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FROM A HARDWARE PRODUCT TO THE SOFTWARE-DEFINED VEHICLE

HARNESSING OPEN SOURCE SOFTWARE DEVELOPMENT TO STRENGTHEN EUROPE'S ROLE AS A KEY INTERNATIONAL PLAYER IN THE AUTOMOTIVE SECTOR

Executive Summary

The fact that vehicle functions and systems are increasingly based on software and electrical/electronic (E/E) components means that the share of value creation from software in vehicles is continually rising.

Recent years have seen growth in OEMs (original equipment manufacturers) investing in software development. The Expert Group on Transformation of the Automotive Industry has reached the conclusion that, to strengthen the competitiveness and autonomy of the local automotive industry, particularly against U.S. and Chinese technology providers, and to increase the potential for value creation, companies must change the way they think. The industry is currently undergoing a transformation: where in the past, software was still always coupled with hardware, today, in-house software expertise has grown and development is increasingly moving towards the pragmatic application of jointly developed solutions based on open source software. In this model, open source software provides the opportunity to bundle skills from across different companies, to cut costs, and to foster the widespread application of standardised solutions. Achieving successful open source development in the German/European automotive industry of software modules that can be used as non-differentiating components of the vehicle software stack across OEMs calls for:

- A comprehensive mindset shift towards open source development
- The creation of an open source-friendly regulatory environment that promotes the development and use of open source software (in particular, IP law, liability law, antitrust law)
- The establishment and continual development of automotive open source communities
- A commitment to funding open source development and open source communities
- The empowerment of SMEs to become involved in the development and application of open source solutions
- The anchoring of open source development in basic and further training

1 Starting Point

The automotive industry is undergoing large-scale change from a materials-defined industry to a software-defined industry. The fact that vehicle functions and systems are increasingly based on software and electrical/electronic components means that the share of value creation by software (SW) in vehicles is continually rising. Obviously in the past vehicles also contained large amounts of SW.

Traditionally, however, product functions and the associated SW were assigned to dedicated embedded electronic control units (ECUs), such as ECUs for motor management, airbags, ESPs, electric windows, and others. In this context, vehicles used ECU-internal SW that was considered an integral component of manufactured special control units and was closely linked to the hardware (HW). This meant that the typical business relationship between automotive manufacturers (OEM) and suppliers was organised in such a way that OEMs specified the requirements for an individual control unit, following which suppliers implemented these project-specific requirements in both hardware and software. Suppliers were responsible for the entire control unit, including the internal SW stack. The introduction of high-performance, microprocessor-based vehicle computers brought about a sea change: for these systems, available memory is no longer the limiting factor, and modern operating systems, particularly Linux-based operating systems, have gained a foothold. These systems provide hardware abstractions, permitting the decoupling of SW and HW and the move towards what is known as domain architecture.

In consequence, SW development evolved from a project-specific process to product-centred SW development.

Recent years have seen OEM investment in software development increasing for a wide range of reasons. The numerous driving forces behind this include avoiding duplicated development in the supply chain, harmonising non-differentiating components, increasing system robustness, and using the ability to innovate in distributed software functions, to list just a few.

As a result, classic automotive companies face growing challenges. There are core software domains that we must have a perfect command of in the future. These include entirely different principles, norms and standards, embedded infotainment and connection to the cloud, with a focus on security, customer experience, and robustness. In addition, safety developments in the field of driver-assistance and security systems, which must be developed in line with ISO 26262 standard, among other things, as well as SW development in the cloud, failure safety, data privacy, and availability, must be taken into account.

To ensure that these various software modules work seamlessly together, effective integration is essential (“automotive-grade integration”). Growing numbers of variants and increasingly complex software are accompanied by a considerable increase in the amount of maintenance required, given that software systems must be refined and updated throughout the entire product life cycle of a vehicle. One approach aimed at reducing the complexity of software and promoting reuse is the increased standardisation of software components and architectures. Two examples of this are AUTOSAR (Automotive Open System Architecture) and SOAFEE (Scalable Open Architecture for Embedded Edge). The aim of these international development partnerships is to develop standardised software modules. Standardisation through standardisation bodies calls for consensus among those involved, which means these developments progress slowly and are not always practical. Agile standardisation with a “code-first” approach is therefore preferable.

The changeover to domain architecture means that SW applications can be developed independently of the underlying HW and marketed separately as standalone SW products. This opens up the whole open source software universe to the automotive industry. As a result, the SW product life cycle is no longer intertwined with the HW product life cycle. The massive growth in SW stacks necessitates a change in mindset in the development of in-vehicle software. Rather than the deeply embedded ECU SW developed 100% by the

automotive industry that the industry is used to, the integration of non-automotive-specific SW packages and modules developed by non-automotive SW experts is now becoming a key factor for success. No individual company will be in a position any longer to cover and to own the entire range of SW stacks1.

