UNICARagil: Agile Development of Self-Driving Vehicles

Raphael **van Kempen**, M.Sc.; Timo **Woopen**, M.Sc.;
Univ.-Prof. Dr.-Ing. Lutz **Eckstein**
Institute for Automotive Engineering (ika), RWTH Aachen University,
Aachen, Germany

Contact: raphael.vankempen@ika.rwth-aachen.de

Content

Summary

Self-driving vehicles as part of a connected mobility system are posing completely new challenges compared to conventional driver-centric vehicles. The UNICARagil consortium has developed disruptive architectures for a future mobility system, covering all relevant domains inside and outside of the vehicle. Its modular structure in combination with adequate project organization and tools enable an agile and distributed vehicle development, which is demonstrated during the ongoing construction of four vehicle prototypes. This paper outlines the key factors enabling this agile vehicle development from an organizational and technical point of view.

1 Introduction

All over the world, both established automotive manufacturers and new entrants to the market are researching and developing connected and automated vehicles and future mobility concepts extensively. Of course, this also applies to the established German manufactures, which base their work on lots of experience and expertise. Nevertheless, having well-established structures and well-tried solutions can also be a drawback as it can possibly suppress disruptive change. This motivated a consortium of eight German universities and eight specialists from industry to put aside established solutions and start again completely from scratch. The UNICARagil project [1] is funded by the German federal ministry of education (BMBF) and research and started in February 2018.

During the first three years of project runtime, concepts have been developed and prototyped across all domains. This comprises the whole range from usage concepts and designs of four vehicle types for logistics, public transport and private mobility to E/E and software architecture as well as safety and approval. Of course, also the automated driving software, which is supported by cloud-based services, is a major part of the project.

The high complexity of the overall system "automated and connected electric vehicle" and a distribution of work packages to more than 100 scientists working at 16 partners distributed all over Germany demanded for efficient project organization and collaboration tools and processes. This paper outlines the organizational framework and the agile vehicle development process that enables the UNICARagil consortium to master this challenging task. This is only possible thanks to the extremely modular and holistic system architecture that was developed during the first years of the project.

Meanwhile, four vehicle prototypes have been manufactured based on this architecture. They are equipped with E/E components, sensors and actuators and the integration of the automated driving software has begun. For the remaining project time, the goal is the finalization and testing of the automated driving software, the integration of the different vehicle interiors and a final presentation of all four independently and automatically operating vehicles.

2 Project Organization and Structure

UNICARagil is a university-driven project supported by specialists from industry, mainly start-ups and small and medium-sized enterprises. The project partners are spread all over Germany and jointly work on the different tasks necessary to develop and build novel connected automated and electric vehicle concepts from scratch. Therefore, a decentralized project structure is needed to shape the foundation of efficient and target-oriented operation processes within the research project consortium. Consequently, there are different managing entities, collaboration and project management processes as well as development methods implemented to achieve the ambitious project targets.

2.1 Project Team

Every research project is built upon a motivated, talented and highly qualified project team. In comparison to other research projects, UNICARagil partners don't work on their own isolated work packages. They jointly work together on one large and tangible project goal, realizing four connected automated and electric vehicle prototypes without building up on proprietary structures or architectures. The common objective of hardware products to be realized forges a strong bond between all project partners and leads to an extraordinary project and collaboration culture within the consortium.
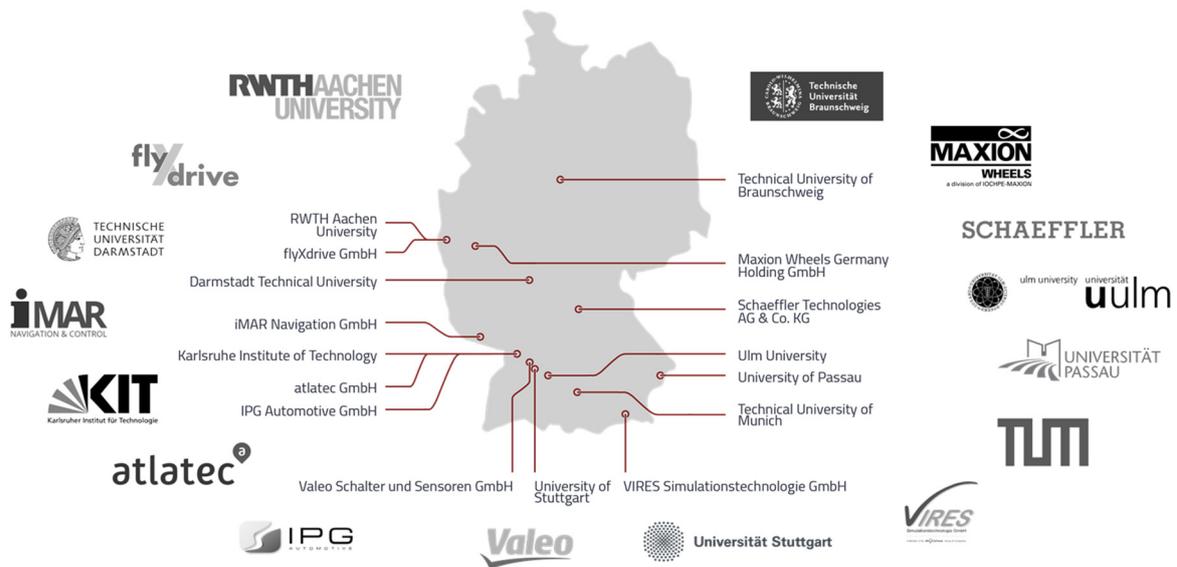

Fig. 1   Overview on the UNICARagil partners.

The project is led by the Institute for Automotive Engineering (ika) of the RWTH Aachen University. Besides the project management, ika is also conducting the project office, the design and construction of the vehicles' structure, the dynamic modules, the autoSHUTTLE and the collective cloud functionalities. Other included institutes from RWTH Aachen University are Informatics 11 – Embedded Software, responsible for the Automotive Service-oriented Software Architecture (ASOA), Institute for Flight System Dynamics, responsible for the Info Bees and the Chair of Management Accounting, responsible for the project controlling.

The Institutes of Control Engineering as well as Computer and Network Engineering from the Technical University of Braunschweig are core partners to the topic of safety, and self-perception. Additionally, the Institute of Control Engineering is responsible for the autoELF vehicle variant.

