BERYLLS STRATEGY ADVISORS

ACCELERATING AUTOMOTIVE R&D: STRATEGIES AND APPROACHES TO MAXIMIZE EFFICIENCY AND SPEED

BERYLLS STRATEGY ADVISORS

INSIGHT

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Exploring Improvement Potentials in Automotive R&D

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Embracing Change

Automotive OEMs face challenges in sustaining profitability due to escalating product complexity, which in turn results in heightened research and development expenditures. Five improvement strategies can help not only to reduce R&D expenditures but also increase innovation cycles.

1

DRIVING INNOVATION: EXPLORING IMPROVEMENT POTENTIALS IN AUTOMOTIVE R&D

The automotive industry has been at the forefront of technological advancement for a long time constantly pushing the boundaries of innovation and design. However, with the rise of digitalization and software-centered products, the industry is facing a new set of challenges. To address these challenges and stay ahead of the curve, automotive R&D organizations need to identify areas for improvement and explore new ways to innovate. As we have laid out in previous Berylls studies, facing these challenges comes with an enormous increase in R&D expenditures, which can endanger the profitability of market players along the complete value chain.

Through our research and work with clients from around the globe, we identified five main improvement opportunities to increase R&D speed and reduce expenditures: Decoupling hardware and software development; using off-the-shelf and open-source components; rethinking the software value chain strategy; leveraging automatization and virtualization; migrating early towards a centralized E/E architecture.

EFFICIENCY POTENTIALS IN R&D

We identified five potentials for efficiency improvement in automotive R&D

Hardware/Software Decoupling

Decoupling hardware and software development allows for increased flexibility and quicker iterations to adapt to evolving customer needs and technological advancements

Off-The-Shelf & Open-Source Software

Leveraging off-the-shelf and open-source products for non-differentiating components helps to reduce costs, accelerate time to market, and sharpens the focus

5

Rethinking Collaboration

Shifting from traditional supplier relationships to eye-level partnerships facilitates faster decision-making, enhances collaboration, and drives efficient change implementation

Automatization & Virtualization

Automatization and virtualization reduce costs and time in R&D by simulating real-world driving conditions, but collaboration and test fleets remain important for gathering data

Centralized E/E Architecture

Investing in a central architecture enables simplification of domain complexities, fosters continuous vehicle evolution, and enhances scalability, and flexibility

2

REDUCING COMPLEXITY TO SPEED UP INNOVATION: THE BENEFITS OF DECOUPLING HARDWARE AND SOFTWARE DEVELOPMENT

One of the most significant improvements in R&D is the ongoing decoupling of hardware and software development. Traditionally, hardware and software have been developed simultaneously, in a sequential way and each software/hardware combination was specific to the particular ECU. Changes in the software, often affected the hardware development and vice versa, making it difficult to incorporate changes and updates in later stages of the development process. This meant, that once a vehicle was produced, the amount of software that could be updated without a hardware change was limited. Furthermore, this also meant that between generations of vehicles, a large sum of the R&D expenditures was spent to redevelop the baseline functionality.

Decoupling hardware and software allows for more flexibility in the development process, making it easier to update software, and also gives the OEM greater flexibility in sourcing hardware components from various suppliers. This leads to the following main benefits:

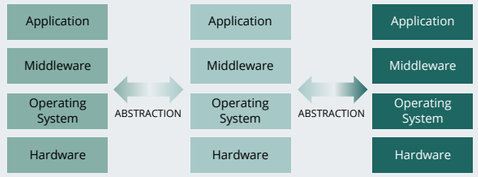
- Faster vehicle and SW/HW-product development cycles
- Lower complexity in development and testing
- Reduced costs for new features, functions, and enhancements to existing products
- Improved flexibility in responding to market demands
- Increased bargaining power by separate procurement of hardware and individual software modules

Decoupling software and hardware can accelerate the product development process significantly. A precondition for this, however, is that the integration is well planned and allows for continuous software integration rather than stepwise versioning of hardware-software distributions. This requires a system architecture in which software applications can be developed against a specified hardware interface and hardware boundary conditions without knowledge about the actual hardware that will be used.

DECOUPLING OF HARDWARE & SOFTWARE

Decoupling hardware and software development allows for increased flexibility and faster time-to-market.

FROM...



