sufficient to compensate for this in future.

ARENA2036: *What is the source of these enhanced requirements?*

Richter: The higher expectations of the customer in relation to safety, comfort, update-capability and online availability is driving the complexity of the systems. At the same time, topics such as high-voltage systems and autonomous driving require new approaches and more complex solutions in relation to architecture, availability and safety.

One important driver, which we are working on in the IIWH, is the move towards automated production of wire harnesses, which places significantly higher demands on data availability and data quality in production than is required in the current, primarily manual production processes.

ARENA2036: *Sub-project 11's white paper takes a close look at the management shell of the Industry 4.0 platform and its application for the wire harness. What are the benefits of using the management shell?*

Richter: The management shell offers a whole range of benefits.

First of all, it enables the joint management and interlinking of existing partial data from development (e.g. KBLs, VECs) and other data artifacts, including even the requirements documents and the process data from production, for example.

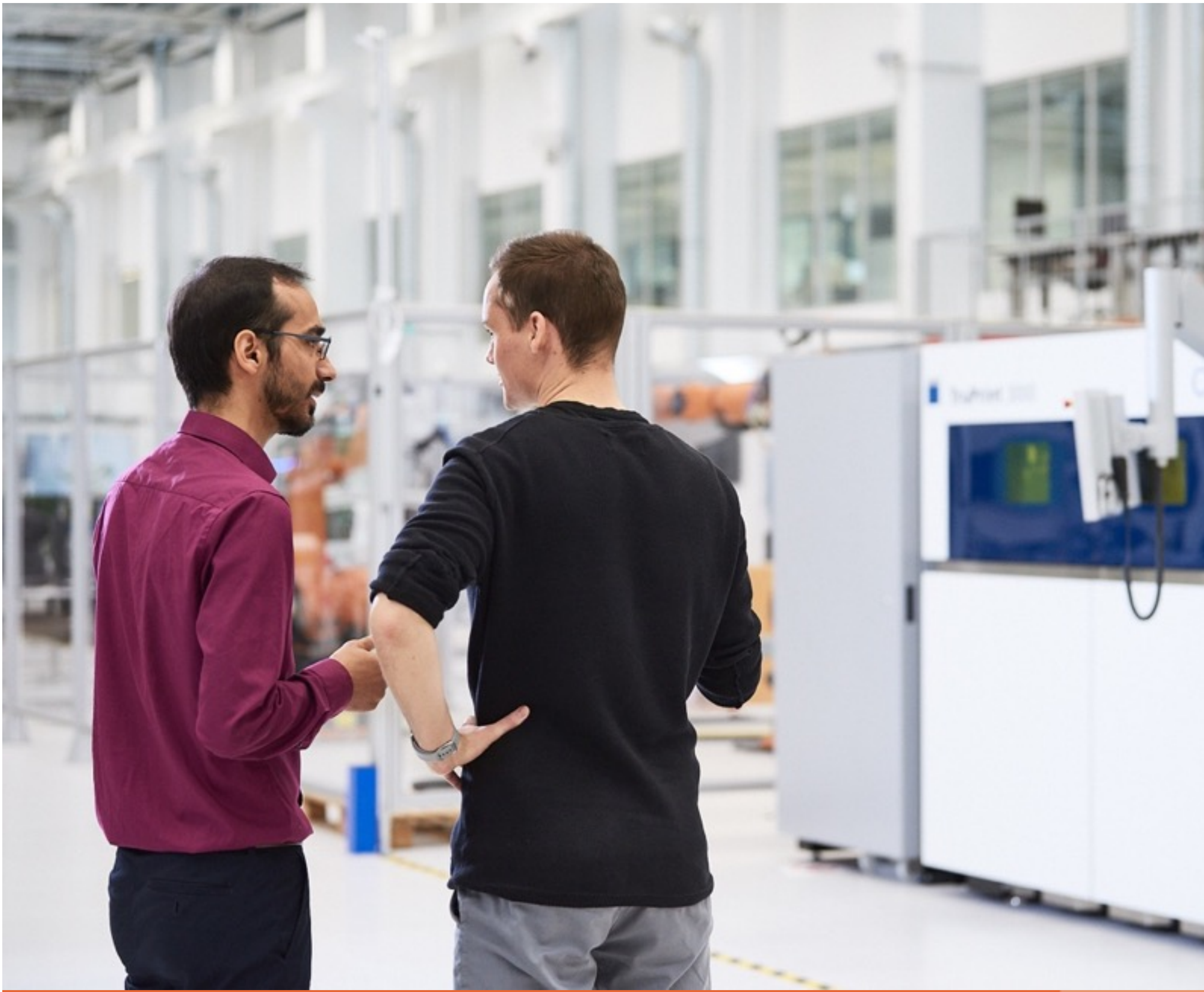
Together with other projects, such as GAIA-X and Catena-X, this creates an inter-company infrastructure, where the wheel does not need to be reinvented for every aspect and which is being advanced by a powerful group of companies from the automotive industry.

