

Optimum Design of a Steer by Wire System using Systematic System Engineering Approach

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ABSTRACT

A systematic system engineering methodology to design and analyze a Steer by Wire (SBW) system optimizes the system performance. The proposed system engineering approach along with dynamic system analysis leads to a robust, reliable and efficient SBW system design. This approach assures a concrete definition by considering possible use cases, regulatory restrictions, user's expectation and constraints from stake holders. The further decomposition of definitions to design and analysis is derived from all these inputs. Performance of the system is evaluated by defining measure of effectiveness and use cases. The dynamic analysis is performed using SysML methodology.

INTRODUCTION

Steer by Wire is a safety critical complex system in automotive electronics that demand optimum design and analysis techniques. The complete migration of all electronic steer by wire (SBW) system from a mechanical or hydraulic system is one of the most challenging tasks. The automotive industry is not fully convinced about the performance as well as the impact of the same in the vehicle electronics transitions. In order to address this issue, it is important to follow a systematic design process which will enable to analyze the effectiveness and robustness of the design beforehand.

In this paper, a new structured approach of system engineering has been presented that defines, analyzes, simulates and captures requirements of a SBW system. In this system engineering approach, three broad areas are covered that are known as operational, functional and architectural. By using these three techniques, design of SBW system is evaluated for its performance, feasibility and robustness of design. The referred system engineering approach initially starts with identification of boundary conditions, defines the possible missions, lays out the operations and also brings out the Measure of Effectiveness (MoE) and Measure of Performance (MoP). In the functional category, the functions, sub

functions and requirements are identified; the data flow and functional allocations are captured through different set of diagrams. Few dynamic simulations to evaluate the algorithm associated with SBW system are performed in functional category. Finally the definition and design of the sub systems in a SBW system and the network connectivity between the sub systems are addressed in the architectural category of the system engineering approach.

All the artifacts generated in this approach are depicted through either static pictorial representation or through dynamic simulation approach. This approach not only defines an optimum engineering solution but also consider the concerns and considerations of all the stake holders such as users, OEMs, developers and management. It is a fool proof engineering methodology that assures an optimum design of the system.

SBW DEFINITIONS THROUGH SYSTEM ENGINEERING APPROACH

The definition of the SBW system starts with collection of inputs in three categories: user requirements, possible use cases, regulations from standards, and constraints from stake holders. Based on these inputs, the system design and analysis is carried out in three different phases such as Operational analysis phase, functional analysis phase and architecture analysis phase.

SBW OPERATIONAL ANALYSIS PHASE

In this phase, the system defines the external conditions that have an impact on the system to be defined. The set of artifacts that need to be generated in this phase are illustrated as follows:

System Boundary Diagram

The system boundary diagram (SBD) depicts the relationship of external systems that directly or indirectly interacts with the SBW system. Through this design, the external interfaces of the system as well as the dependency of the system on other systems get

The diagram illustrates a complex multi-block circuit. A central blue block labeled "Schedulable Switch" has multiple input and output ports. It is connected to several peripheral blocks:

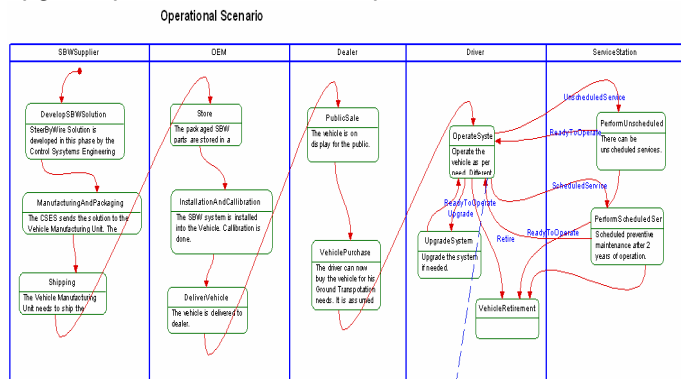
- UnitCh Suspended Only.kbm**: Connected to the top-left of the switch via pD8W and I8WVtoVSD.
- Bldt**: Connected to the top-right of the switch via pD8W and I8WVtoB.
- UnitCh PowerUp.kbm**: Connected to the left side of the switch via pD8W and I8PCKtoSW.
- Schedulable Switch.kbm**: The central component, containing internal logic like pRD, pPD, pLD, pDT, pRW, pRC, and pRQ.
- RelayCntrl.kbm**: Connected to the right side of the switch via pD8W and I8WVtoBldg.
- RelayCntrl.kbm**: Another instance connected to the bottom-right of the switch via pD8W and I8WVtoBldg.
- RelayCntrl.kbm**: A third instance connected to the bottom of the switch via pD8W and I8WVtoBldg.
- RelayCntrl.kbm**: A fourth instance connected to the bottom of the switch via pD8W and I8WVtoBldg.
- RelayCntrl.kbm**: A fifth instance connected to the bottom of the switch via pD8W and I8WVtoBldg.
- RelayCntrl.kbm**: A sixth instance connected to the bottom of the switch via pD8W and I8WVtoBldg.
- RelayCntrl.kbm**: A seventh instance connected to the bottom of the switch via pD8W and I8WVtoBldg.
- RelayCntrl.kbm**: An eighth instance connected to the bottom of the switch via pD8W and I8WVtoBldg.
- RelayCntrl.kbm**: A ninth instance connected to the bottom of the switch via pD8W and I8WVtoBldg.
- RelayCntrl.kbm**: A tenth instance connected to the bottom of the switch via pD8W and I8WVtoBldg.