- Traditional approaches have **strong coupling** between hardware and software design
- **Changes in software often affect hardware** and vice versa, making late changes or updates after production costly and tedious
- Software is often **specific to one ECU** platform

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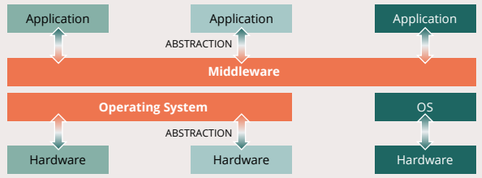


- **Decoupling hardware & software** allows for faster feature development and validation in software
- **Software can evolve freely** at own pace – even after the vehicle has been produced
- Software modules can be shared across **multiple hardware platforms**

Source: Berylls Strategy Advisors

In exploring the delayed adoption of these strategies, three primary challenges emerge. Firstly, OEMs have historically favored SOP-based unit pricing, hindering the shift to performance-based as-a-service payment structures. Secondly, a full system decoupling would necessitate a change in integration responsibility from Tier-1 to the OEM or a specialized integration service provider. Lastly, the assumption of cross-platform and multi-generational software and hardware development brings the risk of procurement volume escalation, potentially leading to an industry oligopoly due to limited risk-bearing players.

To overcome these hurdles, the automotive industry must transition from traditional principal-agent collaborations to true strategic partnerships. These partnerships should align expenses, profits, and risks among all stakeholders in the Tier-n supply chain, ensuring the sustainability of the business model. A crucial initial step involves understanding software-based business and pricing models and adapting existing frameworks accordingly to foster a cooperative and adaptable industry landscape.

3

WHY REINVENT THE WHEEL? USING OFF-THE-SHELF AND OPEN-SOURCE PRODUCTS

Another area for improvement in automotive R&D is the use of off-the-shelf and open-source components. Historically, automakers have relied on proprietary technology, resulting in high development costs and longer time-to-market.

However, with the increasing availability of off-the-shelf and open-source components, manufacturers can reduce costs and speed up the development process. It allows players to focus on developing their core competencies rather than reinventing the wheel. For hardware, this has been used in the past successfully. For example, for an automotive supplier wanting to develop a platform for autonomous driving, it makes sense to use existing sensors as much as possible instead of developing them, saving hundreds of millions in R&D costs.

This approach is not just valid for hardware components, though. Software modules can also be acquired off-the-shelf, or OEMs and suppliers can leverage or even join open-source initiatives to collaborate with other market players in jointly solving problems for everyone.

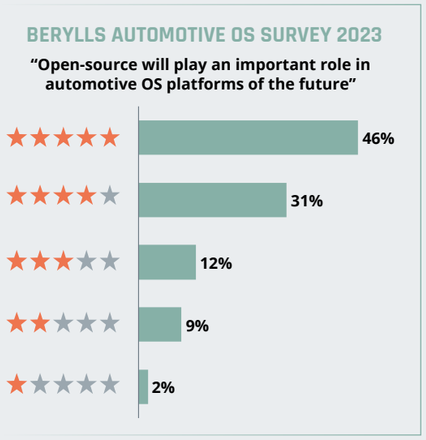
The Berylls Automotive OS Survey 2023 showed that 78% percent of industry leaders expect Open-Source-Software (OSS) to play an important role within the Automotive Operating System business.

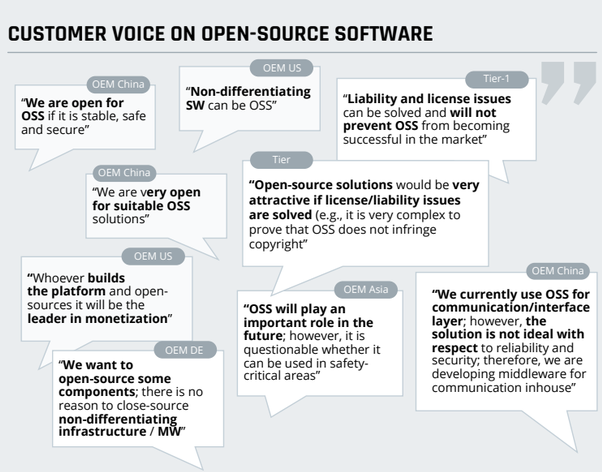
One attempt to push the use of open-source software in automotive R&D is the Software-Defined Vehicle initiative launched by the Eclipse Foundation. This project aims to create an open-source platform for the development of connected, autonomous, and electric vehicles. By leveraging open-source software, the initiative seeks to reduce development costs and speed up the time-to-market for automotive manufacturers. The platform includes tools for designing and modeling vehicle architectures, as well as a suite of software components for vehicle communication, cybersecurity, and other critical functions. This approach would allow manufacturers to focus on the differentiation aspects of their products while relying on open-source solutions for non-differentiating components.