2 Target

Open source software (OSS) will be the key resource for non-differentiating software in the automotive industry. First, OSS is generally perceived as economical and free to use. In addition, OSS can be adapted individually to suit specific business requirements. This means OSS is more flexible than proprietary software. Complete code transparency leads to greater trust and greater security, particularly as large numbers of independent experts check the codebase. The cross-sector use of OSS components also increases quality. In addition, OSS potentially leads to competitive advantages, as it can access the most cutting-edge technology without the need to invest in expensive proprietary software, which means it generates savings. Lastly, OSS enables faster market penetration, and therefore de facto standard-setting.

In view of all of this, in March 2022 the Eclipse Foundation, one of the world's biggest open source organisations, set up a working group on software defined vehicles (Eclipse SDV Project). Taking a "code-first" approach, the goal is to develop one of the first software stacks, with the associated tools, for the non-differentiating core functions in the automotive industry. These new concepts can only be a success if they are based on collaboration across the entire industry. This makes a shift in perspective within businesses from "I can do everything myself" to the pragmatic application of jointly developed solutions absolutely imperative.

Neglecting open source software development would put the European, and therefore the German, automotive industry at a considerable disadvantage. This means that stakeholders in the automotive branch in Germany and in Europe must take the reins in relevant open source communities by contributing their own software modules. In addition, they must use open source software modules in order to achieve the widespread use of these, and they must use the experience gained to develop them further. This will only be possible if there is a change in mindset throughout the whole industry and the associated financing structures. The recommendations for action of the Expert Group on Transformation of the Automotive Industry aim to implement an open source approach that will strengthen the German and European automotive industries and that

- supports technological evolution towards hardware-independent vehicle operating systems with vehicle/cloud integration;
- enables open architectures that facilitate the integration of suppliers, service providers and startups with innovative service offerings, and that provide a relevant market for development partners, for example in the field of app development;
- increases the competitiveness and the autonomy of the European automotive industry, particularly against U.S. and Chinese technology providers;
- supports the value creation potential of the local automotive industry by enabling software alternatives developed in Europe to be used and business models to be established on this basis; and
- safeguards existing and new jobs and improves their future prospects.

[1] Example: Current stable release Linux kernel 6.2.0 (14 February 2023): 24,087,295 uncommented source lines of code in 79,455 files. Estimated development effort ~ 8,000 person years.

The central pillar of the target outcome is the open source development of software modules that can be used as non-differentiating components in the vehicle software stack across OEMs.

The joint coordination of open source development can ensure efficient and targeted implementation that is available to all interested manufacturers and suppliers. A key element of this target outcome will be that all companies involved cooperate in a competitively neutral way and not only use open source products, but actively contribute to their further development. This is crucial to achieving the desired efficiency and creating a relevant, vendor-neutral setting for development partners.

3 Recommendations for Action

The following recommendations for action for the different stakeholder groups in business, policy, the research community, and society can be extrapolated from the target outcome:

➔ **We need a comprehensive mindset shift towards open source development.**

To break away from traditional, proprietary software development, we need a code-first approach that, based on collaboration, promotes the development of OSS building blocks using agile processes. Manufacturers and suppliers will then be able to refine and further develop these building blocks on a product-specific basis. Classic software companies in the IT industry (hyperscalers), on the other hand, will have to adapt to the framework conditions of the automotive world, with long-lasting product life cycles and automotive-grade integration and with the associated safety and security requirements.

Decision-makers and purchasing organisations must be aware of the fact that the use of open source software is not free of charge. The security hardening and maintenance of open source software require at least as much expenditure and effort as those of proprietary software. However, this effort pays off for all projects using the same OSS.

An important change that open source projects bring with them is that, unlike internal software development or standard OEM software that is provided by the OEM at several levels, they cannot be controlled as easily: open source projects cannot be driven by the specifications of a single company. Instead, the direction that open source projects take depends on the contributions of the members of the project team. This means that what was once supplier management has to evolve into cooperative collaboration.

➔ **The regulatory environment for open source development and utilisation must be created and protected.**

The regulatory environment for collaboration on the development and for the utilisation of open source software must be clarified in order to create a secure legal framework. This recommendation for action is aimed at political decision-makers, who must create this legal framework, and legal departments in companies, which must reassess the legal situation. Particular attention should be paid to the following factors:

- IP/licences: The comprehensive use of OSS requires a legal framework that defines the intellectual property of the OSS as belonging to the organisations (for example, foundations) that host the relevant open source software repositories. Comprehensive, standardised licensing regulations would be ideal, but the existing variation in licensing models makes that unlikely.
- Liability: The use of OSS in the automotive sector requires the clear allocation of liability in case of damages caused by software used. As open source software is not certified for the automotive industry by or of itself, the OEM and suppliers bear full liability for the open source software integrated into their products. The foundation that hosts the OSS and owns the IP for the OSS should not be liable for the

application of the software used in the automotive sector, and the same applies to the open source code developers.