The diagram uses green arrows to represent data or control flow between the blocks and their respective ports.

The central block in this diagram is the SBW system and other blocks are the external systems in the vehicle with which the SBW system needs to interact during different phases of operations. The link between the systems captures the interfaces. The characteristics of the interfaces are defined as link parameters.

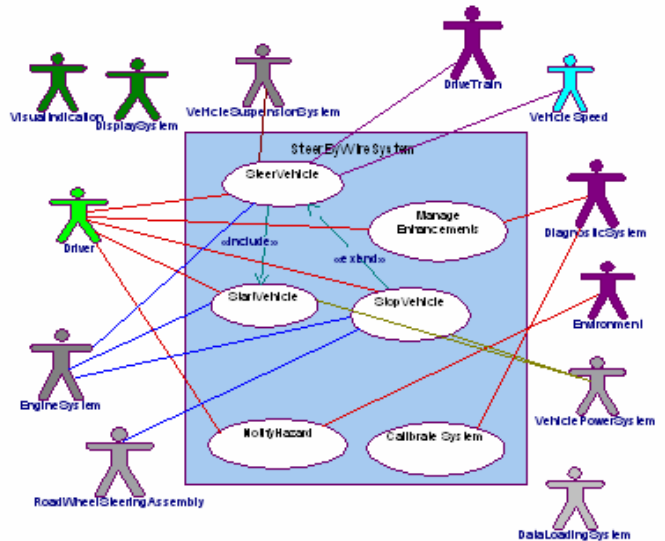
The Operational Information Exchange Matrix (OIEM) is the add-on artifact of the SBW. This document captures detail characteristics of individual interfaces shown in Fig.1. The characteristics include types of interfaces, medium of transmission, rate of transmission, source, destination and other constraints such as security and safety.

The illustration of operational scenario captures all possible operational phases that the system goes through during the complete life cycle phases. The common phases that a SBW system might consider are development phase, factory phase, service phase, upgrade phase and retirement phase.



In figure 2 above, different operational life cycle phases have been illustrated using SysML modeling. The link and relationship between different phases during the life cycle operations enables the system to define dependencies between all phases. Clear definition of dependencies in these phases brings out the impact of change of one small module in one phase in other phases. Also, helps the designer to design a modular system considering the change in system blocks in different phases.

The intention of capturing use case diagram for the SBW system is to capture the user's requirement, customer's requirements and other constraint in a pictorial representation. The use case diagram along with other functional analysis helps in capturing the system requirements for the SBW system. All the stake holders and external entities that make use of the SBW system is defined through the Use Case Diagram.



In the above picture (Fig. 3), the SBW system is represented through set of major functions at the central block. The external entities such as all stake holders are represented as actors as they contribute some how to the SBW system in some scenarios. The dependencies of actors to multiple functionalities as well as dependencies of functions to multiple actors help in prioritizing the functional lists that need to be defined in next phase of design and analysis.

The functional analysis phase of the SBW system starts with identifying list of functions for the SBW system. The functions are generally derived from the operational artifacts and use cases considering all users and customer requirements. The list of functions that is derived in this phase mostly depicts the capability of the SBW system to meet the requirements.