The initiative has already gained the support of major automotive manufacturers and suppliers. Whether the group will actually deliver a working platform that can be shared amongst the members is yet to be seen. The upside promised by the working group itself does look attractive, as it estimates that the use of open-source software, might save up to 30% in development costs.

OPEN-SOURCE SOFTWARE

Open-source software will be an important topic in automotive operating systems and beyond.





Source: Berylls Strategy Advisors Automotive OS Expert Survey

To ensure that automotive manufacturers can distinguish between differentiating and non-differentiating features, they need to adopt a strategic approach to their software portfolio. This involves conducting customer studies to identify the aspects of the product that are most important to end-users, and which are influencing the buying decision between brands. By prioritizing the features that truly matter to customers, manufacturers can allocate their resources more efficiently, and deliver products that better meet the needs of the market. Moreover, automotive players must also assess their core capabilities, as the desired in-house development of crucial software components might require a certain degree of outsourcing until the necessary capabilities are ramped up internally.

The adoption of open-source components in the automotive industry faces notable challenges, primarily rooted in three concerns. Firstly, OEMs express apprehension about software maintenance responsibilities and liability in case of issues. To address this, a shift in perspective is crucial; open-source collaboration requires active contribution, urging OEMs to ensure ongoing software maintenance as contributors. Secondly, navigating diverse software licenses, particularly copyleft licenses that demand public disclosure, poses a challenge. To avoid legal complexities, specialized software and open-source experts are essential, accompanied by meticulous software inventory management through a Software Bill of Materials (SBOM). Automated SBOM generation, integrated into the CI/CD pipeline, reduces human error. Thirdly, supplier reluctance to contribute or release open-source components stems from monetization concerns. While direct code monetization might be restricted, there still exist many ways to profit. Suppliers can offer premium versions with added features, compatible packaged distributions, or ancillary products and services like support, training, or maintenance, ensuring sustainable revenue streams. The industry's shift towards embracing these strategies necessitates a proactive approach and comprehensive understanding of the open-source ecosystem.

4

COLLABORATION IS KING: THE NEED TO RETHINK THE OEM/SUPPLIER RELATIONSHIP

Collaboration between suppliers and OEMs has long been a part of automotive R&D. However, as the industry evolves, so must the way that these collaborations are structured and executed. In the past, collaboration was often inefficient, with lengthy change request approval processes that could take weeks or even months. To meet the demands of today's fast-paced market, the industry must shift towards more eye-level partnerships that enable faster and more agile decision-making.

One successful collaboration approach is the use of joint product teams of suppliers and OEMs in which developers work on the same software repositories, ideally co-located. By adopting this approach, the development team can respond quickly to changes in the market or customer needs, without the need for lengthy change approval processes. For instance, one OEM implemented this approach to develop a new infotainment system for its vehicles. By working closely with its suppliers in joint agile product teams across all functions, the team was able to reduce development time by 50%.

To fully leverage the additional efficiency of collaboration, suppliers and OEMs must agree on the use of a state-of-the-art toolchain for configuring, developing, and integrating software. Historically, different companies have used different toolchains, which can make collaboration more difficult and time-consuming. For example, if an OEM uses one toolchain and a supplier uses another, there may be a need to parse or synchronize between the two toolchains, which can introduce errors and slow down the development process.

By using off-the-shelf tools, both suppliers and OEMs can avoid these issues and streamline the collaboration process. A standardized toolchain can provide a common platform for communication and collaboration, allowing all parties to work from the same data and information. This can reduce the risk of errors and improve overall efficiency, ultimately leading to faster development times and better products. As mentioned above, the Eclipse Foundation's Software-Defined Vehicle initiative is an example of an effort to establish a standardized toolchain for the automotive industry. By collaborating with OEMs, suppliers, and other industry stakeholders, the initiative aims to create an open, vendor-neutral platform that can be used by all companies involved in automotive R&D.

