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1 Introduction

Innovation is key to succeed in the new normal. This is the simple message of the recent Vector client survey 2021. Yet, innovation must be balanced with the ongoing market pressure for competitiveness in terms of cost, quality, and competences. Vector has summarized in this white paper best practices from Vector Forum 2021 and from our recent projects. Hands-on industry case studies from Mercedes-Benz, Porsche, Siemens Healthineers, Volkswagen, ZF and Vector practically show across disciplines how to innovate with software.

We all know the story of the bear attacking two campers at night. One just starts running, bare-foot and with pajamas. The other gets into his fancy sneakers and shouts to the other, he would be faster with shoes”. Whereas the first shouts back, that while there is no way to outrun the bear, it is sufficient to be faster than his comrade. The rest as we say is history, or a nice meal – depending on perspective. The same holds for innovation as Christof Ebert, CEO of Vector Consulting Services summarizes his experiences from worldwide innovation projects. “Just be faster than your competition. Continuously.”

Software-driven innovation is the call of the day. Many technologies, such as digital transformation, autonomous systems, quantum computing, or biotech just wait to be introduced to new products and services. In January 2021 Vector published results from a client-survey which gave one clear message: Innovation matters. Companies worldwide see innovation as the major challenge both short-term and for the future1. The path to innovative solutions is marked by the four ACES that is Autonomy, Convergence, Ecology, and Services. Addressing these basic needs will create new business models to thrive upon.

There is no simple cookbook recipe for innovation. History is littered with the skeletons of companies that slept over innovations and would rather maintain their cash cows until they starve to death. Kodak invented the digital photography but bet on their classic cash cow of physical imaging, until they were gone. Nokia was the mobile phone market leader and lost within few years due to not improving user experience. Blackberry experimented with novel designs for smartphones yet stayed with keys. Still, there are lots of good examples from which we can learn.

Our ambition at Vector with this report is to share such experiences from global leaders and thus show how to learn and translate to your own environments. With case studies from companies such as Mercedes-Benz, Porsche, Siemens Healthineers, Volkswagen, ZF and Vector this white paper summarizes how to innovate with software.

2 Software Evolution

During the pandemic lock-down during 2020, Volkswagen has created its new global software division, called Cariad. While others have been complaining about the constraints with the lock-down, Volkswagen group has taken it as trigger for software-driven innovation. The name is program, as Cariad stands for "Car. I Am Digital." Dr. Maximilian Montenbruck, department head for vehicle motion at Porsche and now also working in Cariad has summarized some of the key learning along the way towards a software company. He sees three major methodical challenges in developing software with high functional integration across industries:

> Architecture
> Toolchain,
> Collaboration.

These challenges interact with each other and thus cannot be solved in isolation.

Traditionally, there was an organization which established a tool chain and then looked to software architecture. This is changing today, by giving priority to architecture. Across industries, the three-tier layered architecture with distributed responsibilities is established. Fig. 2 shows this evolution which can be mapped to the abstraction layers of the ISO/OSI stack. Porsche’s current solution is the HCP platform project with high-performance computers in the middle tier serving intelligent actuators and sensors and connecting to the cloud for flexible updates. The high quality of Porsche cars demands software updates over a long life-cycle, much longer than other cars. This needs thorough software updates management and high emphasis on cybersecurity. Flexible and adaptive software packages being continuously

updated create new challenges towards quality and testing. Often the new technologies demand heavy test efforts in brute force mode. With new technologies, machine learning, adaptive AUTOSAR, all deal with real time communication. It is tough to have test depth. New test methods and coverage schemes are demanded. Looking to sometimes bizarre software and architecture decisions in our industries, Montenbruck warned about Conway’s law: “No matter what you do, the software architecture will resemble the organizational architecture.” Volkswagen group is mitigating this risk with new functional paradigms. The new software organization is creating modular software with low interaction and coupling together with a strong toolchain to overcome this legacy organization trap.

