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Integration to face modern Quality Challenges in Automotive

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Abstract

Integrated design has proved since many years the interest to put together the different actors involved in the life cycle of a product during the design process. Integration facilitates the design of complex systems, giving each participant the capacity to introduce their own constraints as justified) needs. Integration can also be a concept used to face industrial challenges when different views concern the same object. This paper introduces a novel vehicular qualification concept facilitating the integration process for quality and risk management in automotive industry. The creation of a common view about quality, safety and reliability of automobile products and systems permits the different experts in quality, functional safety and Lean Six Sigma to collaborate in an integrated manner.

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Keywords: Integration, Quality, Knowledge Management, Integrated Manufacturing, Sector Skill Alliance

1. Introduction

Integrated design has proved since many years the interest to put together the different actors involved in the life cycle of a product during the design process [1]. Integration facilitates the design of complex systems, giving each participant the capacity to introduce their own constraints as justified needs [2]. This needs a strong capacity to communicate between actors and to understand that each view can bring some specific constraints. When working on the life cycle of the product, we have to take into account that the different stakeholders do not belong to the same world, as defined by Boltanski&Thevenot [3]: a person in charge of marketing has not the same logic of action, the same scales of value and a collective knowledgewith the head of a manufacturing plant. The same logic of action and scales of value can be easily imposed if people are thinking about the global system and the interest of the

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enterprise and not the own interest. But the creation of collective knowledge requires spending of time in order to create vehicular objects.

Electronics and software control 70% of modern cars' functionality; studies predict 90% and more tomorrow, however mechanics is still present and important. The induced system complexity makes it increasingly difficult for automotive companies to master interdisciplinary, horizontal issues such as quality, reliability, and functional safety.The holistic nature of these quality requirements and the ever increasing need for shortening development cycles imply that the topics linked to risk aspects have to be addressed in a totally integrated way.The strong need for it is manifested by the fact that this research has been selected for co-funding by the European Commission as a pilot action for the automotive sector in the AQUA project of the H2020 Sector Skill Alliances program. Section 2 of this paper explains the three different views concerning the risk with a look on the internationals standards and norms about Development Quality (Automotive SPICE® [4], ISO/IEC 15504), Functional Safety (ISO 26262 [5], IEC 61508) and Six Sigma (production and process quality). Section 3summarizes one of the key results obtained so far, which is essentially a novel qualification program for integrated quality engineering and management in automotive.Section 4 concludes the paper and gives an outlook on further research and valorization activities.

2. Three different views concerning risks in automotive industry

In the overall product engineering process life-cycle, three specific processes are directly in charge of the risk reduction and quality requirements (Fig. 1). During the research and development phase, the quality assurance controls that all the needed processes starting with the system requirement definition and ending with the start-up of series are effectively assumed. In system requirements, the safety goals from the hazard and risk analysis and the countermeasures from the FMEDA (Failure Modes, Effects and Diagnostic Coverage Analysis) are considered and a Functional Safety Concept is created. In systems design the functional safety concept is refined into a set of technical safety requirements and a technical safety concept. The Six Sigma experts intervene as soon as the first prototype occurs and during all the production phase.