ARENA2036: *What are the next steps in SP11?*

Richter: Based on the design fields identified in the white paper, we have established a series of sub-projects as part of a funded overall project. IIWH sub-project 11 will be a consolidated representative of these sub-projects and continue to actively support the work.

ARENA2036: *Mr Richter, thank you for the interview.*

Richter: Thank you very much.



4 Prospects for phase 2.2

(July 2021 to June 2022)

4.1 Roadmap for phase 2.2

In phase 2.2, the Innovation Initiative Wire Harness enters its third year. Phase 2.2 will once again last for 12 months and is based on a comprehensive planning process for the content and budget resulting from the assessment of the progress and the results of phase 2.1 (see chap. 2). The structure of phase 2.2 is effectively identical, as shown in the following figure.

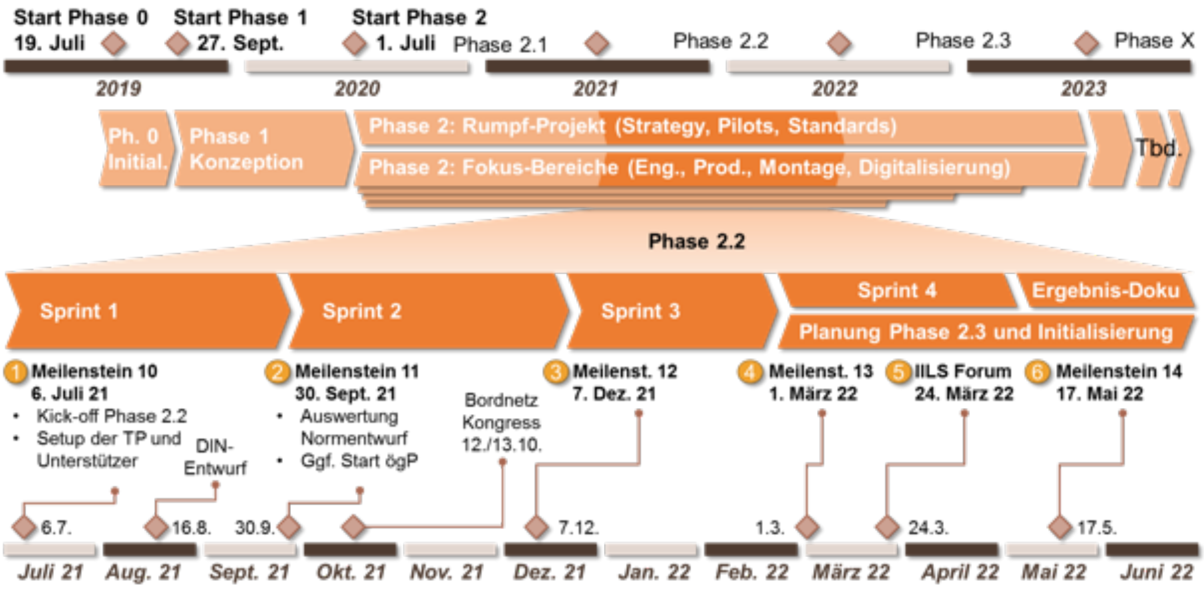


Figure 28: IIWH roadmap and derivation of the milestone dates for phase 2.2

The roadmap shown in Figure 28 has the same periods between milestone meetings as phase 2.1. These will once again also be joined by several measures to **transfer results** in phase 2.2:

- On 22 September 2021, several presentations at the 'small' on-board electrical system conference in Landshut were contributed by the Innovation Initiative Wire Harness, although, given the 120 participants, it was 'small' only relative to the Ludwigsburg Conference. This allowed several sub-project heads to present the work of the IIWH as well as its relevance for practical application.
- On 12 October 2021, an additional presentation was held at the Ludwigsburg Automotive Wire Harness Conference. The IIWH used this opportunity to provide an overview of the overall progress of the initiative.
- The next IIWH forum will take place on 24 March 2022. At this full-day event, the Innovation Initiative Wire Harness provides the opportunity to participate in a 'deep dive' across all sub-projects and discuss questions directly with the sub-project heads.

The reporting of VDI nachrichten also needs to be mentioned in connection with the transfer of the results: on 10 September 2021, VDI nachrichten published a very well-written two-page report on the IIWH.[5]

[5] See: VDI Nachrichten No 36 from 10 Sept. 2021, pages 6 – 7.