Dr. Ingo Alfter, chief engineer for global customer product platform at ZF looks to innovative software concepts for safety-critical products from a supplier perspective. A general trend faced by suppliers across industries is to drive innovation by software, become hardware independent, and activate functions on demand with flexible business models such as pay per use. Safety-critical software components are getting smart – and vice versa. Examples include active safety with its various safety critical software systems like Anti-lock Braking System (ABS), Electric Power Steering (EPS), Electric Park Brake (EPB). Fig. 3 highlights these intelligent actuators. This needs dedicated architecture to handle the rising complexity. In implementing the new architectures, we currently see an evolution away from traditional functional design and the current domain architectures towards future zone architectures which are cloud-oriented and can be easily adjusted with new content, both user experience, functionality, services, and software. Obviously not all functions will move to cloud-based services. Comfort based functions may move into domain or zone-based, however steering and braking being safety critical and real-time will remain as individual smart actuators in separate ECUs.

This evolution leads to the software-defined vehicle with much more computing power than what we are used to. Smart actuators will merge various functions and demand fast and reliable bus systems for efficient communication. With their specific demands on functional safety and real-time performance, they operate independent of the cloud, yet consider inputs from the cloud. Imagine a braking system in a vehicle being aware that there is a slippery or icy road ahead. It can adjust to these changing road conditions and thus improve safety of vehicle and driver. To cope with specific OEM needs, ZF has created a platform with four abstraction levels, namely base software platform, customer product platform, product controls, final product software. Testing of smart components will remain a challenge. Alfter underlines the need for a virtual ECU: “The evolution of hardware takes too much time and does not match the new time frames in continuous deployment. Virtual ECUs facilitate early simulation and testing.” ZF has created the necessary underlying software platforms which are highly flexible and follow a Service-Oriented Architecture (SOA). A fully new toolchain ensures consistency on ZF projects across suppliers and facilitates exchanging software and documentation in the respective formats demanded by the OEM.

3 Digital Acceleration

Digital innovation happens across industry domains. The medical industry for instance, since long is dealing with very similar challenges as we have today in IoT and automotive. Medical implants connect with cloud services, medical image analysis is a powerhouse of AI, digital twins have been used long before they became fashionable in automotive and industry automation, and regulations and homologation are certainly more demanding than in automotive and aerospace. V. S. Mani, head of marketing and communications at Siemens Healthineers Development Center in Bengaluru, India claims that digitalization enables a more humane healthcare. As it is already evident from Siemens experiences. Digitalization enables new treatments and certainly more efficiency in healthcare workflows. More data is generated, hence more need for AI to analyze. The future of healthcare brings fundamental changes: Siemens sees four strategies to accomplish the medical software innovation, namely expanding precision medicine, transforming care delivery, improving patient experience. Mani emphasizes the high innovation speed in medical software: “Today worldwide medical data and thus knowledge doubles every 73 days. This creates a relentless pressure to innovate.”

Siemens is engaged in many entirely novel software-driven innovations to advance medicine, from which we can learn across industries. Here are some examples which have made or will make their way to other industries:

- Digital avatar for procedure optimization so that a medical doctor can perform a complicated and critical procedure on the avatar and get familiar with the situation.
- Pathway companion to use AI for actionable insights for personal care and collects data from electronic medical records, lab tests, genome mix, pathology, etc. to achieve a better understanding of clinical condition of patient and use this information to improve diagnosis, to better plan therapy, monitor it and to improve the subsequent follow ups.
- Evidence-based recommendations and course correction together with comparison with other patients’ cohorts to provide clinical context in one single view to get a holistic understanding.
Digital twin of organs of patient to explore the intervention, check effectiveness of medication and also for experimentation, for instance, the digital twin of the heart helps to position the probes for cardiac resynchronization therapy, in order to put the probes properly to restart the heart.

Predictive models all aggregated helps to construct the AI-powered digital twin to derive actionable insights and assist decision making.

A current showcase illustrates the immediate advantages. AI-Rad Companion, which is an AI-driven radiology workflow solution, identifies abnormal patterns in lungs of Covid-19 patients like lung opacity and lung severity score so that radiologists can, much faster than before, analyze the severity and monitor the progression of abnormalities in patients with symptoms of Covid-19. Fig. 4 illustrates how medical workflow are driven by such innovative software.