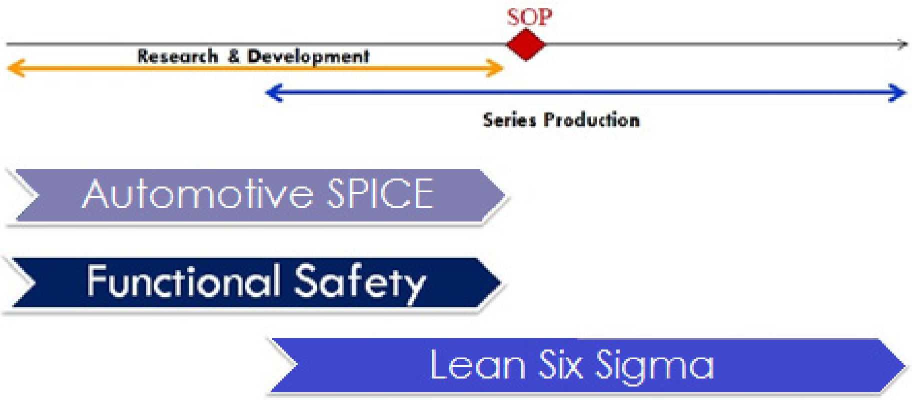

Fig. 1. Integrated Product Engineering Process (PEP) – Timeline View

The holistic nature of these quality requirements and the ever increasing need for shortening development cycles imply that the topics linked to quality aspects have to be addressed in a totally integrated way. Furthermore, the capability of suppliers to master this integration is increasingly a subject of rigorous assessments demanded by OEMs [6]. This strong need, however, is confronted with a lack of qualified specialists and even more so of interdisciplinary "all-rounders" that can act as the links between different expert groups [7]. The research presented here addresses this lack by identifying the essence of the concerned specialist topics and integrating it in a compact and modular certified and e-learning enabled training program. The "essence" is considered to be the veryshare of

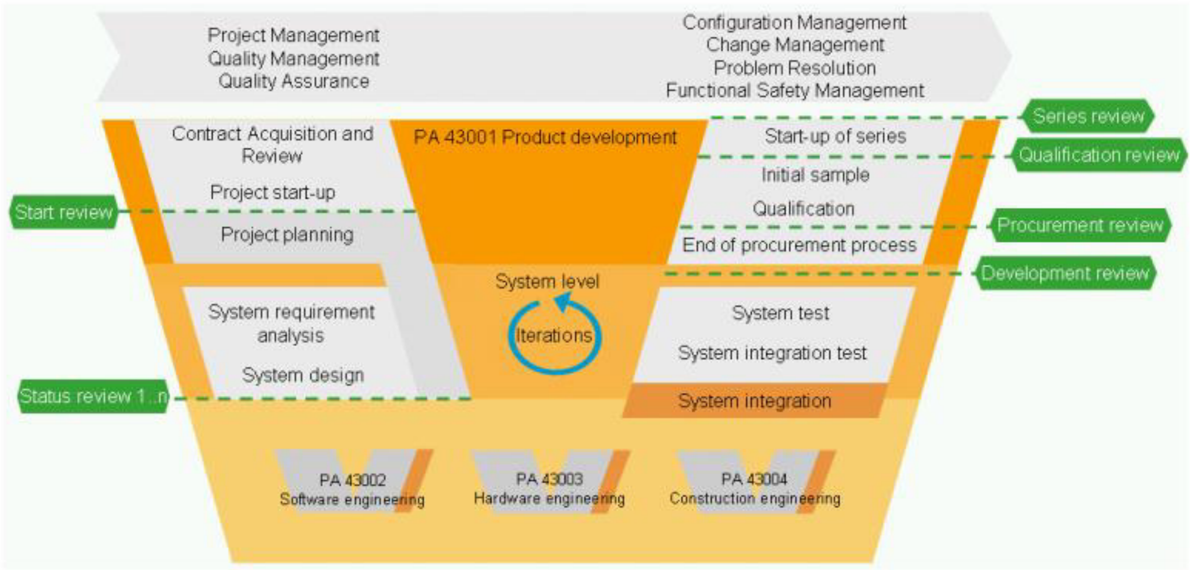

Fig. 2.Implementation of the V-model on system level in Automotive SPICE [8]

knowledge in all three topics that is vehicular, i.e., that can drive the integration of related stakeholders within existing organizations. Identifying and explicitly elaborating this vehicular knowledge [9] has never been done before, and is therefore considered a real research challenge. The strong need for it is manifested by the fact that this research has been selected for co-funding by the European Commission as a pilot action for the automotive sector in the AQUA project of the Horizon 2020 Sector Skill Alliances program.

Before getting the capacity to integrate the Development Quality view, the Functional Safety view and the Six Sigma view, we need to have a look at the specific concepts that each of theseviews follows.

2.1. Development Quality view

In Automotive industry, Development Quality is based on the International Standard SPICE® [4] and the standard ISO/IEC 15504. SPICE uses the V-model to define the product development life-cycle (Fig. 2). Starting with the specification of the project and the project planning, the product development life cycle go through the system level with the requirement analysis and the system level, then to the system engineering with the detailed design of the different parts and there integration, before returning at the system level with the system test and at the product development level with the qualification and start of production.