The Institute for Automotive Engineering from Technical University Darmstadt jointly works on the autoELF together with Braunschweig. They are also responsible for modular safety assurance, safe halt and vehicle control. The Chair of Physical and Satellite Geodesy is the core partner on the topic of localization. After starting at the Security Engineering Group at the Computer Science Department of TU Darmstadt, the topic of IT security moved to the University of Passau during the first half of the Project.

The Karlsruhe Institute of Technology is partner with two Institutes. The Institute for Measurement and Control is working on the topic of visual environment perception and planning within the automated driving function. The Institute of Material Handling and Logistics is responsible for the package handling within the autoCARGO vehicle variant.

The autoTAXI is built up at the Chair of Automotive Technology at the Technical University of Munich. The chair is also working on the geometrical structure of the vehicles with a focus on the vehicles' doors. In addition, the Chair of Ergonomics conducts the vehicles' ergonomics and HMI.

University Stuttgart joined the consortium with the Chair in Automotive Mechatronics. Within the project, Stuttgart is responsible for the E/E architecture, the thermal management and the brainstem hardware.

Besides KIT, the Institute of Measurement, Control and Microtechnology from Ulm University is working on the mechatronically independent Sensor Modules and the environment perception model.

In addition to the university chairs and institutes mentioned above, the consortium is supported by some specialists from industry. Atlatec GmbH from Karlsruhe is providing high definition digital maps for the automation functions. FlyXdrive GmbH from Aachen is building up the Info Bees. IPG and Vires are supporting with their simulation toolchains in the fields of controlling and the cloud environment model, respectively. iMar is an expert in satellite based localization and Schaeffler is working on the wheel hub drives for the UNICARagil vehicle prototypes. Maxion Wheels and Valeo joined the consortium as associated partners and are providing prototype wheels and supersonic sensors, respectively.

2.2   Organization Structure

As previously stated, a decentralized project structure with over 100 researchers at 18 different locations working on one project goal requires a well-rounded and understandable organization structure that is also lean in form of administration overhead. Especially for publicly funded consortia projects, project management faces some additional challenges due to the missing employment relationship compared to in-house industrial projects. In case of some escalation, one partner cannot take measures on some other partner's employees, since the ministry individually funds each partner. Therefore, the main goal of the project management entity is to fulfill the objective, by being the central correspondence between partners and managing the collaboration.

In order to achieve fruitful collaborations between the different project partners, a decentralized and domain-oriented organization structure was established.
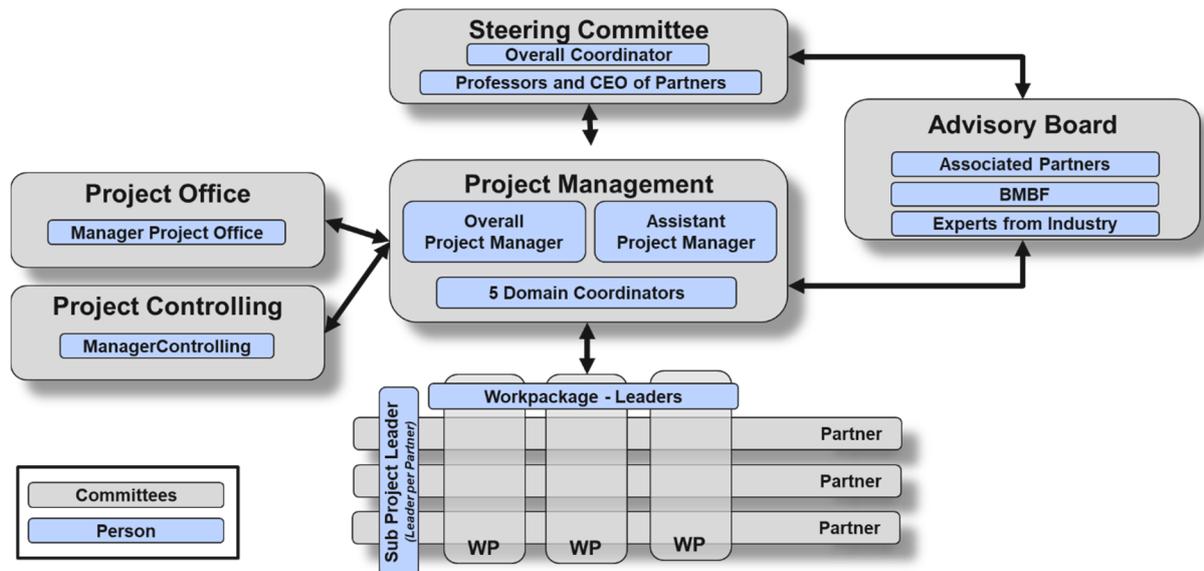
Fig. 2   Overview of the project structure.

Fig. 2 provides a schematic overview of the project organization structure. Basically, the project is structured in six main work-packages (MWP) that divide into several sub-work-packages (WP). These sub-work-packages are the main level of communication. Each sub-work-package is in the responsibility of a work-package leader (WPL). Since every partner is individually funded, each partner provides a subproject leader (SPL) additionally. The SPL are in charge of the administrative issues, like financial reporting. Together with the WPL, they form a matrix organization.

Since most of the WPs interact in different ways and multiple cross-dependencies are present, the project additionally introduced five different project domains [2].The domains focus on the topics of geometry, mechatronics, software, automation and safety. A domain coordinator (DC) is responsible for each of these domains and focusses on observing and connecting the WP dependencies and results on the domain-specific topic. The DC are part of the project management team and thus are in regular and intense contact to the project managers. The overall project is coordinated by the project manager with support of the assistant project manager. Their task is to organize and moderate the collaboration between all WPs and domains. They are supported by the DC with their specific domain expertise.

On the administrative side, the project management is supported by the project office, which is responsible for meeting organization, press relations and reporting. Additionally, the project controlling is the overall financial entity, controlling the financial progress of the project compared to time and technical progress.

Project management is directly reporting to the steering committee, which is composed by the chair or institute directors, as well as CEOs or department managers of the industrial partners. Decisions affecting the project's objective are to be discussed within the regular steering committee meetings. The advisory board is supported by an external advisory board staffed by the associated project partners, the Federal Ministry

for Research and Education and other technical experts from various automotive and IT bond companies.

The next chapter describes how these different and decentralized project entities jointly work on one collaborative project objective.

2.3   Knowledgebase and Collaboration Structure

The key to good collaboration is sufficient but lean communication processes, as the project has shown over the past years. Therefore, UNICARagil has structured its communication processes topic-dependent to reduce the number of telephone conferences and keep the meetings productive.