Obviously, medical software demands highest quality standards. With digitalization, the standards and regulations are getting stricter with the cloud-based service. There are quite a lot so not going into details of what goes into cloud and what goes into embedded systems. Digitalization needs connectivity to the outside world but that of course is also a primary attack target for hackers. Cybersecurity of medical devices is the need of the hour. There are strict guidelines on how data is handled. Every code is designed for security. Security is embedded at all stages. It is no longer an extra feature but a co-feature. It is not a desire but is a must. Siemens is using continuous code quality management. Every piece of software has a certain quality level. For a particular iteration, a top goal is selected such as reliability or maintainability. Static code analysis throws a huge bunch of errors, this comes in a way for an engineer to make progress. So, the most relevant and the most critical ones are selected in that iteration or sprint. Once those code checks are fulfilled, then test cases are executed and finally the software is checked in. A combination of both agile and DevOps is used. At the beginning of every sprint, a lot of code instrumentation takes place to make sure it fulfills the desired quality level.

Digital transformation is a key consulting focus of Vector. No wonder that “software-driven innovation” is a guiding theme across Vector client base. Dr. Ulrich Bodenhausen, manager at Vector Consulting Services sees a direct correlation between innovative software and innovative development. He claims, “From our experiences with clients worldwide across industries, companies need innovative development processes and infrastructure to be competitive. There is no innovation without adequate development processes.” Most companies are currently transforming their development processes for similar reasons:

- New technologies such as ML/AI, SOA, green IT, connectivity, etc.
- Convergence of business IT and product IT, multiple development partners, ecosystems, distributed development, etc.
- Complexity management, competence management, efficiency, and “new normal”

Workflow management is mandatory but not sufficient. With more agility and flexibility, the process-first philosophy comes to its limits. Some companies still entirely entrust on tool-chain. PLM/ALM is ok, but certainly not good enough. We face today highly complex toolchains due to blindly following tool vendors in a lock-in. Fig. 5 illustrates the different levers in innovative software development.

Innovations to our observation in different client projects are often hampered by insufficient internal alignment of technologies, competences, management, processes. Many companies often struggle with heterogeneous and legacy tool-chains and processes. Bigger organizations suffer from “over-the-fence” mentality where artifacts are thrown to another location, which will eventually start a ping-pong of who must solve which problem. Overly complex frameworks such as agile S4Fe also contribute, which creates even more burden and complexity than CMMI. Complexity is increasing with multiple development partners and the need to coordinate them. To mitigate such risks, Vector has been contributing to the recent VDA guideline on agile collaboration. The objective is to facilitate new forms of development, partnerships between organization and several levels of collaboration such as linked, aligned, and combined.

Innovation with autonomous systems gained speed recently as some legal obstacles have been removed. Vector is not only active with its products such as data loggers, but also in standardization such as SOTIF. A major theme in Vector consulting is novel testing methods. Vector as the testing company has strong credibility in testing of autonomous systems and is asked from companies worldwide on how to innovate testing methods, away from brute force and questionable coverage schemes. Bodenhausen explains, “There is a competition of learning algorithms. Never say it is supervised learning, or reinforcement. We really need to benchmark the algorithms with others. There are several other methods like automation by deriving variants and doing transfer learning. The combination will give you the best result.” Data matters in learning, as well as testing. The saying is there is no data like more data. But this means brute force with high effort and still big risks of overlooking a critical corner case. Synthetic generation of data will facilitate efficient data generation while capturing the corner cases. In this topic, Vector is highly engaged with various research projects in this field, such as University of Stuttgart with its Robo-Test incubator.
4 Extended User Experience

An exciting user experience (UX) is the single most relevant decision-driver when buying a product. Like when we meet somebody, it is the first look, which makes us feel good, or not so good. OEMs therefore increasingly embark on exciting UX for vehicles. This includes appealing design, but even more flexibility with on-demand functionality. Matthias Schneider, director of MB.OS cloud, data and user interface at Mercedes-Benz shows how to keep a UX fresh by using different OTA update mechanisms. The Mercedes Benz Operating System (MB.OS) is at the core of keeping the user experience fresh, engaging, and exciting for the customers. Schneider has a simple yet effective message: “Luxury creates desire.” Features such as biometric authentication, OLED display, gesture control, personalized infotainment of the seat, augmented reality, automated driving functions all serve one purpose, namely, to provide an advanced UX and thus satisfy clients beyond their basic expectations. Without a compelling and exciting user experience, it will be difficult to retain customers and gain new customers. With the growing functionality in the car, it is even more important for the user experience to be up to the mark for the customer to experience these new functionalities in the best possible way. Today the major OEM all own their operating system for several reasons:

- Control the interface to the customers
- Speed of execution, such as updating fifty plus ECUs in production, development, and field
- Digital recurrent revenues as new profit pools
- Integrated cybersecurity hardening

Functionality is updated along several streams, namely functions added from backend, updates via Wi-Fi, and activation of pre-installed features. An enhanced user experience has one key precondition and that is continuous and secure software updates. Flexible and fast software updating has reached all industries, not just because of UX, but also because of increasing cybersecurity attacks. There is no security without continuous updates. Achieving frequent software updates within safety-critical environments such as automotive, medical and transport is far from trivial. Over-The-Air (OTA) updates demand Software Update Management Systems (SUMS) and Cyber Security Management Systems (CSMS). Security is not brought into the system as an afterthought. It is a key design element from the hardware stack upwards to functions, applications, and user experience. This of course needs careful life-cycle management support during the lifetime of the vehicle. Support and maintainability depend on the ECU or software module. Infotainment and navigation updates will be available for many years after end of production. Adding, for instance, a speech signal in ‘Hey Mercedes’ to say a funny joke, can be done almost forever to keep the customer excited. Update management also demands strategies for roll-back in case of problems during the update. Technically, there are mechanisms to perform roll back, it is needed in terms of development. However, being mandatory for a growing user experience and cybersecurity robustness, roll-back is questionable.

Jörg Francis, manager of software and data management at Volkswagen provides hands-on insights to software update management in the Volkswagen group. The core is a software update management system covering the entire Volkswagen group. It is demanded by regulations such as UNECE R.156 on SUMS but also numerous security standards. SUMS is the enabler to perform secure, safe, and frequent software updates. Fig. 6 shows the evolution from current asynchronous updates with regular service and per function service towards a well-orchestrated update management with a system perspective. Enhanced user experience is achieved by such software updates, but also the updates themselves need to provide a UX. The driver must be informed about updates to come so he can prepare and judge, when it would be most convenient. Unlike the annoying IT updates which we face in our laptops, smartphones and other appliances, safety-critical systems need to make update management part of the user experience – in a positive sense. R.156 is mandatory by July 2022 for new vehicles and July 2024 for old vehicles. It regulates the technical requirements to ensure secure processes to bring software to the car, ensure safety to the driver and thus bring new functionalities in cars. The regulation is split into two parts, namely technical requirements such as RxSWIN to identify components, and requirements to harden the products against external attacks. Each software element can be traced both at the OEM and by external agencies to ensure it is the released software and fits to the overall homologation.

Francis distinguishes the constraints in vehicles, “Software update management in vehicles must balance between flexible and innovative user experience and the demands of homologation, such as functional safety.” Most updates are not functional change but close open security leaks. This implies new and better integrated interfaces between OEMs and their suppliers. The OEM who brings a product to the market is by law responsible for its overall quality. Therefore, UNECE certification and overall homologation always targets the OEM, not its suppliers. To achieve the demanding SUMS objectives, the OEM will break down cybersecurity management and SUMS into functional requirements which are available to its suppliers. SUMS is not one process. It is a method and management system across the entire product life-cycle to ensure quality. If for instance a Tier 1 has implemented new software and generates a new component he must have detailed know-how of interfaces to achieve the necessary security. For this very reason there will be no ad-hoc function changes. OEM
Software processes are looking at baselines, which bring specific new software to the customer. These baselines need to document changes and impacts towards certification authorities. Of course, the OEMs will try to generate open space without impact on homologation to update functionality. However, soon such open spaces can cause an issue in the long run given the growing cybersecurity risks and thus product liability.