However, the global V-model has to be seen for each of the technologies used in a modern car and is transformed in fact in a 3V model running in a concurrent way for the HSM elements (hardware, software and mechanical parts) (Fig. 3). When designing the HSM requirements analysis, HSM architecture, HSM design or HSM tests, the different actors have to work in an integrated way to avoid a complex solution [2], taking into account the different constraints of the other actors and added there suitable constraints in a just need [1]. Here is the veritable challenge as normally people in charge of hardware, software or mechanical parts come from different disciplines: electronics, computer sciences and mechanical engineering, and cannot easily understand which interactions are mandatory and cannot be avoid without damage for the global system. In addition to that, from an organizational point of view these experts are typically separated in different departments and/or divisions.

2.2. Functional Safety view

The functional safety view gives the different aspects the project has to tackle concerning the safety life cycle, defining first the safety goals for the system from the hazard and risk analysis, and from the FMEDA the functional

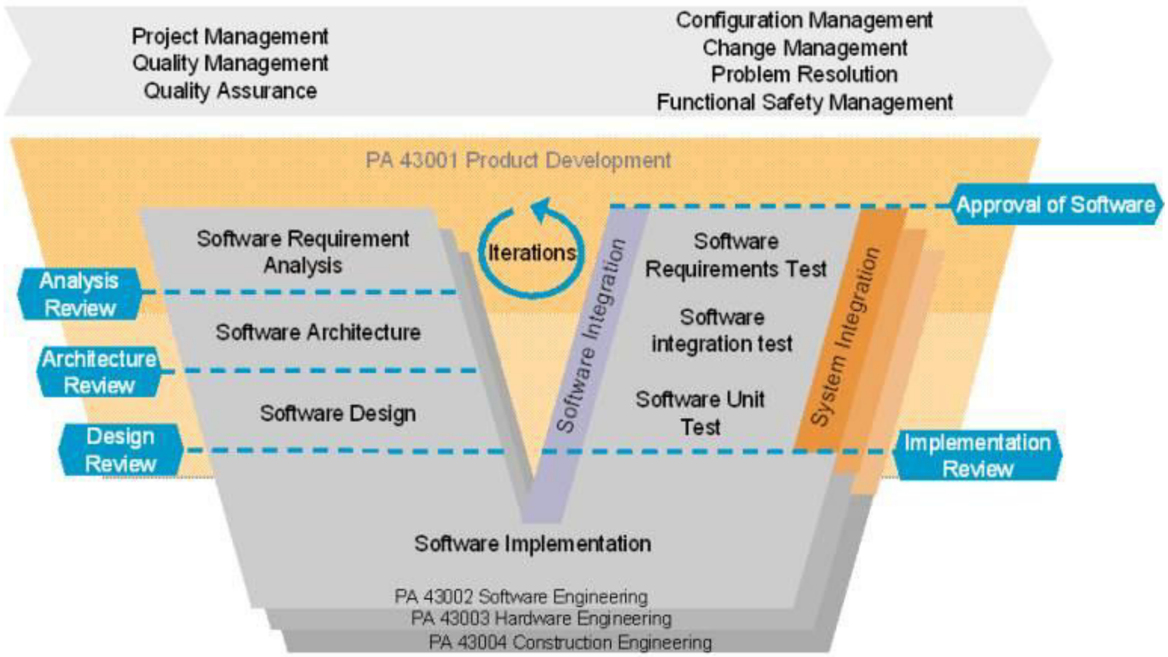

Fig. 3.Implementation of the 3V-model in concurrent processes

and technical safety concepts. These requirements are translated in different diagnose layers implemented with redundant design and FIT (Failure in Time) rates. Each of the safety requirements implies testing the safety mechanisms on the right branch of the V-model if we apply this model to the functional safety concept (Fig. 4), applied at 4 different levels for the automotive industry: level 1 meaning the release for bench test, level 2 the release for test driver on a closed test circuit, level 3 for a test driver on the public road and level 4 for the normal driver on the public road.