The main anchor for all project communication is a weekly WPL web conference. This call marks the beginning of each week of work with all leaders of the different sub-work-packages and, if necessary, the sub-project-leaders. Important aspects of the call are administrative tasks, such as the project reporting or press relations, as well as non WP-related decisions on the project proceedings and general organization. If necessary, the project management decides on building task forces on important topics discussed within the call, whereby the topic can then be discussed and decided on within a smaller group of experts and can later be presented in the WPL call.

Additionally, each WP organizes its internal communication independently or WPs join to domain web conferences. As an example, the geometry domain established weekly or bi-weekly telephone conferences since the beginning of the project, to keep all geometry-related works organized and in line.

The steering committee meets once a month in a minimum. The meeting is used to present the current project status and discuss urgent topics related to the future project progress. If a decision by the steering committee is necessary, a decision matrix needs to be prepared by the technical researchers in charge of the topic. This decision matrix gives an overview on the different decision possibilities, their expected outcome and possible consequences. The steering committee organizes semiannual advisory board meetings, in which selected project topics are presented and their impact to the industry is discussed.

At least semiannual, there are consortia meetings planned, where, in non-COVID times, parts of the consortium meet in person for several days to host workshops on different urgent topics and to report on the milestones.

The Federal Ministry is included in several of this meetings, like the consortia meetings and the advisory board meetings. Additionally, there is a regular meeting between BMBF, the project management and the overall coordinator in order to get a regular face-to-face update.

The following figure gives a brief overview on the derived meeting structure.

Meeting Type / Participants	Consortium Meeting	Advisory Board	Steering Commitee	BMBF regular Call	Work Package Leader Call	Domain Spcific Calls	Task Forces
Regularity	semiannual to quarterly	annual to semiannual	monthly	quartely to monthly	weekly	weekly to bi weekly	if required
BMBF	+	+	0	+	0	0	0
Steering Committee	+	#	+	0	0	0	0
Overal Coordinator	+	+	+	+	0	0	0
Project management	*	*	*	*	*	0	*
Project office	*	*	*	*	*	0	0
Project controlling	+	0	0	0	+	0	0
Domain Coordinators	+	#	+	0	+	*	#
Work Package Leaders	+	0	#	0	+	#	#
Project researchers	+	0	0	0	0	#	#

*	organization
+	mandatory participation
#	participation if necessary
0	no participation required

Fig. 3   Overview on the project meeting structure.

The above mentioned meeting structure is highly relevant for all project partners, in order to stay informed about the current work progress. Nevertheless, an official reporting structure is implemented in the system for multiple reasons. Firstly, reporting to BMBF is a mandatory key element in the funded research project, in order to justify the funding. Secondly, regular reporting is needed for the project controlling entities to keep track of the project progress and adjust project plans if necessary. Therefore, a sequential reporting system is implemented.

Within UNICARagil, every report is based on sub-work-package level. There are reports on a monthly, quarterly and annual basis. Each report summarizes the work package progress of the report period in the categories of technical, time and financial progress. Additionally, a risk management process referring to DIN ISO 31000:2018 [26] was established within the project reporting.

1. Monthly report:
    a. Formalized quarter-pager per WP
    b. Progress on: technical development, time consumption
    c. Risk assessment
2. Quarterly report:
    a. Formalized one-pager per WP
    b. Progress on: finances, technical development, time consumption
    c. Risk assessment
    d. Additional statements by project management and project controlling
3. Yearly technical report
    a. Written report
    b. Technical progress and time consumption only
    c. Partner specific

With all the necessary meetings and reports, documentation of open questions and decisions gets very important. Even more important is the documentation of the technical progress and the results of single working tasks. Especially regarding software and hardware interfaces, different work packages rely on each other, so that a solid knowledge base needs to be built upon is required. Therefore, Confluence [27] is used as a collaboration tool, which suits multiple purposes:

- Central place for meeting minutes and discussion protocols
- Central place for project reporting and milestone documentation
- Organizational documentation
    - PR materials
    - Contact data
    - Financial overviews
    - Time plans
- Technical WP documentation and collaboration

The following workplace structure evolved during the past years and proved its feasibility in other projects adapting the UNICARagil structure, as well.
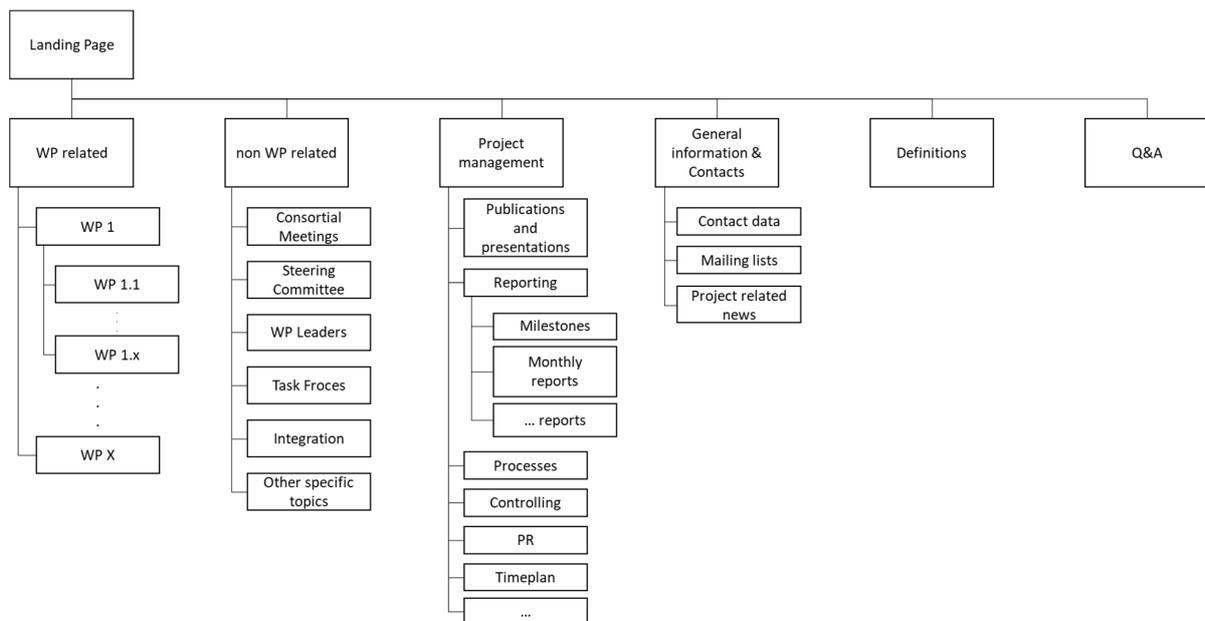

Fig. 4   Overview on the collaboration workspace structure.