### 5 “New Normal” Means that New Is Normal

Today the smartphone is the benchmark for any software-driven innovation. Indeed, there is lots we can learn from smartphones. The look and feel must be appealing and adjust to our emotions – and vice versa. Functions and services must be flexible and available on demand. Software innovations must be feasible also on old hardware platforms. So far, we describe the analogy with smartphones because vehicles or medical devices are more challenging. They demand functional safety and highest reliability. At most they might result in fail operational, while IT systems periodically crash, independent of the size and suppliers. Some hardware platforms run for decades almost as if new, while smartphones are thrown away after few years. Cars are updated and maintained long after end of production, while Microsoft and Apple stop supporting after a few years the respective software was shipped.

Yet a many such systems such as vehicles, robots and medical telesurgery are not simple gadgets. They are safety-critical and thus must exhibit much higher quality than traditional IT-systems. For instance, when there are adaptive algorithms in vehicles, their behaviors must be specified, approved, and homologized. Underlying AI rules must be transparent, and upon self-learning, it must be ensured that still valid rules are not overwritten. While Google, Amazon and others have centralized IT systems which facilitate roll-back, vehicles must be autonomous in their usage and updates of software. In short, while we enjoy a smartphone-like user experience, we don’t want to face its downsides, such as frequent crashes and nondeterministic behaviors. Fig. 7 summarizes the main levers of software-driven innovation.

Innovation is the major driver to competitiveness and thus surviving in these fast-changing times. New must become the normal. Software-driven innovation must leapfrog not only legacy, but also current practices of IT systems and apps. This report summarizes industry best practices in times of lock-down and adjusting engineering to the new normal. From our industry projects at Vector Consulting, we have distilled five key success factors for software-driven innovations, namely:

> Create new needs
> Build on an existing platform
> Use an agile team
> Proof value
> Grow incrementally

Let us look to a simple yet powerful software-driven innovation. 50 years ago, in 1971, Ray Tomlinson enhanced existing messaging towards the first electronic mail. Working on ARPANET (Advanced Research Projects Agency Network), a network connecting computers and predecessor of today's Internet, he discovered that users communicated by messaging to other users on the same computer. He thought beyond this simplistic pattern and anticipated sending asynchronous messages to any computer – worldwide. Tomlinson used the “@” to indicate a destination in the format <username>@<name of computer>, which is essentially how email has been addressed ever since. When inventing the e-mail fifty years ago, in innovating collaboration software, he followed the above five success factors. He stimulated new needs to allow people asynchronous communication. He used an existing platform rather than waiting for something fancy and perfect. He worked in a small team and incrementally improved the service. He proved value by bringing the results to his community, where he for instance coached a woman who used e-mail to create one of the first newsletters – and eventually became his wife.

Software-driven innovation not just happens. It demands hard work. Statesman Winston Churchill, who certainly has seen more trouble than most of us, concluded: “A pessimist sees the difficulty in every opportunity. An optimist sees the opportunity in every difficulty.” Christof Ebert of Vector aligns and summarizes along the story with the two campers attacked by the bear: “No need to outrun the bear. Just be faster than your competition. Avoid the perfectionism trap and innovate incrementally.” The biggest risk is staying with legacy – and being outrun by competition.
Take part in our annual Vector Client Survey until November for a chance to win an exclusive prize. More information: www.vector.com/trends-survey

For more information on software-driven innovation plus access to the industry presentations and videos, please visit: www.vector.com/consulting
Figures:

**Figure 0:** Teaser image (Image rights: Vector)

**Figure 1:** ACES drives software innovation (Image rights: Vector)
Figure 2: Layered architecture facilitates distributed responsibilities (Image rights: Porsche)

Figure 3: Future vehicle architectures towards the Software-Defined Vehicle (Image rights: ZF)
**Figure 4:** The evolution of computational models in medical software (Image rights: Siemens Healthineers)

**Figure 5:** ACES Drive Innovation (Image rights: Vector)

**Figure 6:** Frequent software updates in complex environment need excellent orchestration (Image rights: Volkswagen)
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*Figure 7: Software-Driven Innovation along base technologies (Image rights: Vector)*
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