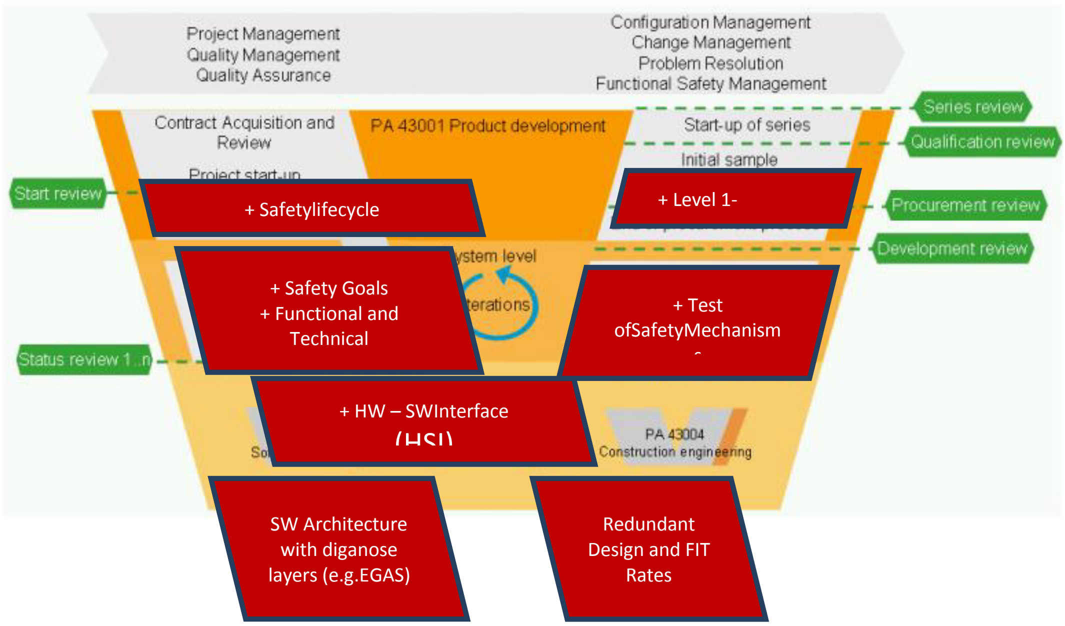

Fig. 4.Functional Safety based Implementation of the V-Model on Systems Level

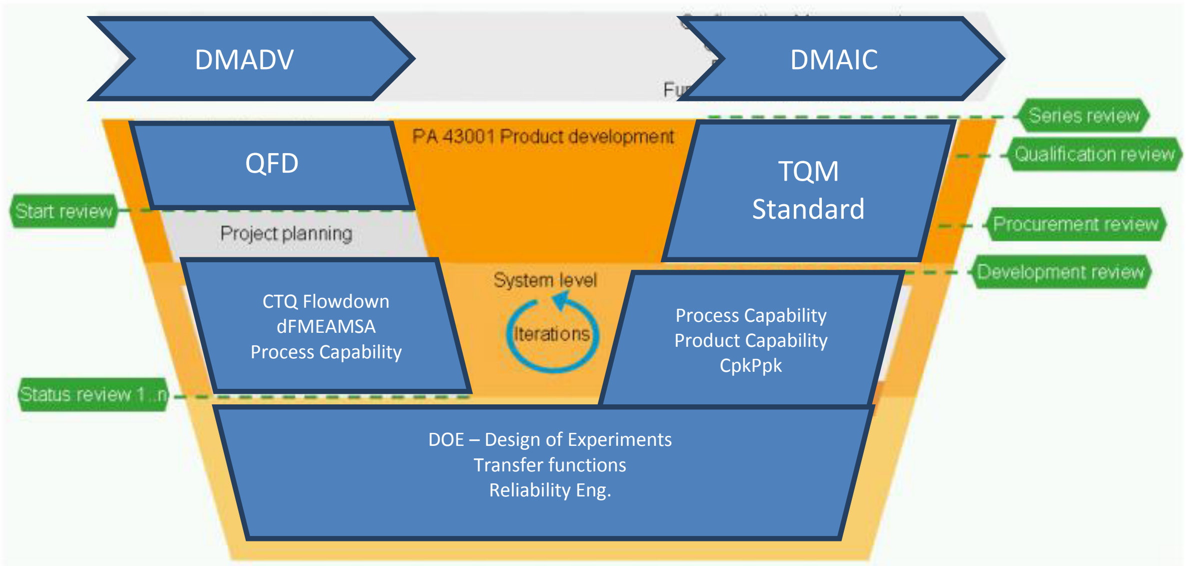

Fig. 5.Mapping of Selected Six Sigma Tools / Methods onto the V-Model on Systems Level

2.3. Lean Six Sigma view

We can also ask the Six Sigma experts to position them in this framework, and the result is shown in Fig. 5. In Six Sigma the management of the improvement project follows the DMAIC (Define – Measure – Analyze – Improve – Control) and DMADV (Define - Measure - Analyze - Design – Verify) cycles. Six Sigma tools like QFD (Quality Function Deployment) and VOC (Voice of the Customer) help in identifying the customer requirements which have the highest impact on success. For systems design the DFMEA (Design FMEA) helps to analyze potential malfunctions and causes. It defines counter measures in turn that help to increase the product reliability. A method like DOE (Design of Experiments) helps in system design to analyze the dependency of design parameters and decide about optimized design parameters which have an impact on e.g. reliability and quality.

