

An Integrated Methodology for Defining, Modeling, and Validating Complex Automotive Systems

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ABSTRACT

Systems engineering is not a new discipline for today's automotive OEMs and suppliers. So, why is it that many feel the discipline is under-utilized or not utilized at all in main-stream product development? For those that do believe systems engineering is a key activity in the development cycle, why is it common to disagree on a definition of what it is or how it manifests itself in the development cycle?

If we examine the development activity of leading OEM's and suppliers in any industry, there can be no doubt that product development is a complex and intensive activity. Many disciplines are utilized with many specialized skills deployed throughout the lifecycle of the typical product, and even more so in the automotive industry. One can point to several processes that seem to indicate the presence of systems engineering, yet the ability to clearly define whether or not - and to what degree - we leverage systems engineering is still difficult. This paper will explore the benefits of looking at systems engineering as a core process from which the automotive community develops products and technology.

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THE GROWING NEED FOR SYSTEMS THINKING

Systems engineering is certainly not new in the automotive industry. Most leading automotive companies have formalized the discipline in one form or another within their Electronics/ Controls/Software development process. However, many companies voice a frustration that "systems thinking" is not predominant within the remainder of their organizations, and in fact that many engineers have a completely part centric mentality. Furthermore they feel that their processes are document driven and that the systems are verified/validated through physical prototypes. So this begs the question, "What is it that we can do to improve our systems engineering implementations?" Let's start with the basics; a "simple" definition of systems engineering.

Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem:1

Taking into consideration this definition, plus "best practices" seen throughout the industry, a robust systems engineering implementation should also include:

- Capturing "How the product works"
- Insuring at all times that the subsystems meet requirements of the holistic system
- Providing the ability to quickly and efficiently manage interfaces
- Comprehension of part reuse in various subsystems
- Quick analyzation of the impact of requirement changes on entire systems
- Quick verification of the function or dis-function of the system being modeled

TODAY'S PARADIGM: REQUIREMENTS AND PARTS

In a short amount of time, the automotive industry has transformed into a global cross-platform, cross-program paradigm. The complexity of today's vehicles has also increased exponentially (See [Figure 1](#))², with the amount of electronic and mechatronic content driving the product innovation paradigm.

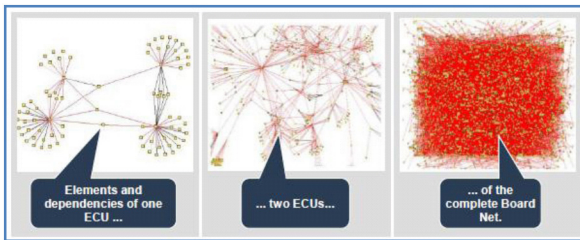


Figure 1. Electrical Control System Complexity

Currently the use of systems tools and processes -- in part or in whole - doesn't always result in effective results. Since the systems engineering process can be present in many levels of product decomposition, we will focus our efforts on highlighting how effective a system engineering framework can be in understanding the higher level architectural development in the automotive industry. This is appropriate as we will be positioning the importance of establishing a framework for the understanding and decomposition of the product that should be present at all levels of decomposition. By nature, the decomposition activity prescribes a higher-level composition view of the product. So, how is this high-level view constructed, and can we gain real benefits from that view?

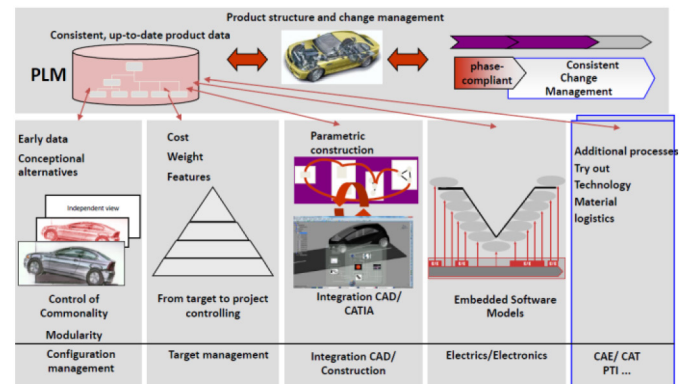
The current use of systems engineering in the automotive industry includes only two main structures; requirements and parts. Many will argue that other objects and representations exist, but these representations are typically transformations of the physical part structure or the requirements structure. They are built not to look at or understand the product in a different way; they are built to better format or fit the tool or process that is consuming the product information. Even if there is a significant transformation in the structure, or view of the product, this view is not valued independent of the tool that the structure is used for.

For instance, the transformation of an engineering bill-of-materials to a manufacturing bill-of-materials is typically a re-organization of the parts of a product to better reflect the manufacturing and/or sourcing process. The view is a necessary transformation of the part structure, but is typically not maintained as a core structure for understanding, architecting, and improving the system. In addition, the formation of a CAE structure for the purpose of analysis is a modified representation of the physical part to allow for easier consumption of the data by the CAE tool being used. Many of these transformations exist, but they do not fundamentally change the way a product is viewed or understood.

For this reason, we typically use the requirements and physical part structure as the main framework with which to understand the product, connecting the needs of the customer, with the outcome of the development process. The lack of a common framework between the requirements and part structures represents a gap in progressing our understanding of "why" (requirements) we are developing the product, and the transformation to the parts we are developing to fulfill the

requirements. We miss some fundamental questions about the products that we are developing. Specifically, "what" are we developing, and "how" are we going to achieve our goals.

The different domains and disciplines have to converge



A PARADIGM SHIFT: MODEL BASED SYSTEMS ENGINEERING ENABLED THROUGH INTEGRATED REQUIREMENTS, FUNCTION, LOGICAL DEFINITION, PHYSICAL REPRESENTATION

If we are to better understand the decomposition and critical questions of "what" and "how," then we must increase our scope of the development framework beyond requirements structures and part structures. We must include a framework that is suited to answer these questions, and it must be fundamentally and independently valued as part of the development process.

Inserting two structures to answer these questions can significantly increase our understanding of the development process and product. The structures inserted between requirements (R) and physical (P) part structures include the functional (F) and logical (L) structures. The functional definition and relationships help us to understand "what" we are developing, and the logical structure helps us define "how" we are going to accomplish our goals. The combination of these new structures transforms the traditional view to the requirement, functional, logical, and physical structure view, or simply RFLP.

These structures are created to help us understand fundamentally different aspects of our designs. As such, the structures are independent of each other, but completely integrated. Requirement structures provide context as to why we are developing product, capturing the context of the customer needs and enterprise objectives. Functional definitions and relationships provide insight in terms of what we are going to accomplish with the solution, providing development with a view of what the end product will do to accomplish these goals. The logical structures define how we accomplish these functions, potentially capturing different approaches to the problem that can be studied and compared.