4.2 Content focus areas: expansion and configuration

The spectrum of topics at the level of development, production, assembly and digitisation also provides the framework for phase 2.2. All existing sub-projects will be continued within this framework in phase 2.2. The focus is on expansion and smooth continuation of the excellent work. The existing sub-projects will essentially continue their work along the same core questions on which the former work was focussed. In particular, these include the following questions:

- What must a wire harness look like so that it can be (more) easily **automatically manufactured** and assembled?
- What does this mean for the **components** of the wire harness?
- What does this mean for the interfaces to the **periphery** of the wire harness?
- Which **parameters** are required in the development process so that the developer can **verify** whether his design complies with the **design rules** and is thus **automation-friendly**?
- How can the wire harness be structured, **modularised** and **untangled**?
- How can the wire harness be divided into **automatable production units**?
- How can we **quantitatively compare** which components can be processed more efficiently using automation?
- How can we ensure that the **quality assurance** of all work phases can be realised directly **inline**?
- How can we meet the **demands** of traceability of the production steps using automation?
- How can the wire harness be automatically **installed in the car body**?
- How can the components of the wire harness be **digitally described**?

Many of the answers to these questions are presented at the sub-project level in chapter 3. Many more answers will be added during phase 2.2. However, new questions also arose during phase 2.1:

- Which basic concepts exist for the **automated production** of a wire harness? What could **automated production** effectively look like?
- What will the **supply chain** and logistics of the future look like with automated production?
- What does a continuous **digital process chain** need to look like so that an automated machine knows what it is supposed to produce?
- How can automation help improve **sustainability**?

These questions will now be addressed. The following new sub-projects were launched as scheduled at the start of phase 2.2:

- **Production process and equipment**: The aim here is, particularly from the perspective of the assemblers, to assess the basic concepts and approaches of automation with regard to the specific requirements of the wire harness and derive requirements that support general implementation, especially with regard to the need for standardisation.

- **Logistics processes**: This is being managed by the Institute of Mechanical Handling and Logistics of the University of Stuttgart and will determine the possible approaches for automating key transport and handling tasks, especially at the interface between assemblers and OEMs.
- **Continuous digitisation**: This topic covers the three focus areas of digital twins, digital process chains and the digitisation of change management.
- **Sustainability**: This looks at factors and influencing variables as well as how they are changed by automation approaches, particularly with regard to the carbon footprint (German Supply Chain Act).

The 'Production' and 'Logistics' sub-projects will continue to work on the content identified during the preparatory phase (peer group) and develop specific approaches.

The 'Continuous digitisation' sub-project will also continue on with the results from the preparatory phase – in this case, the potential of the management shell approach for the digital continuity of the supply chain was developed in a white paper. Due to the successful application for a publicly funded joint project 'Management shell for wire harness VWS4LS', this sub-project will be flanked by a separate consortium for 3 years; however the final funding decision is still outstanding. This project will also create a bridge to Catena-X, so the value chain of the wire harness may also benefit from this flagship project.

The 'Sustainability' sub-project will investigate the interactions resulting from automation of the value chain in terms of sustainability. This will commence with a preparatory phase, the results of which will be collected in a white paper. Automation is expected to offer a range of benefits from a sustainability perspective, but it will also involve additional challenges.

Another area of focus is a greater emphasis on the potential of automation with regard to **high-voltage** wire harnesses and components. In this case, the partners are pursuing the declared goal of expanding on the existing focus on the low-voltage area. A conscious decision was made not to establish a separate sub-project and instead configure high voltage as a cross-cutting topic across several existing sub-projects. This will ensure that high voltage solutions are as consistent as possible with low voltage solutions and that specific high voltage approaches are only added where the framework conditions clearly differ. Initial activities based on this model have already commenced in the sub-projects. As a flanking measure and to standardise and make the individual activities transparent across the various sub-projects, the partners will establish a dedicated point of contact role for this cross-cutting topic with the appointment of one or two experts. Looking forward, this model could – if feedback is positive – also be transferred to the high frequency area, for example.

4.3 Publication and further expansion of the DIN standard

Probably the most important milestone in phase 2.2 will be the publication of DIN standard 72036.

The draft standard will be published in October 2021. The following public commentary phase will last until the end of 2021. The comments received then need to be assessed within the scope of the DIN working group and revisions implemented. Just like during the drafting of the standard, these adjustment measures will be headed by the sub-projects and partners of the Innovation Initiative Wire Harness, which will submit well-prepared proposals to the DIN working group. These proposals will naturally be jointly discussed with other members of the working group. The DIN working group will obviously have the 'final word' on the best implementation of the changes.