3. The AQUA integrated view

As we have just seen in the previous sections, each of the three views: the development quality, the functional safety and the six sigma views can be developed with the same V-model. In this model, four concepts play a specific role: the life cycle concept, the requirements phase, the design and performance activity and the integration and testing period. In order to permit the integration of the different actors who have to intervene during each of these concepts, the Knowledge Alliance for Training, Quality and Excellence in Automotive (AQUA) propose to establish a common vehicular language. In contrast to a vernacular language which is only used by a specific trade, the vehicular language proposes a common understanding that enables the exchanges and interactions among two or more actors belonging to different trades.

Let us have a look on the Fig. 6, giving the example of the requirements phase. The specific knowledge shared by the experts in quality deployment, and in the Automotive SPICE, is linked to capability level requirements and traceability. In the same time, the functional safety managers use the ASIL and the functional and technical safety concepts, while the Six Sigma engineers rather care about the capability in production, the voice of the consumer (VOC) or the critical to quality (CTQ) notions.

The creation of the AQUA layer has been done byuniting at the same table the different experts in order to identify and formalize the common interest that will create the conditions of synchronized work during a project.

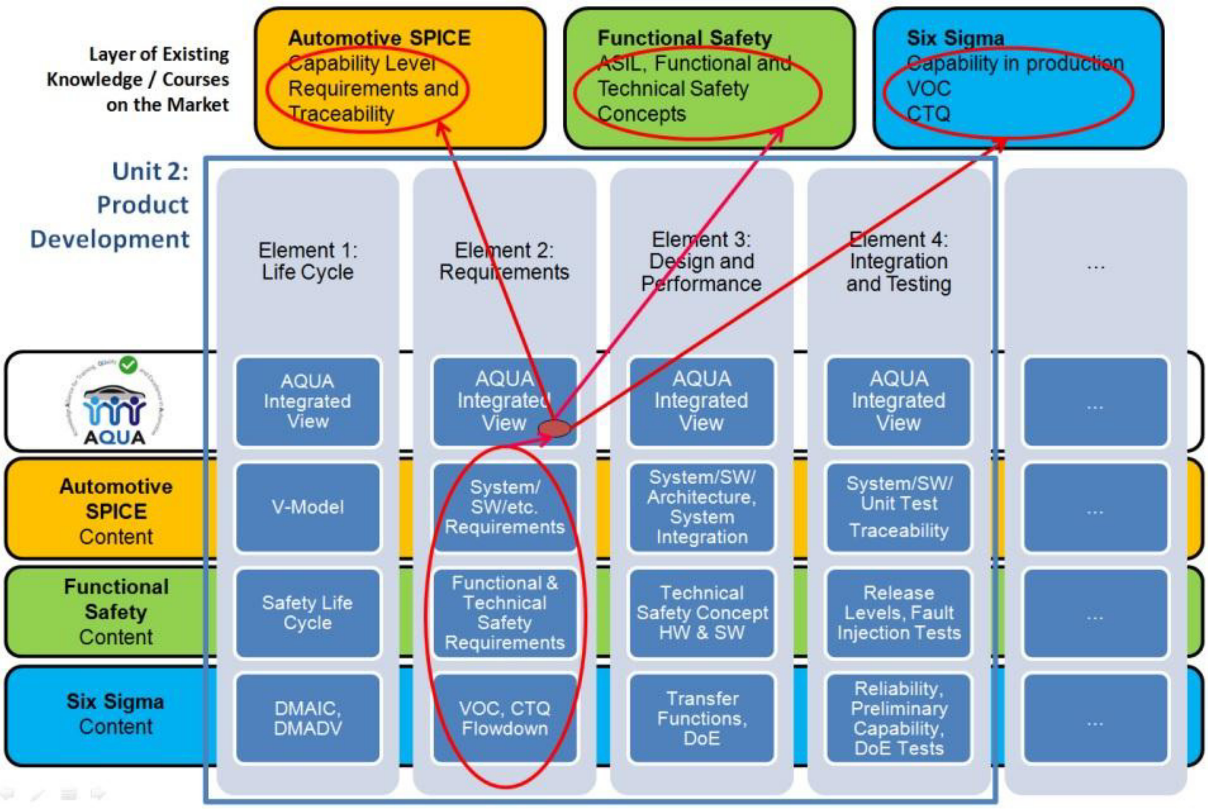

Fig. 6.The AQUA integrated view

3.1. The capability concept for quality and safety management

As an example of the AQUA modules, the “Capability” element in the training unit “Quality & Safety Management” establishes and explains the holistic capability concept, using a combined use of methods.