- Antitrust law: As part of the relevant OSS licence, the use of OSS should be classified as freely available to any interested party. The scope of development work defined within the framework of OSS should be made public and should also be available to every interested party. OSS developed within these guidelines should be classified as non-critical for the purposes of antitrust law.

➔ **We need automotive open source communities to be established and continually developed.**

If we are to actually harness the benefits of OSS and move beyond the initial perception that OSS is simply "free software", then active participation in relevant open source communities is a crucial prerequisite for the maintenance and adaptation of open source software modules. It is also important to help shape these communities and to steer them in a useful direction. This calls for considerable investment in participation in open source projects, and also in quality assurance.

Coordinating contributions within open source communities in advance, rather than simply participating in isolation in open source projects, would be more efficient, ensuring greater impact of the effort invested. The fact that this process takes place in public also helps avoid any risk of antitrust issues. A shared understanding of an open, overarching reference architecture for the automotive sector, within which the elements that are not of competitive relevance are specified and implemented, is necessary in order to target open source development to the key needs of the automotive companies involved.

Mapping useful open source projects and compiling a joint roadmap for participation in open source communities would seem to make sense. There are already a number of open source communities that should be used as a starting point for joint activities in terms of software modules for software stacks to be deployed in vehicles, automotive-specific components for back-end solutions, and software tools.

➔ **A commitment to funding open source development and open source communities is essential.**

National and European support measures can help to promote collaboration in developing and using OSS by providing funding that fosters active participation in open source projects. This funding will help create appropriate levels of commitment in participating companies and should be seen as an incentive to future participants, creating the conditions that will ensure the open source communities and projects continue independently. This necessary funding calls for a change in the traditional project application process, moving towards an approach that is more suited to open source options. A project proposal for open source activities cannot provide an outline of detailed tasks over a three-year period, given that open source projects are not designed or handled in this way. Instead, we need a more agile, non-bureaucratic approach to funding. Financial support should depend on actual contributions made to open source communities over a defined time period. Rather than providing comprehensive research reports, any code contributed to the project should justify further financial support ("code-first approach").

➔ **We must empower SMEs to become involved in the development of open source solutions ("Fit for OSS").**

While large companies have in-house departments that know the ins and outs of the regulatory environment for the utilisation of OSS, for example licensing and IP questions, and that can carry out tests of newly developed open source software before it is used within products, SMEs do not have these skill sets. They also often do not have the option to participate actively in OSS communities under their own steam. It is therefore necessary to empower SMEs and startups in particular to utilise OSS in their own products. This applies to legal and technical questions that they encounter in the use and ongoing development of OSS. In the same way, SMEs and startups must be empowered to play an active part in OSS communities and OSS

projects. This could be, for example, drawing up roadmaps for OSS projects, or contributing to specific OSS projects.

This support is therefore relevant in terms of organisational and legal frameworks, as well as in terms of potential financial support for SMEs to participate in OSS communities and OSS projects.

➔ **Open source development needs to be anchored in basic and further training.**

The processes as well as the financial and legal aspects of open source development must be incorporated into the curricula of colleges and universities and into training for skilled trades. We must attract the skilled software development professionals who are in such short supply. At the same time, we must create awareness among managers, decision-makers and policymakers of the underlying background to open source development. We must publicise the advantages of collaborative open source development, without forgetting to critically assess the potential risks.

About the Expert Group

The Expert Group on the Transformation of the Automotive Industry (ETA) is an independent advisory body of the Federal Ministry for Economic Affairs and Climate Action (BMWK). The Expert Group develops targeted and addressee-oriented recommendations for politics, businesses, and society in order to successfully shape the long-term structural change in the industry. The overarching goal is to achieve climate neutrality and to safeguard economic value creation and jobs in the German automotive sector.

The ETA is made up of 13 experts from science, industry and society who have been appointed by Federal Minister Dr Robert Habeck for the 20th legislative period. Other experts as well as relevant institutions and interest groups are involved in the work of the ETA through flexible and agile working formats. The members do not receive any remuneration or expense allowance for their participation in the ETA. The Expert Group is supported by procedural assistance and scientific research commissioned by the BMWK. The ETA has an affiliated committee at the Federal Ministry for Digital and Transport (BMDV), the Expert Advisory Council on Climate Protection in Mobility (EKM). Both bodies are integrated into the federal government's Strategy Platform Transformation of the Automotive and Mobility Industry (STAM).

The ETA is responsible for the content of the document on hand. The Expert Group prepares statements, position papers and reports, some of them in its working groups, which then are discussed, passed and published by the ETA.

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