The described project structure and organizational requirements laid a solid foundation for the agile and highly parallel connected and automated vehicle development within the UNICARagil project.

3 Agile Vehicle Development

Cost reduction has always been a key driver for innovations in automotive production. To keep development and manufacturing costs within a limit that is accepted by customers, it is desirable to re-use components whenever it is possible. Therefore, most carmakers base their model range on the same platform or a common modular kit. OEMs often buy in self-contained components comprising software and a dedicated ECU from Tier 1 suppliers. This has led to a bloated network of various control units, communication protocols and interconnections. Several analyses estimate that this cannot cope with the growing proportion of E/E and software in automated vehicles and a consolidation of ECUs (e.g. into few domain ECUs) is expected [22], [21], [24]. Consequently, several developers from potentially many different entities will have to integrate software using shared resources. This requires efficient tools for collaboration and coordination of interfaces in combination with a middleware that orchestrates the software modules.

Mastering the high system complexity in terms of safety and approval is also a key challenge for developing automated vehicles. While UNICARagil also addresses modular strategies for safety and approval [3], [20], this chapter will focus mainly on geometry, mechatronics and software.

3.1 Modular System Architecture

Within the UNICARagil project [2], automated vehicles are rethought from the beginning. Modularity across all domains creates flexibility in the application of automated vehicles and makes it possible to address various use cases based on e.g. the same platform, sensor and dynamics modules [4].

The vehicles are part of a user-centric connected mobility system (cf. Fig. 5). An end-to-end digital interaction concept creates a convenient user experience. Control room operators are monitoring a fleet of automated vehicles to ensure constant availability [18]. If required, they are able to bring the vehicle to a halt at a safe location at any time.

Cloud services extend the vehicle automation [13]. A combination of environment information [14] from vehicles, infrastructure and the info bee [28], a sensor-carrying drone, creates a collective environment representation that enables cooperative driving. Additionally, by collecting data from the fleet, it is possible to continuously analyze and improve algorithms.
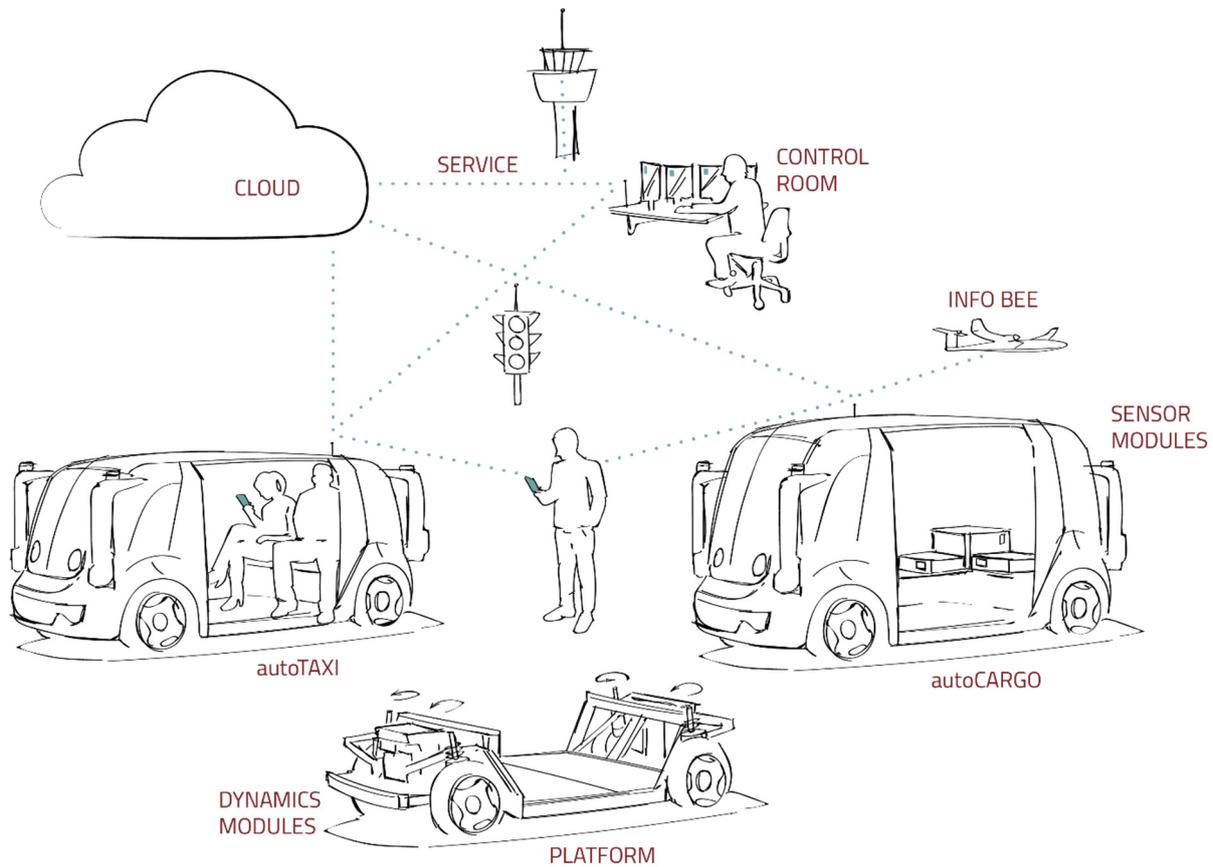
Fig. 5   The overall UNICARagil mobility system.

3.2   Scalable Geometric Architecture

Four exemplary use cases are actually prototyped in UNICARagil, but many more are conceivable:

- Using a flexible network of stops, the **autoSHUTTLE** integrates rural areas into public transport [8].
- The **autoTAXI** has a ridesharing option and provides the adequate interior for each travel reason, e.g. for working during the ride [9].
- Using an efficient storage system, the **autoCARGO** solves the last mile for delivery between parcel centers and customers [10].
- The **autoELF** is an individual private vehicle. Its inclusive use concept makes automated driving accessible for all people [11].

All applications are based on a common mechanic platform [7] that is scalable in length and contains the wiring and components for energy, computing and cooling. Add-on modules, which are scalable in height, adapt the vehicle to a specific use case, e.g. for public transportation, logistics or private use. Sensors and actuators are packaged into modules with defined interfaces, which makes them exchangeable and upgradable.