In a first approach, a common definition of the 6 capability levels of SPICE concerns the development process, as shown in the Fig. 7. The INCOMPLETE level concerns the chaotic processes. In the PERFORMED level, processes are intuitively performed and incoming and outgoing work products exist. During the MANAGED level, processes and work products are managed, responsibilities are identified. Defined processes are tailored to specific projects and resources are managed at the ESTABLISHED level. Metrics for the measurement and control of process performance and outcomes are applied when we reach the PREDICTABLE level, and finally, the OPTIMIZING level permits to get quantitative measures in order to continuously improve the process.

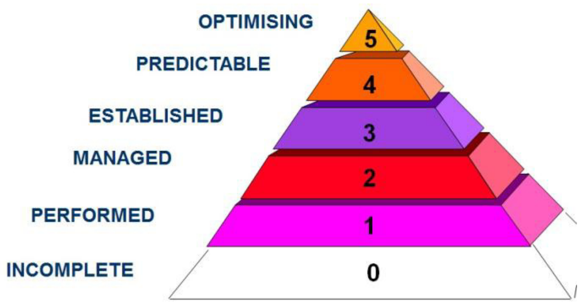

Fig. 7.The six capability levels

Froma functional safety point of view, the safety capability of a system must prove the absence of unreasonable risk due to hazards cause by a malfunctioning behavior of the complete system. For this it is interesting to extend the four Automotive Safety Integrity Levels (ASIL) of the standard ISO 26262, normally devoted purely to the electronic hardware and software domain to the global production system, and to transfer them to the mechanical parts domain. The higher the safety integrity level, the more safety mechanisms have to be included in the product or system. Each ASIL level requires specific methods to be applied. This leads to hardware, software and material redundancy, requiring a significant investment in diagnose capabilities. ASIL can also fix specifications on the acceptable tolerances for different parameters. This concept allows building trust in the product.

As a complementarity notion, the Six Sigma theory permits to build trust in the ability to produce. Six Sigma analyses the deviation of the production processes to assure that the final product respect the given specifications. So the Six Sigma expert first has to understand what the different actors want to achieve, and how the process capability assures these wishes. A non-capable process can have too much variation or an average that is not centered. So the Six Sigma focuses in determining the inherent process variation, resulting from common causes, and those resulting from special causes.

The trust in and capability of the process, product and production (P^3) creates a strategy for a holistic concept that permits to satisfy the customer, as illustrated in Fig. 8.

