EVS30 Symposium
Stuttgart, Germany, October 9 - 11, 2017

ARENA2036

Active **R**esearch **E**nvironment for the **N**ext Generation of **A**utomobiles

–

Agile production and lightweight construction for electric mobility

Max Hossfeld, Peter Froeschle

ARENA2036, Pfaffenwaldring 19, 70569 Stuttgart, max.hossfeld@ARENA2036.de

Summary

ARENA2036 is Germany's largest and leading research factory dedicated to the future of mobility and its creation. It serves as a key enabler for the European Automotive Industry by disrupting and redesigning the entire value chain so as to promote the future, fully digitized and electrified mobility. Enabling affordable and sustainable mobility by rethinking the entire automobile value chain for the age of electrification is the key objective for ARENA2036. ARENA2036 pools the competences of some 24 world-class scientific as well as industrial partners by uniting their best talents on the Stuttgart campus. On campus, about 200 researchers are working on the "versatile production of the future for intelligent, multi-material lightweight construction with functional integration" in four interconnected areas of research. ARENA2036 itself is being continuously improved based on the latest research in sociology, work science, facility layout planning, etc.

Keywords: battery, communication, digitalization, mobility concepts, strategy

1 Introducing an Entirely Novel Kind of Cooperation

In a recent *Harvard Business Review* article, David Burkus observed that "Innovation is not an idea problem." Instead, he continues, "it's a recognition problem." More precisely, this means that it is the limited capability to recognize innovative ideas worth pursuing within the somewhat stiff frameworks of established corporations. This is to say that typical corporate research and development departments are rather working on 'reforming' their respective products to ensure stable profits than to risk disrupting their business case by facilitating truly revolutionary thought. In a word: they are literally researching so as to further develop.

As opposed to this, the innovation platform ARENA2036 – **A**ctive **R**esearch **E**nvironment for the **N**ext Generation of **A**utomobiles – stands for entirely novel ways of collaborative R&D by means of cooperation, thus aspiring to actualize disruptive potentials. As such, it is a platform that allows experts

from the sciences as well as from the industry to jointly work on lightweight construction technologies and on future production systems. The common goal that all partners are mutually striving to achieve is the implementation of the "versatile production of the future for intelligent, multi-material lightweight construction with functional integration." Both branches of this research – i.e. with regards to the production on the one hand and focused on the product on the other – are key to the development and finally to the implementation of a sustainable Industry 4.0 across the board.

It is self-evident that such an ambitious research program requires entirely novel approaches to research and development as such. ARENA2036 therefore promotes inter- and transdisciplinary as well as completely equitable cooperation, collaboration, creativity, and disruptive thought processes within a quasi holocratic environment, in order to pave the way for the actualization of truly innovative potentials.

The ultimate ARENA-goal is to fully implement this comprehensive concept for product and production by 2036; the 150th anniversary of the automobile.

2 ARENA2036 – Germany's Largest and Leading Research Factory

As Germanys largest and leading research factory, ARENA2036 is dedicated to the future of mobility and to its creation. Rethinking both product and production along the lines of a fully digitized Industry 4.0 makes ARENA2036 a future-oriented key enabler for the European Automotive Industry of tomorrow. For this purpose, researchers on as well as off campus are disrupting and redesigning the entire value chain of future mobility.

The fundamental assumption is that the next generation of automobiles is the outcome of a similarly fully digitized production. This is to say, in order to actualize the potential conceived to describe the so-called Industry 4.0, product and production have to be monitored by way of a life-cycle data management that incorporates a closed and continuous information chain from cradle to grave for each component; spanning development, production, usage, and recycling.

Taken together, this means that ARENA2036 paradigmatically designs the future value network by creating, producing, and operating digitized as well as personalized automobiles, thus taking on the role of a trailblazer for the coming autonomous and accident-free, individualized and fully integrated lightweight vehicle. In order to cover such a vast and highly complex field, some 200 researchers from about 24 world-class scientific as well as industrial partners, pool their competences on the ARENA2036. The premise for instituting such a productive collaboration between the sciences and the industry is as a functioning public-private partnership as well as public funding.