The intertwining of E/E architecture and geometric design required intensive coordination and several iterations but lead to a highly integrated but still modular and versatile platform.

3.3   Modular E/E Architecture

Automated driving requires a vast amount of sensors, actuators and computers that run the AD software. Changing one component usually affects several other components in both hardware and software. It is desirable to reduce dependencies to a controllable extent and to ensure that changes only affect a small group of people. Therefore, closely related software modules are executed on a shared domain ECU (cf. Fig. 6) in UNICARagil.

Each of the four **dynamics modules** of each vehicle is a fully functional entity. It comprises a wheel-hub drive, brake, steering and suspension as well as a dedicated ECU. This runs speed and steering controllers that can be accessed by the trajectory controller using specified interfaces. The ECU monitors its health status and an emergency stop controller is able to bring the vehicle to a safe halt in case of a degradation [19].

A **sensor module** [6] comprises an inertial measurement unit, one lidar and two radar sensors as well as one stereo camera and to RGB cameras. This means a large amount of data being generated during the ride. Therefore, the sensors are directly coupled with a dedicated sensor module ECU that processes the data and runs localization and perception algorithms such as AI-based object detectors. The self-monitoring recognizes degradation of the sensor module's capabilities, which can be considered in other services, e.g. for route planning or to initiate a safe halt.

The **cerebrum** ECU combines the environment representations and localization of all sensor modules. In combination with a HD map of the traffic infrastructure, a maneuver is chosen and a trajectory is generated and sent to the trajectory controller running on the brainstem ECU. Additional services are provided by an off-board **cloud backend**, which is connected via 5G mobile communication.

The **brainstem** is the safety-critical ECU. It runs the trajectory controller and a self-awareness service that monitors the overall system and is able to initiate a halt at a safe location using a fallback environment perception using simple sensors in the platform at any time. While dynamics and sensor modules provide a degree of redundancy due to their number, the brainstem ECU has a duo-duplex architecture, which makes it fail-operational [17].

An Ethernet ring that interconnects all ECUs and a redundant power supply [16] are both part of the safety strategy.
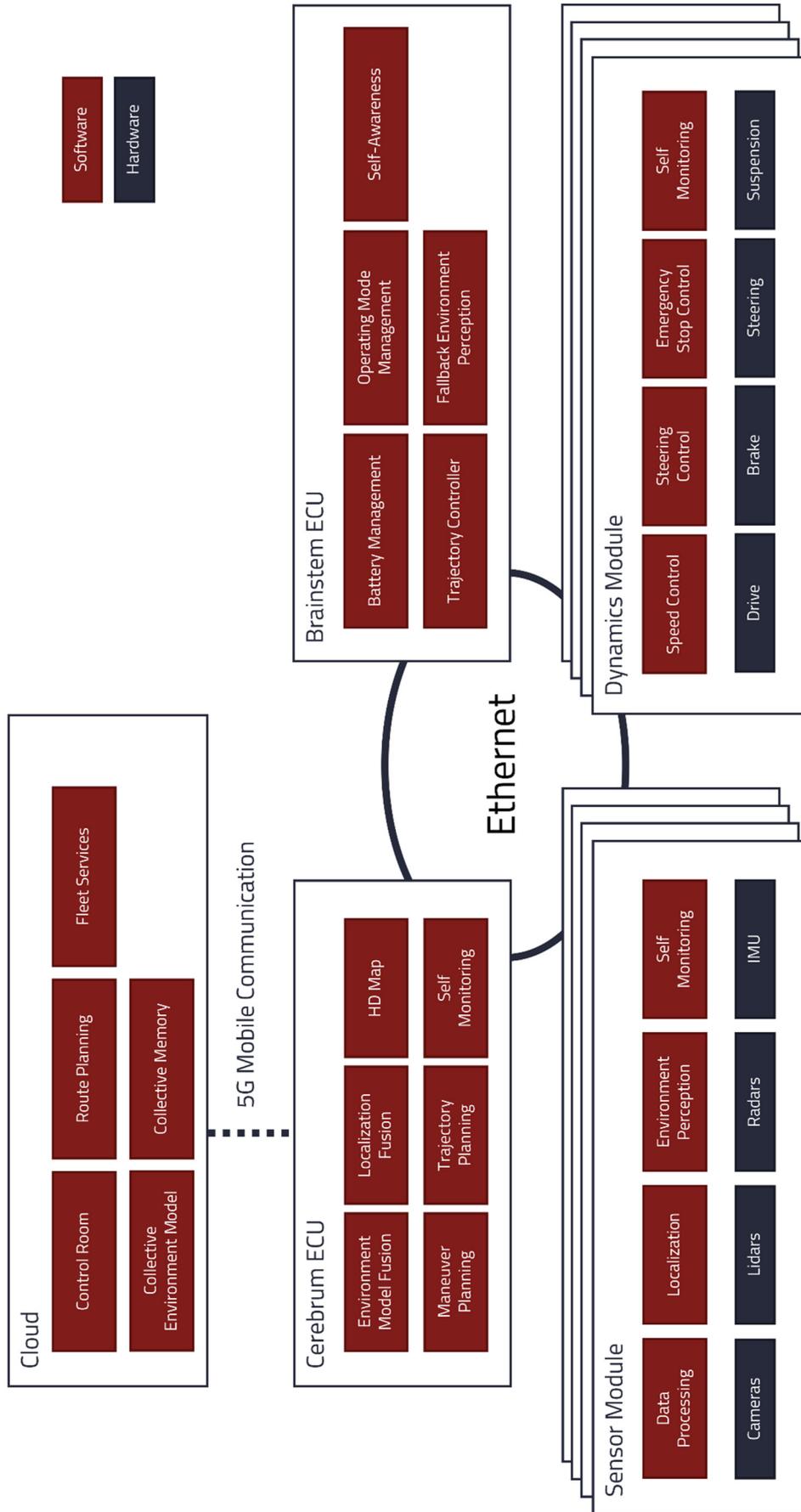
Fig. 6   Modular E/E architecture in UNICARagil.