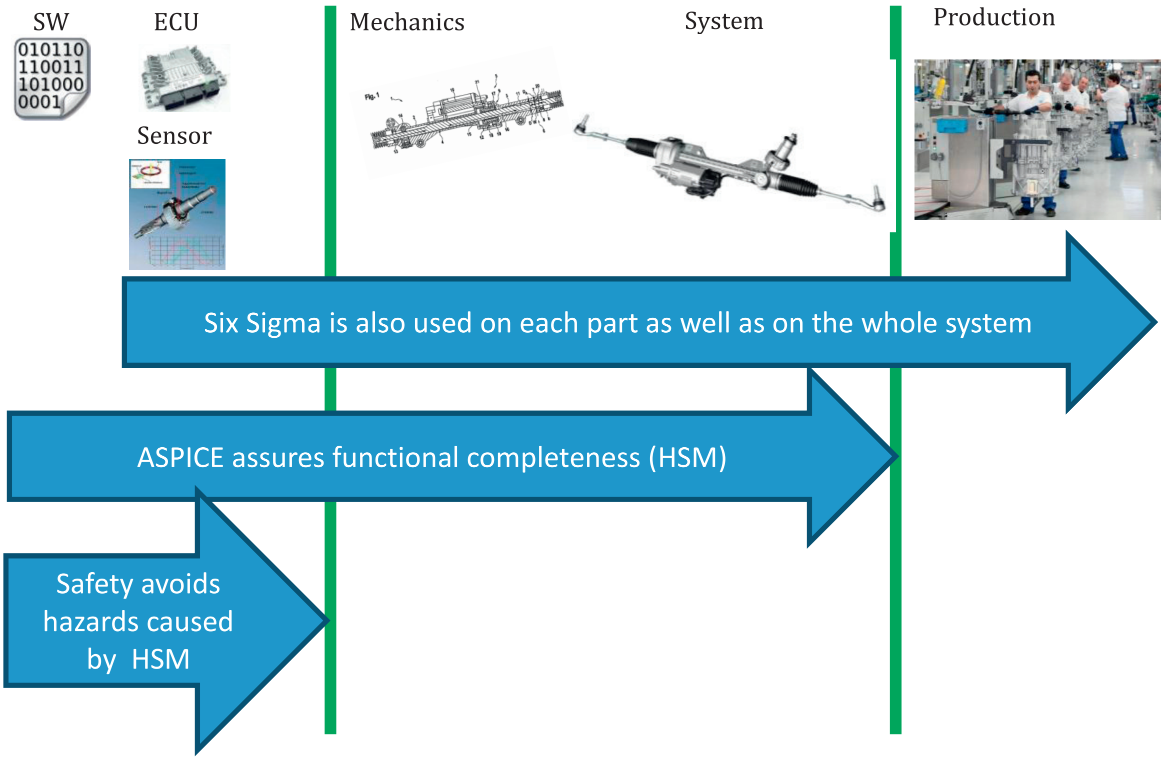

Fig. 8.Overlapping the P^3 implementation

3.2. The complete AQUA structure

During the realization of the AQUA training, the different experts structured the course in units containing different elements, as required by the ECQA, European Certification and Qualification Association [10]. For each of these skill elements, training material in the form of slides with notes has been developed. To facilitate e-learning, recorded versions of these presentations have been made available in the integrated e-learning environment of the

ECQA. Furthermore, for each performance criterion, a set of multiple-choice test questions has been created. These questions are the basis for the certification of candidates within the ECQA exam portal.

- Unit 1: Introduction
  - U1.E1: Standards, Norms, and Guidelines
  - U1.E2: Organizational Readiness
- Unit 2: Product Development
  - U2.E1: Lifecycle
  - U2.E2: Requirements
  - U2.E3: Design
  - U2.E4: Integration and Testing
- Unit 3: Quality and Safety Management
  - U3.E1: Capability
  - U3.E2: Hazard & Risk Management
  - U3.E3: Assessment and Audit
- Unit 4: Measure
  - U4.E1: Measurements
  - U4.E2: Reliability

4. Conclusion

The need for organizations, methods and tools for the integration of different expert groups and departments has been widely documented in the research community over several years. Our research addresses this challenge for the topic of quality and risk in automotive essentially via the terminology lever in that it has developed a sophisticated and worldwide unique training architecture around the principalvehicular terms and subjects in the area of quality in development and production of mechatronic systems and subsystems. The idea and approach are completely new, and first dissemination actions targeting automotive suppliers in Austria, Czech Republic, Germany, France, Slovenia, and The Netherlands have confirmed their high relevance to their needs.

Given the huge challenges that organizations have been facing with the realization of integrated product creation concepts, we believe that our research results can be considered a significant contribution to the research question of how such integration concepts can actually be driven, leveraged, and deployed in existing industrial environments without changing the complete organization and central processes (as changing these takes a long time and huge investments).

Future research activities include the assessment of several indicators obtained by the actual deployment of the training program in several companies in terms of efficiency, effectiveness, influence of the training lever on the organizations' integration capabilities, etc. These figures, in combination with further experiences and feedback collected during the trainings will enable progress in judging the relative importance of the explicit presence and support of vehicular knowledge in an organization in order to leverage stakeholder integration for a very specific objective.

More information about AQUA and free access to the training can be found on the EMIRAcle web site [11]

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