The scope of the comments is not currently foreseeable. However, the experience with the VDA indicates that a majority of the work involved in preparing the draft standard has been completed and the revision phase will be completed during phase 2.2 (target: end of the first quarter). Realistically, the IIWH partners should be able to look forward to a complete, published standard at the milestone 14 meeting on 17 May 2022.

But this does not mean that the standard is done and dusted. Even today, the plan is for the standard to be extended. Firstly, with new results from the existing sub-projects and, secondly, with the results of the new sub-projects. This means that many of the results and much of the progress in phase 2.2 will once again serve as a substantive basis for standardisation.

The IIWH plans to comprehensively expand DIN standard 72036 with a new release in 2023. The results of phase 2.2 will form an important basis for this new release. For example, the following extensions of content are currently in the pipeline:

- Additional design rules for the design of the wire harness and the components
- Design rules and/or approaches for separating and deriving modules for automated production
- Design rules for automating the inline quality assurance (traceability)
- Methodological approaches for quantifying the automation capability at the component level (automation index)
- Reference process model for the key sections of the value chain (esp. development process, manufacturing process, assembly process, digital interoperability)

Further contributions are expected from the new sub-projects, but these cannot currently be defined. In any case, the DIN standard is likely to undergo a significant expansion.

4.4 The IIWH remains open to new partners

The Innovation Initiative Wire Harness is not pursuing an explicit growth interest, but it is fundamentally open to additional partners that are interested in actively contributing to the success of the major transformation task of automation in the spirit of precompetitive cooperation. Several partners have already joined and are enriching the collaboration with their own contributions and additional expertise – a win-win for all involved.

At the start of phase 2.2, two more industry heavyweights, TE and Yazaki, joined the IIWH, as well as the medium-sized enterprise Wezag. The fact that even mid-tier suppliers are seeing added value in the IIWH is pleasing and is consistent with the objective of ensuring that all partners work together on an equal footing.

The onboarding is very simple: new partners decide which sub-projects they consider a priority and name their experts who will be involved in these sub-projects. A new partner usually starts with 2 to 3 sub-projects. The expansion or adjustment of the commitment with additional sub-projects 'on the go' is possible at any time.

Once a partner has named its experts, they receive access to the joint file repository, in which the minutes of the sub-project meetings clearly show the current situation in the sub-project. A bilateral onboarding meeting is usually also held with the sub-project head. The Project Office sends new participants all scheduled meetings directly via Outlook invitation. And then it's off to work.

There are no barriers within the IIWH. Every sub-project can follow the work being carried out by other sub-projects. This setup has proven its worth multiple times, for instance, when jointly discussing the design rules.

This principle of the treating all partners equally at the content level also applies to the costs. All partners bear an equal share of the direct project costs. ARENA2036 is supplying all partners with a proposal with identical content and an identical budget for the upcoming project phase. The number of partners at the time of budgeting is decisive; in the case of phase 2.2, this is the 16 partners that defined the planning for phase 2.2 at the end of phase 2.1. The same approach applies in phase 2.2. The content and budgets for phase 2.3 will be developed in March and April 2022. As a rough guide, this is once again expected to be a middle five-figure amount. New partners that are not already members of the ARENA2036 association will also be charged the member fees.

Whatever the case: if you are interested or have any questions, get in touch with us!

5 IIWH partners in der phase 2.1

Innovation Initiative Wire Harness Partners in Phase 2.1

Aptiv Services Deutschland GmbH
Am Technologiepark 1
42119 Wuppertal
Germany

Bayerische Motoren Werke Aktiengesellschaft
Petuelring 130
80809 Munich
Germany

Robert Bosch GmbH
Robert-Bosch-Str. 2
71701 Schwieberdingen
Germany

Coroplast Fritz Müller GmbH & Co. KG
Wittener Str. 271
42279 Wuppertal
Germany

DRÄXLMAIER Group
Landshuter Str. 100
84137 Vilsbiburg
Germany

Gebauer & Griller Kabelwerke Gesellschaft mbH
Muthgasse 36
1190 Vienna
Austria

Komax AG
Industriestr. 6
6036 Dierikon
Switzerland

KOSTAL Kontakt Systeme GmbH
An der Bellmerei 10
58513 Lüdenscheid
Germany

Kromberg & Schubert Automotive GmbH & Co. KG
Raitestr. 8
71272 Renningen
Germany

KUKA Systems GmbH
Blücherstr. 144
86165 Augsburg
Germany

Mercedes-Benz AG
Mercedesstr. 120
70372 Stuttgart
Germany

Nexans autoelectric GmbH
Vohenstraußer Str. 20
92685 Floss
Germany

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