In the automotive industry, partnerships frequently stumble due to a lack of clear understanding of goals, framework conditions, and cultural barriers. These uncertainties often lead to premature termination, especially when it comes to issues concerning intellectual property. While not every detail can be contractually specified in advance, establishing a shared foundation, hence, is pivotal. Partners must align on goals, individual contributions, partnership duration, intellectual property usage, and how each party's business model integrates. Crucially, there must be agreement on the partnership's conclusion, ensuring a comprehensive understanding that safeguards against potential pitfalls. Clarifying these elements upfront promotes the sustainability and success of automotive partnerships.

5

THE IMPORTANCE OF AUTOMATIZATION AND VIRTUALIZATION

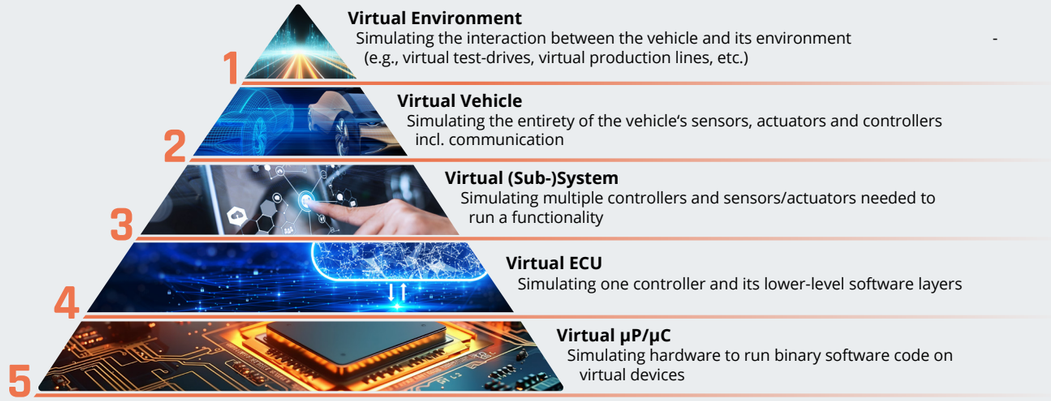
While testing and validation is a critical part of the R&D process, it can be time-consuming and expensive. Automatization and virtualization are two approaches that can help reduce costs and time during this step of the development process.

Automatization involves using software to automate tasks such as test execution, data collection, and analysis. This approach has been used in many industries and has been shown to reduce costs by up to 80%.

Virtualization involves creating a virtual representation of an object or system that can be used instead of its real counterpart when performing tests or simulations (e.g., simulating an entire car). This enables the frontloading of tests in a virtual environment before the hardware is available for actual hardware-in-the-loop testing. Additionally, through virtualization, the amount of data collected by tests can be increased manifold as there is no need for multiple physical devices.

VIRTUALIZATION LEVELS

Virtualization in the development of automotive systems can be used on multiple levels.



Source: Berylls Strategy Advisors

A leading example of how virtualization can play a crucial role in the testing and validation of autonomous driving technology is the use of platforms that create a virtual environment to simulate real-world driving conditions, allowing for a wide range of scenarios to be tested without the need for physical vehicles. This approach not only saves time and money but also enables more thorough testing and can lead to increased safety and reliability of autonomous driving features. Our Experts estimate a reduction of 50% in test efforts and time on the road through virtualization in ADAS development.

However, it's important to note that not everything can be simulated, and test fleets are still necessary for the gathering of real-world data. This provides an opportunity for collaboration, particularly for smaller OEMs, who may struggle to generate the necessary amount of data with their limited test fleets. This opens opportunities for suppliers and software companies that can assume the role of a neutral data provider for autonomous driving testing. By collaborating, all companies benefit from shared expertise and resources, ultimately leading to a faster time to market and improved performance without exposing their algorithms and differentiating features.

6

SUCCESSFUL IMPLEMENTATION OF CENTRALIZED ARCHITECTURES

As vehicles become more complex, it is essential to invest in the right architecture to manage their complexities.