Initially, in 2012, the University of Stuttgart together with seven partners answered a call by the Federal Ministry of Education and Research (BMBF) for the formation of a so-called Research Campus. Since then, ARENA2036 has turned into a BMBF-flagship project that is furthermore supported by the European Regional Development Fund (ERDF), and of course by its more than 25 partners.

In 2017, ARENA2036 moved into its new 10.000 m^2 research factory campus located in Stuttgart, Germany. This trend-setting building architecturally resembles ARENA2036' research topics: it is constructed using lightweight material, it is energy efficient, and it not least allows for utter flexibility regarding all processes. As for the latter, this means that it is specifically designed to facilitate an atmosphere of belonging with the project as well as to serve as a place for testing new ways of creatively working together. More precisely, this amounts to the following key features of the 2.500 m^2 office area: flexible as well as open office space(s) so as to guarantee short distances, quick transfers, and heightened creativity. There are furthermore recreation areas as well as brainstorming areas that – among other things – serve to level out established hierarchies and to foster "out of the box"-thinking. Simultaneously, the 7.500 m^2 shop floor allows for actually giving the flexible production of the future an honest try.

Additionally, the ARENA2036 building (Picture 1) on University of Stuttgart campus has a twofold knock-on effect: on the one hand, it heightens the ARENA2036 visibility by attracting numerous visitors from politics and industry, on the other hand, it initiates cooperation beyond the campus itself, thus serving as a catalyst that strengthens the industry of the region.

Picture 1: ARENA2036 research factory

3 The ARENA2036 Project-Scape

ARENA2036 started out with four base projects, which conjointly aim at contributing to the implementation of the ARENA2036 vision. Namely: bringing to life the “versatile production of the future for intelligent, multi-material lightweight construction with functional integration”. This ambitious vision will be achieved by pursuing the following three strategic goals: First, the Product2036, which will be characterized by lightweight construction with functional integration, thus redefining the borders of lightweight design based on multifunctionality and new materials. Second: the Production2036, which will be highly efficient due to its versatility. And lastly the ARENA2036 itself as a novel research environment that continuously works on shaping the transformation of technology.

In July 2013, ARENA2036 therefore launched the four initial projects “LeiFu”, “ForschFab”, “DigitPro”, and “Khoch3”. Building on those projects, nine new supplementary projects were conceived and initiated. The initial projects themselves are being continuously further developed; viz. “Digital Fingerprint” ensues from “DigitPro”, “FlexCar” builds on “LeiFu”, and “CPPS”, “Digital Shadow”, as well as the “Fluid Production” come from “ForschFab”.

In the following, I will first give you a brief overview over the contents of the four base projects, before turning to some paradigmatic moments from the associated research.

3.1 “LeiFu” – Intelligent Lightweight Design with Functional Integration

“LeiFu” aims at answering some of the most prevalent questions of the automotive industry today: how can we save natural resources and energy whilst simultaneously reducing production cost? The headline of “LeiFu’s” answer to these questions reads as follows: Lightweight Construction with Functional Integration. The spectrum of functionalities that may be integrated in materials spans from sound

absorption and thermal insulation over thermal, sensory, or electric functions all the way to liquid or energy storage; all this goes to show that there is vast potential in researching lightweight design on the basis of functional integration. The advantages resulting from the use of function-integrated materials are of great relevance, especially for the field of electro mobility.

The LeiFu-project currently focuses its research on the fundamentals with regards to select single functions and demonstrates them by means of a specifically constructed CFK-Sandwich-Floor Module (Fiber Composite Design). This floor module not only contributes to reducing the overall weight of the vehicle but it is also equipped with a battery-box, with technologies to enhance the mechanical characteristics, and with inductive charging coils. “LeiFu’s” long-term goal beyond its current research focus is to transfer the functional integration also to metals.

In addition to the setup of associated demonstrators, economic feasibility studies for the serial production are implemented, whilst design rules, tests, and valuations are developed.