3.4 Service-Oriented Middleware

In 2017, the software of an average car was made of approximately 100 million lines of code while Windows 7 needs 40 million lines only [23]. While more lines of code is definitely no measure for better code, this illustrates the increasing proportion of software in vehicle development. Thus, computer science problems are transferred to automotive engineering. In computer science, service orientation is a common design paradigm to abstract software modules to their interfaces. UNICARagil introduces the Automotive Service-oriented Software Architecture (ASOA) [5] as a service-oriented middleware matching automotive requirements [12]. It enables communication in a diverse network of embedded systems and high-performance computers and abstracts applications from ECUs, which makes services exchangeable and updateable during the vehicle's lifecycle. This is an important feature of a complex software system and a common practice in consumer electronics.

The ASOA is connected to a **vehicle operating mode management** that handles transitions between the available operating modes *automated operation*, *control center operation, safe halt* and *manual operation*. It evaluates transition conditions between operating modes and ensures a safe orchestration of services at any time. The operating mode management is further explained in [25], which is also part of this colloquium.

3.5 Integration and Testing

A tight schedule that only allows about two years for software integration and testing in four vehicles requires efficient and parallel planning. To ensure that all components being developed at various partners will work together in the overall system, clearly defined requirements and guarantees of each component are mandatory. This holds for geometric as well as for mechatronic components. The modular geometric structure of the UNICARagil vehicles and clearly defined interfaces allowed a parallel manufacturing of the platforms, add-on modules, and sensor and dynamics modules at different partners.

The specially developed UNICARagil Architecture Tool [12] helps to model the large multitude of mechatronic components. It allows an agile specification of guarantees and requirements across multiple domains:

- **Functional guarantees and requirements** are used to divide tasks into components and derive the functional architecture of the overall system.
- Guarantees and requirements of **software services** fulfilling functions can be definitions and links of messages being exchanged between services as well as their demands for computing and network resources.
- Guarantees for **control units** are e.g. their provided computing power and network resources.
- Components can also have **thermal or energy requirements**, e.g. their demand for cooling or battery power, which must be fulfilled by other components with appropriate guarantees.

The Architecture Tool checks guarantees and requirements and notifies responsible persons in case of conflicts or unmet requirements. Thus, potential integration problems are already uncovered in advance to ensure a smooth integration.

For each vehicle, the whole software integration period is divided into four phases each followed by a test of the overall system. With each successful integration phase, a new vehicle operating mode will be released and can be used in the upcoming phase. In addition to the four modes (*automated operation*, *control center operation, safe halt* and *manual operation*) that will be available in the final vehicle, the *manual testing* and *generic testing* modes were added for integration purposes only.

1. The first phase is mainly dedicated to the integration and testing of the dynamics modules. The vehicles are not yet equipped with their final interior but with a workplace for the test driver (cf. Fig. 9). The ***manual maneuvering*** operating mode allows direct acceleration, steering and braking using a sidestick and brake pedal with low velocities. With this setup, the basic functionality of the dynamics modules in combination with the thermal and energy networks is tested. Additionally, the brainstem ECU runs the first version of the ASOA middleware including the operating mode management.

2. The next phase leads to ***manual testing*** mode. The test driver still manually operates the dynamics modules, but the vehicle is also equipped with sensors and data processing ECUs. Camera images are forwarded to monitors at the test driver's workplace to ensure a good view. In this operating mode, the vehicle dynamics state estimation and localization can be calibrated and tested with higher velocities. Furthermore, sensor data can be recorded for testing and optimizing pre-developed perception algorithms.

3. With the cerebrum, all ECUs are finally installed in ***generic testing*** mode. The cerebrum provides a high-definition map that is aligned to the vehicle using video-based localization.

4. In *generic testing* mode, a highly parallel integration of the software stack for the modes ***automated operation, control center operation*** and ***safe halt*** is possible. The modules for *environment perception*, *behavior and trajectory planning* and *motion control* are firstly tested separately using test inputs. Also in parallel, the *self-awareness* service and *safe halt* degradation function are integrated as well as the connection to the *control room* for teleoperation. In further steps, the modules are tested in interaction. Eventually, all operating modes are available and transitioning between them can be tested.

Manual Maneuvering
- Dynamics Modules
- Manual Operation

Manual Testing
- Sensor Modules
- Data Recording

Generic Testing
- Cerebrum ECU
- HD Map

Fully-automated Driving
- Environment Perception
- Behavior and Trajectory Planning
- Motion Control
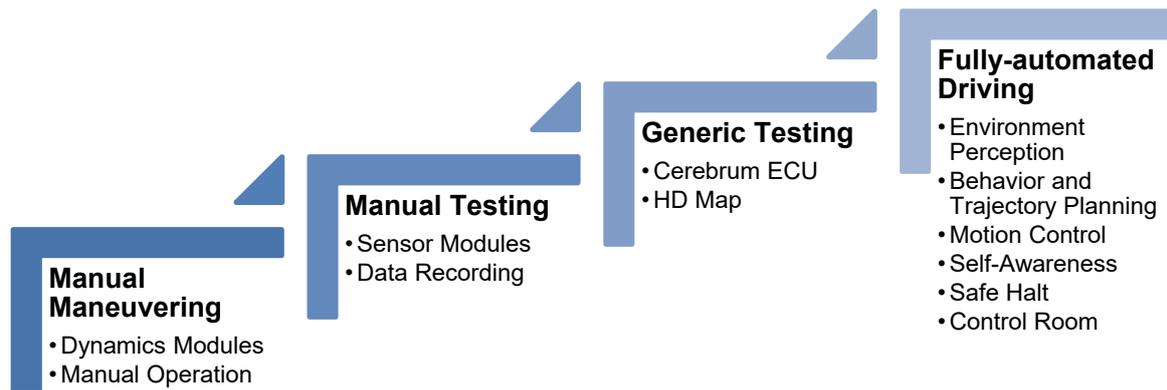- Self-Awareness
- Safe Halt
- Control Room

Fig. 7　　　Integration phases derived from operating modes.

For each integration phase, tasks and dependencies were identified and workloads were estimated. This resulted in an integration and test plan with 350 tasks and more than 600 dependencies for all four vehicles.

4 Current Progress of the UNICARagil Project

At the time of writing (July 2021), all four vehicle prototypes are fully built-up in hardware. After the first vehicle platform had been delivered in December 2019, the remaining platforms as well as the add-on modules have been manufactured during the year 2020. Although the coronavirus pandemic complicated the progress, in September 2020 all platforms and add-on modules were completely manufactured and painted by the prototype builder. At the same time, the integration of thermal and energy networks into the first platform had already begun at University of Stuttgart.