The current mainstream trend of domain architectures refers to the division of the vehicle's systems into separate domains, such as powertrain, chassis, and body control. This approach allows for more efficient development and easier integration of components within a domain. However, it still results in substantial architectural complexity, as many modern features in a vehicle require cross-domain communication.

The use of a central architecture in vehicle design means that there is a single computer acting as the „brain" of the vehicle, combining multiple domains. This approach simplifies hardware complexity by utilizing software and allows for continuous improvement of the vehicle even after it has been produced.

Incumbent OEMs are often hindered by financial and technical limitations: Financial limitations because a centralized architecture at first does not bring about efficiencies and on the contrary will lead to higher development costs as well as a significantly higher unit cost for the "brain" of the vehicle. This must be offset by the aftersales potential of selling new functions to the fleet in the market, reduced cost of retrofitting old vehicle platforms with new systems in at least the infotainment and ADAS domain, often leading to tremendous rework in the E/E architecture, and longer product lifecycles with only minor changes, as shown by the Tesla models. The technical limitations often lie in the fact that automakers do want to retrofit their old product series with the new E/E architecture but the entire vehicle architecture including EMC, cooling, and spatial requirements was not designed for centralized architectures. Similarly to retrofitting BEV technology into ICE platforms, OEMs therefore most often accept the inferior performance in favor of keeping their product legacy.

To realize the potential of a centralized architecture, OEMs must shift their focus from immediate profits to long-term revenues, a transformation exemplified by Tesla's innovative approach. Tesla's electric vehicles incorporate a central computer orchestrating functions from battery management to infotainment. This core hub, vital for handling extensive data and enabling over-the-air updates, not only fosters continuous enhancements but also maximizes revenue over the vehicle's lifespan. Tesla's strategy, evident in initiatives like the profitable „Acceleration Boost," showcases the revenue-boosting capabilities of this approach. These advancements, while requiring significant upfront investment, can translate into substantial savings in terms of warranties and recalls due to the shift from hardware to remotely updateable software.

However, traditional automakers face obstacles. Financial constraints arise due to increased development and unit costs for the central vehicle „brain," offset only by potential aftersales revenue and reduced retrofitting expenses. Moreover, technical challenges emerge as retrofitting existing models demands extensive modifications in electronic and spatial domains, often hindering a seamless transition. Despite these hurdles, the profitability and longevity brought by centralized architectures hint at a transformative future for the automotive industry.

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7

THE ROAD AHEAD: EMBRACING CHANGE

The automotive industry is at a crossroads. With the advent of electric vehicles and the simultaneous investments into software-defined vehicles and autonomous driving, there are new opportunities for innovation that can help automakers improve their business models and stay competitive. Despite these benefits, this also comes with many challenges such as managing the exploding costs associated with R&D projects and developing algorithms that are safe enough for everyday use. Therefore, the automotive industry must embrace improvement potentials to remain competitive in today's market.

1. Operating Model:

OEMs must assess their current capabilities in delivering truly software-defined products and adjust their operating model accordingly. This includes steering and governance, working models, PMT (processes, methods, and tools) as well as capability and talent management.

2. Vehicle Architecture:

OEMs want a target architecture that reduces the hardware complexity of their products and enables them to develop software-based lifecycle improvements continuously and separately. Furthermore, OEMs must decide for each element in their software stack whether to develop it in-house, procure it from Tier-1 suppliers, or leverage open-source software or other partnership models.

3. Virtualization & AI:

OEMs must develop a clear understanding of the benefits of virtualization and artificial intelligence applications along the entire development process and partner with technology specialists where necessary to significantly reduce R&D expenditures and times.

The five improvement potentials discussed in this article - decoupling of hardware and software, use of off-the-shelf and open-source products, rethinking collaboration, automatization and virtualization in testing and validation, and centralizing E/E architectures - are crucial for OEMs and suppliers to achieve greater efficiency, faster time to market, and cost savings. To ensure success in this new era of mobility, where new players are pushing into the existing markets and are gaining market share quickly, companies need to be aware of these improvement potentials and then act on them.

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Berylls Strategy Advisors – The expertise of our top management consultants extends across the complete value chain of automobility – from long-term strategic planning to operational performance improvements. Based on our automobility thought leadership Berylls Strategy Advisors stand out with their broad experience, their profound industry knowledge, their innovative problem-solving competence and, last but not least, their entrepreneurial thinking.

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