3.2 “ForschFab” – The Agile Production of the Future Automobile

The research area “ForschFab” (Research Factory) explores the agile production of the future automobile. A new paradigm for producing automobiles is necessary as product variance increase in three dimensions. Firstly, electrification of the drive train results in vehicle concepts that are different from traditional vehicle concepts for ICE drive trains. However, these new vehicle concepts need to be produced with the same means of production as automobiles with traditional vehicle concepts in the years to come. This calls for agile production concepts which can adapt to changes in production volume of traditional and new vehicle concepts as the market for electric vehicles evolves. Secondly, lightweight construction is the key for building electric vehicles with competitive weight and for reducing the carbon footprint of ICE powered vehicles. However, lightweight production will bring new materials and manufacturing processes to the shop floors which need to be integrated in running production. Thirdly, the number of models will further increase and finally lead to the production of personalized vehicles whose design and characteristics can be highly tailored to individual customers’ needs. The customer will be included in the design process of the fully digitized vehicle as a prosumer. However, production will need to be able to master the resulting single piece variant of the car to comparable cost of the mass production of today.

This is to say, the ultimate goal of “ForschFab” is to produce highly personalized vehicles with alternative drive trains and new materials that replace the standardized mass-market products of today. For this to happen, it is first necessary to develop concepts as well as process- and logistic-modules for the flexible production beyond the classical assembly line. In order to achieve this goal, ARENA2036 is constructing a pilot plant for the agile production of the future on the Research Campus. At this, ARENA2036 is focusing the research efforts on improving the overall cost-effectiveness of automotive production, mastering the increased variance due to new drive trains, materials, processes and personalized car and on reducing the environmental footprint of the automotive industry.

In a first step the rigid assembly line and fixed cycle times are abandoned. By replacing rigid assembly lines by versatile autonomously guided vehicles (AGV) the research factory of ARENA2036 is able of giving every product variant its optimal production run. Value creating tasks are carried out in loosely coupled production modules. The cycle time of these production modules can differ between different production modules and can even be adapted to the product currently produced. The second step focuses on making the means of production themselves more agile. This involves splitting the production machinery in smart modules which can dynamically interact and learn from the past.

This Research Factory brings together the research and development from the areas “Construction and Materials” and “Simulation and Digital Prototype”, thus developing the basis for a radically new and holistic production concept.

3.3 “DigitPro” – Integral Digital Prototype for Serial Production

E-Mobility will completely change the requirement of automotive concepts. Highly flexible production systems and optimized lightweight structures are necessary to fulfill, on the one hand the volatile evolution of automobiles and on the other hand to decrease the weight of automotive structures in order to increase the range for the electrical drive.

For the introduction of lightweight materials with functional integration to automotive manufacturing on an industrial scale, a continuous data exchange across all process steps has to be guaranteed. This exchange has to range from component and module development to virtual tests such as crash behavior, to process development and production planning, all the way to Computer Aided Manufacturing (CAM). Existing digital prototypes for metallic materials cannot be used for hybrid structures, since weight-optimized materials (such as fiber-reinforced plastics; FRP) generally have anisotropic characteristics with the consequence that the component-capacity displays a strong dependency on the direction of force; at this, the characteristics dependent heavily on the orientation and the processing of fibers.

In this joint project, we are therefore constructing a holistic digital model – based on an FRP-structure by way of example – concerning all steps of the design, the construction and the production, whilst continuously transferring necessary data from one step of the process to the next.

This simulation-tool allows us to construct future components in such a way that we are able to accurately meet all requirements whilst saving large parts of the physical testing and to prepare the start of production.

3.4 “Khoch3” – Creativity, Cooperation, and Competence Transfer

The project “Khoch3” scrutinizes the work on as well as within ARENA2036 itself. Its research thus commences with the following essential questions: How do top performers from University, research institutes, and industry comport beneath the same roof? How do ideas emerge, what promotes creativity, how is it possible to quickly transfer results from the Research Factory to industrial production?

At the cross sections of ARENA2036, the special work environment – viz. the Research Factory – is continuously developed based on ergonomic research. Accordingly, the analysis and reflection pertaining to the research campus is an essential element to this area of research. “Khoch3” is furthermore generating methods in order to better coordinate the development of technology with the development of products so as to expedite the transfer of emerging competences. Knowledge regarding the competence requirements will therefore be ascertained directly from the research and development process, which will in turn be made available for professional education and advanced training in the region.

Therefore the project is preparing the transfer of technical results out of ARENA2036 to the shop floor of the industrial ARENA-partners, a new approach for qualifying the future staff is to be developed: The idea is to extract to future needs in qualification and the necessary know how directly out of the R&D-processes. That way, the dual training of future workers can prepare them for the challenges of this new world of automotive production.