After the on-board networks had been set up in three vehicles at University of Stuttgart, the dynamics modules including dedicated ECUs, wheel hub drives, brakes and steering could be assembled, integrated and tested at RWTH Aachen University. This completes the first integration phase of these vehicles. While the fourth vehicle is currently being equipped with dynamics modules, the next integration phase has already started for the other vehicles at Ulm University, Technical University of Munich, and Technical University of Darmstadt.

The prototypes are currently being equipped with sensors and data processing hardware and the precise self-localization is calibrated so that first data can be recorded with the UNICARagil vehicles. The data is then used to test and optimize the perception algorithms that have been developed using other vehicle prototypes and simulation before. Furthermore, additional services are integrated into the ASOA middleware, e.g. for light control and displaying status information on the monitors for the test driver. This makes the *manual testing* operating mode available, which is then tested extensively in the overall system.

In parallel to the vehicle construction, progress was also made in many other work packages during the past year. Simulation was used extensively for the development and virtual validation of the trajectory controller [6] as well as for the cloud-based services Collective Environment Model [15] and Collective Memory. The Info Bee is completely built in hardware and capable of transmitting images.

More insights into the progress of the UNICARagil project will be presented in the colloquium talk.

Fig. 8   The autoCARGO on its first ride out of the workshop.

Fig. 9   Project coordinator Prof. Dr. Lutz Eckstein at the test driver's workplace (still without monitors here).

5 Summary and Outlook

The UNICARagil consortium has not set itself an easy task. Designing and building a completely new vehicle from scratch with no previous model to base on has raised a lot of questions and challenges. However, this was a chance to break with existing structures and analyze what is actually required for the connected and driverless electric vehicles of the future. By combining the expertise of leading German universities and specialists from industry, a holistic architecture for a future mobility system has been created. The architecture covers the hole range from geometric and mechatronic design to software and safety as well as user interaction and cloud-based connectivity.

The task is now to prove the practicality and benefits of the developed concepts in real vehicle prototypes. We could already demonstrate our vehicles moving with fully-functional on-board networks and the dynamics modules. Now, the whole team is eager to make them drive autonomously. During the next months, algorithms for perception, planning and control, which have been developed and tested in simulation and other vehicle prototypes before, will be integrated into the UNICARagil vehicles. We are expecting to be able to show the first vehicle in automated test operation within the context of the 2022 IEEE Intelligent Vehicles Symposium in Aachen.

By the end of the project in 2023, the vehicles will also be equipped with their application-specific interiors and are demonstrated in a cooperative mobility system.

6 Acknowledgment

7 Abbreviations

AD   Automated Driving

ASOA   Automotive Service-oriented Architecture

OEM   Original Equipment Manufacturer

ECU   Electronic Control Unit

E/E   Electrics/Electronics

8   References

[1]   The UNICARagil Project, 2021.
      Website: https://www.unicaragil.de/en.

[2]   Woopen, Timo, Lampe, Bastian, Böddeker, Torben, Eckstein, Lutz,
      Kampmann, Alexandru, Alrifaee, Bassam, Kowalewski, Stefan, Moormann, Di-
      eter, Stolte, Torben, Jatzkowski, Inga, Maurer, Markus,
      Möstl, Mischa, Ernst, Rolf, Ackermann, Stefan, Amersbach, Christian,
      Leinen, Stefan, Winner, Hermann, Püllen, Dominik, Katzenbeisser, Stefan,
      Becker, Matthias, Stiller, Christoph, Furmans, Kai, Bengler, Klaus,
      Diermeyer, Frank, Lienkamp, Markus, Keilhoff, Dan, Reuss, Hans-Christian,
      Buchholz, Michael, Dietmayer, Klaus, Lategahn, Henning,
      Siepenkötter, Norbert, Elbs, Martin, v. Hinüber, Edgar, Dupuis, Marius,
      Hecker, Christian, 2018.
      UNICARagil - Disruptive Modular Architectures for Agile, Automated Vehicle
      Concepts.
      In: 27. Aachener Kolloquium Fahrzeug- und Motorentechnik: October 8th - 10th,
      2018 - Eurogress Aachen, Germany, pp. 663-694.

[3]   Stolte, Torben, Graubohm, Robert, Jatzkowski, Inga, Maurer, Markus, Acker-
      mann, Stefan, Klamann, Björn, Lippert, Moritz, Winner, Hermann, 2020.
      Towards Safety Concepts for Automated Vehicles by the Example of the Project
      UNICARagil.
      In: 29th Aachen Colloquium Sustainable Mobility 2020, Aachen.

[4]   Martens, Timm, Pouansi, Brice, Li, Minglu, Henkel, Niclas, Wielgos, Sebastian,
      Schlupek, Martin, Eckstein, Lutz, 2020.
      UNICARagil Dynamics Module.
      In: 29th Aachen Colloquium Sustainable Mobility 2020, Aachen.

[5]   Mokhtarian, Armin, Kampmann, Alexandru, Alrifaee, Bassam, 2020.
      The Dynamic Service-oriented Software Architecture for the UNICARagil Pro-
      ject.
      In: 29th Aachen Colloquium Sustainable Mobility 2020, Aachen.

[6]   Buchholz, Michael, Gies, Fabian, Danzer, Andreas, Henning, Matti, Hermann,
      Charlotte, Herzog, Manuel, Horn, Markus, Schön, Markus, Rexin, Nils, Dietma-
      yer, Klaus, Fernandez, Carlos, Janosovits, Johannes, Kamran, Danial, Kinzig,
      Christian, Lauer, Martin, Molinos, Eduardo, Stiller, Christoph, Wang, Lingguang,
      Ackermann, Stefan, Homolla, Tobias, Winner, Hermann, Gottschalg, Grischa,
      Leinen, Stefan, Becker, Matthias, Feiler, Johannes, Hoffmann, Simon, Dier-
      meyer, Frank, Lampe, Bastian, Beemelmanns, Till, van Kempen, Raphael,
      Woopen, Timo, Eckstein, Lutz, Voget, Nicolai, Moormann, Dieter, Jatzkowski,
      Inga, Stolte, Torben, Maurer, Markus, Graf, Jürgen, v. Hinüber, Edgar, Siepen-
      kötter, Norbert, 2020.
      Automation of the UNICARagil Vehicles.
      In: 29th Aachen Colloquium Sustainable Mobility 2020, Aachen.