With electric powertrains replacing traditional combustion engines another disruptive innovation is to come, also leading to a renewal of qualification requirements, so that tool currently being developed in ARENA2036 could help handling that change too.

“Khoch3” stands for creativity, cooperation, and competence-transfer, and will soon be expanded by communication.

4 Associated Research

In the following, I want to briefly outline three associated projects that stand paradigmatically for the potential to generate new areas of research out of the ARENA2036 Project-Scape. The three projects I am referring to are: “LEICHT – Lightweight Energy-Efficient Innovative Chassis with Hubmotor Technology”,

“PuVerSand – Spot Joining of Structurally Load-Bearing Sandwich-Structures”, and “SerAddMeHa – Series-Production Readiness of Additive Print-Technologies By Means of Metallic Semi-Finished Products”.

“LEICHT” focuses on the prototypical realization of the chassis with an efficient regulation (driving function development). The DLR-department for Lightweight and Hybrid Design Methods as well as the Institute for Internal Combustion Engines and Automotive Engineering of the University of Stuttgart are working on the LEICHT-project, which is funded by the Ministry of Finance and Economics Baden-Württemberg.

The second project, “PuVerSand” compares various joining concepts. The project “PuVerSand” aims at transferring spot and detachable joining technologies or elements to sandwich structures adequately, optimizing the overall composite system, and to enable the exploitation of the existing lightweight potential.

The Project “PuVerSand” is conducted in collaboration with the DLR-department for Lightweight and Hybrid Design Methods, the Fraunhofer-Institute for High-Speed Dynamics (EMI) as well as for Mechanics of Materials (IWM) in Freiburg, and the Natural and Medical Sciences Institute (NMI) at the University of Tübingen. “PuVerSand” is supported by Leichtbau BW GmbH.

The last of the three, “SerAddMeHa”, serves the fundamental research to the end that components for automobile manufacturing will be produced from metallic semi-finished products in a shorter production time due to the application of laser-based 3D-Printing. For this purpose, the Fraunhofer-Project group “Lightweight Construction Technologies” at the Fraunhofer-Institute for Manufacturing Engineering and Automation (IPA) jointly researches with the DLR-department for Lightweight and Hybrid Design Methods.

5 Collaborations

Such a broad project-scape based on the successful cooperation beneath one roof becomes possible only on the basis of ARENA2036’ membership structure. The ARENA2036 network is made up of the University of Stuttgart, non-university research institutes, large corporations as well as small and medium-sized enterprises. Taken together, these partners cover a wide range of areas of expertise. They range from automotive suppliers to aerospace engineering research and from textile as well as material sciences to ergonomics. ARENA2036 brings together this wealth of knowledge beneath one roof, in order to sustainably ensure the actualization of all synergy potentials that exist in the Stuttgart region.

6 Conclusion

The innovative ARENA2036 approach to simultaneously rethink the product and the production allows for a consolidation of the existing competencies in the Stuttgart region regarding lightweight design and production. The various research projects enable our partners to take up and participate in technology exchange, as in the field of e-mobility.

In the long run, ARENA2036 thus contributes to strengthening Baden-Württemberg’s world leading position in the automotive industry. I have shown that this not only requires a close-knit link between science and industry but also between lightweight design research and production technologies. Such an endeavor is exclusively practicable on a research campus and will continuously as well as sustainably be pursued in the ARENA2036 research factory.

Authors

Dr. Max Hossfeld is CTO and research coordinator at ARENA2036. Before that he held management positions both in research organizations and industry.

Max Hossfeld, born in 1985, studied mechanical engineering at the University of Stuttgart, from which he also received his Ph.D.

Peter Froeschle is the Managing Director of ARENA2036 e.V. Prior to that, he headed the department "Strategic Energy Projects & Market Development Fuel Cells / Electric Vehicles" at Daimler AG for 10 years.

In addition, he was appointed Deputy to the Board of Management of New Energy World from 2004 to 2013 and represented the automotive companies as a member of the board of directors of a PPP for fuel cell and hydrogen development.

Peter Froeschle, born in 1965, finished his studies in technical cybernetics and economic cybernetics at the University of Stuttgart. He later expanded his management skills at the St. Gallen Business School.