[7]   Böddeker, Torben, Bonerz, Claus Bertram Heinrich, Guthause Philipp, Ludwig, Jan, Merdivan, David, Oberdärder, Andrej, Oiekenbrinck, Lars, Spohr, Sebastian, Wolsfeld, Rainer, 2020.
Skalierbarer modularer Strukturbaukasten: Von der Anforderungsermittlung bis zum Hardwareaufbau
Online [Access: 02-07-21]: https://www.unicaragil.de/hzevent#Strukturbaukasten

[8]   Westerkamp, Philip, 2020.
autoSHUTTLE: Automatisierter öffentlicher Personennahverkehr
Online [Access: 02-07-21]: https://www.unicaragil.de/de/digitales-halbzeitevent.html#autoSHUTTLE1 and https://www.unicaragil.de/de/digitales-halbzeitevent.html#autoSHUTTLE2

[9]   Schockenhoff, Ferdinand, Kipp, Manuel, 2020.
autoTAXI: Taxi@Work
Online [Access: 02-07-21]: https://www.unicaragil.de/de/digitales-halbzeitevent.html#autoTAXI

[10] Markert, Kai, Ries, Maximilian, Hu, Haohao, 2020.
autoCARGO
Online [Access: 02-07-21]: https://www.unicaragil.de/de/digitales-halbzeitevent.html#autoCARGO

[11] Schräder, Tobias, Stolte, Torben, Jatzkowski, Inga, Graubohm, Robert, Maurer, Markus, 2019.
An Approach for a Requirement Analysis for an Autonomous Family Vehicle
In: 30th IEEE Intelligent Vehicles Symposium, Paris, France, June 2019

[12] Kampmann, Alexandru, Alrifaee, Bassam, Kohout, Markus, Wüstenberg, Andreas, Woopen, Timo, Nolte, Marcus, Eckstein, Lutz, Kowalewski, Stefan, 2019.
A Dynamic Service-Oriented Software Architecture for Highly Automated Vehicles.
In: 2019 IEEE Intelligent Transportation Systems Conference (ITSC), Auckland.

[13] Lampe, Bastian, Woopen, Timo, Eckstein, Lutz, 2019.
Collective Driving - Cloud Services for Automated Vehicles in UNICARagil.
In: 28th Aachen Colloquium Automobile and Engine Technology 2019, Aachen, Edition 1, Volume 1, Pages 677-703.
DOI: 10.18154/RWTH-2019-10061

[14] Lampe, Bastian, van Kempen, Raphael, Woopen, Timo, Kampmann, Alexandru, Alrifaee, Bassam, Eckstein, Lutz, 2020.
Reducing Uncertainty by Fusing Dynamic Occupancy Grid Maps in a Cloud-based Collective Environment Model.
Forthcoming in: 2020 IEEE Intelligent Vehicles Symposium (IV), Las Vegas, USA.

[15]   van Kempen, Raphael, Lampe, Bastian, Woopen, Timo, Eckstein, Lutz, 2021.
       A Simulation-based End-To-End Learning Framework for Evidential Occupancy
       Grid Mapping.
       Forthcoming in: 2021 IEEE Intelligent Vehicles Symposium (IV), Nagoya,
       Japan.

[16]   Goth, Marcus, Keilhoff, Dan, and Reuss, Hans-Christian, 2020.
       Fault Tolerant Electric Energy Supply System Design for Automated Electric
       Shuttle Bus.
       In: 20. Internationales Stuttgarter Symposium, Stuttgart, Germany.

[17]   Niedballa, Dennis and Reuss, Hans-Christian, 2020.
       Concepts of Functional Safety in E/E-Architectures of Highly Automated and
       Autonomous Vehicles.
       In: 20. Internationales Stuttgarter Symposium, Stuttgart, Germany.

[18]   Feiler, Johannes, Hoffmann, Simon, Diermeyer, Frank, 2020.
       Concept of a Control Center for an Automated Vehicle Fleet
       Forthcoming in: 23rd IEEE International Conference on Intelligent
       Transportation Systems (ITSC), 2020.

[19]   Ackermann, Stefan, Winner, Hermann, 2020.
       Systemarchitektur und Fahrmanöver zum sicheren Anhalten modularer automa-
       tisierter Fahrzeuge.
       In: 13. Workshop Fahrerassistenzsysteme und automatisiertes Fahren. Walting,
       16.-17.07.2020.

[20]   Klamann, Björn, Lippert, Moritz, Amersbach Christian and Winner, Hermann,
       2019.
       Defining Pass-/Fail-Criteria for Particular Tests of Automated Driving Functions
       In: 2019 IEEE Intelligent Transportation Systems Conference (ITSC), Auckland.

[21]   Meissner, Falk, Shirokinskiy, Konstantin, Alexander, Michael, 2020.
       Disruption in automotive electronics and semiconductors.
       In: Roland Berger. Focus - Computer on wheels.

[22]   Burkacky, Ondrej, Deichmann, Johannes, Doll, Georg, Knochenhauer, Chris-
       tian, 2018.
       Rethinking car software and electronics architecture.
       Online [Access: 02-07-21]: https://www.mckinsey.com/industries/automotive-
       and-assembly/our-insights/rethinking-car-software-and-electronics-architecture

[23]   Desjardins, Jeff, 2017.
       How Many Millions of Lines of Code Does It Take?
       Online [Access: 02-07-21]: https://www.visualcapitalist.com/millions-lines-of-
       code/

[24] Rieth, Peter E., Raste, Thomas, 2015.
Integrationskonzepte der Zukunft.
In: Winner, Hermann, Hakuli, Stephan, Lotz, Felix, Singer, Christina, Handbuch
Fahrerassistenzsysteme, ATZ/MTZ-Fachbuch.
DOI: 10.1007/978-3-658-05734-356

[25] Jatzkowski, Inga, Stolte, Torben, Graubohm, Robert, Maurer, Markus, Kamp-
mann, Alexandru, Alrifaee, Bassam, Kowalewski, Stefan, Buchholz, Michael,
Dietmayer, Klaus, 2021.
Integration of a Vehicle Operating Mode Management into UNICARagil's Auto-
motive Service-oriented Software Architecture.
In: 30th Aachen Colloquium Sustainable Mobility 2021, Aachen.

[26] International Organization for Standardization,2018
Risk management - Guidelines (ISO 31000:2018)

[27] Atlassian. Pty Ltd, 2021
Confluence website,
Online [Access: 14-07-21]: https://www.atlassian.com/de/software/confluence

[28] Siepenkötter, Norbert, Voget, Nicolai, 2020.
Info-Biene. Luftgestützte Verkehrsüberwachung.
Online [Access: 14-07-21]: http://unicaragil.de/hzevent#InfoBiene