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Synligare utveckling av inbyggda fordonssystem – visualiserad kravhantering och samverkan

Visibler Development of Embedded Automotive Systems - Visualised Requirements Management and Collaboration

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1 Introduction

This document reports on the validation of project results performed in Synligare project. Needs and concepts from Workpackage 1 and 2 has resulted in tooling prototypes in Work package 3. These tools have been applied to example systems identified and refined in Work package 4. During example modeling, tools and methods proposed and developed in the project have been used, refined and assessed.

The report describes project objectives in Chapter 2 and a description on how project goals were met in 3. Some of the Technologies needed to meet the goals were characterized in Chapter 4. The example system used to validate tooling and concepts are described in Chapter 5. Chapter 6 summarizes the validation activity using sample diagrams and screenshots from the project tooling. As a complement to the summary, [7] reports on the validation of the Requirement Allocation plugin for EATOP. The report is closed with a Summary and reflection.

2 Background

The Synligare project proposal identified 5 project objectives, that was guiding the work. Below, these are summarized as a basis for their evaluation in the subsequent chapter.

2.1 Project Objectives

The expected measurable, quantitative and qualitative results of the projects were stated in the project description according to below:

- Identify 5 metrics for the characterization and follow-up of software development
- Identify 5 relevant views to provide overview of a complex requirement set and related entities
- Increase predictability concerning safety, quality and performance
- Reduce the amount of misunderstandings in the communication of specifications
- Reduce the time for development and verification by 10%

2.2 Means

In order to reach the project objectives, a set of engineering needs and use cases have been explored. The basis has been literature surveys, interview studies and clinics, resulting in a set of items to detail, prototype and validate. The main items were as follows:

- Modelling support

  EAST-ADL modelling support in three tooling platforms

- Tooling support for metrics calculations

  Support for computing model based product and progress metrics in two tooling environments

- Views

  Model based graphical, tabular and tree based views in three tooling environments

- Analysis methods

  Model based safety analysis and property analysis

- Methodological concepts

  Collaboration and specification evolution concepts in a model based setting

3 Validation of Goals Fulfillment

In this chapter, the fulfillment of project objectives will be assessed.

3.1 Metrics

The project goal ”Identify 5 metrics for the characterization and follow-up of software development” has been fulfilled by the identification, definition and prototyping of a set of metrics. In addition, a flexible and portable metrics definition format has been defined and prototyped.

- Requirement validation ratio

  The fraction of requirements that has been validated and approved

- Requirement allocation ratio

  The fraction of requirements that are assigned to structural elements

- Function-to-node allocation ratio

  The fraction of functions that have been allocated to hardware components

- Feature and function realization ratio

  The fraction of features or functions that are realized by concrete entities

- Architecture complexity

  The Henry-Kafura complexity of a system architecture providing a metric of the structural complexity

- Custom metric

  Any metric that can be expressed in terms of model element existence, property values, etc.

The above metrics have been deemed useful for engineers to assess the product and work progress, and for project managers to assess project progress.

Some of them are useful for control and progression of work, while others are more of an assessment of the result. The Henry-Kafura metric is an example of the latter.

3.2 Views

The project goal ”Identify 5 relevant views to provide overview of a complex requirement set and related entities” has been fulfilled by by the identification, definition and prototyping of a set of views.

- Graphical architecture view

  Functional architecture, hardware architecture and fault propagation structures are presented in a way that respects element hierarchy, ports and connectors. This is critical for understanding systems, although work tasks are more effective in other views.

  The view has support for dynamic population of diagrams and automatic, architecture-aware place-and-route.

- Graphical view with custom elements including safety

  Any model element can be visualized in a diagram, showing element properties and relations. Because elements have dedicated shapes and icons, model content can be

interpreted graphically. The complex structure of models, and the organization into a tree structure with packages for different parts of the model makes such graphical views useful or even necessary to explore and understand model content.

- Tree view with dynamic context

  A standard tree view only shows properties and elements directly owned by each element. The augmented view that shows related elements when browsing a tree provides immediate access to the context surrounding a model element. This is a useful view to quicly get an overview of models and thus the often complex system specifications.

- Virtual Tree View

  As described above, standard tree views only show direct containment hierarches of architecture models. EAST-ADL and AUTOSAR uses a type-prototype concept for defining hierarchies in a way that supports reuse of components and substructures. The virtual tree view has been found indispensible in browsing and understanding such system architectures, as it allows smooth traversal of these structures.

- Table view

  When browsing models elements, the properties of one element at a time is shown. With the table view, it is possible to see several elements simultaneously: One element in each row, and the properties of each element in the columns. This view has been found to provide excellent overview of the information and quick access to updating the values.

In addition to the listed views, various aid views, such as search views, connector creator view, version assignment, etc. have been prototyped. In general, each such view increase productivity and understanding, and is appropriate in the context of the complex information that is handled in model based systems engineering.

3.3 Predictability

The goal “Increase predictability concerning safety, quality and performance” was addressed and is deemed as fulfilled by a set of analysis capabilities complemented by view and editing support.

- Safety

  Safety analysis is provided by the support for error propagation modeling and analysis. The automatic generation of error propagation models from architecture models as well as the support for FTA and FMEA analysis, have been found efficient and useful for increasing predictability of the functional safety.

- Quality

  Predictability of quality is has been addressed by a combination of view and editor support. Compared to document-based collaboration, models secure consistent and correct exchange of data. The improved view support provided by the project provides for overview of content, and the ability to spot missing or erroneous content. Simularly, the editing support provided by the project reduce the number of mistakes and thus quality issues.

- Performance

  Product performance can be observed in many dimensions or domains, such as energy consumption or weight. The project has provided means to increase performance predictability by means of analysis support for property annotations. Because these are mode-based, it is possible to predict e.g. power consumption in a given mode across a complete system or vehicle, which is otherwise tedious and error prone.

3.4 Qualitative improvement: Fewer Misunderstandings

The goal “Reduce the amount of misunderstandings in the communication of specifications” was addressed and is deemed as fulfilled by the combination of methodology, representation and views developed in the project.

Because syntax and semantics are specified for the selected system representations (EAST-ADL and AUTOSAR), OEM and supplier engineering organizations can interpret models in the same way. This is a more compact and unambiguous specification compared to documents.

The views and metrics developed in the project provide further facilitation. While models may be complete and consistent, views and metrics makes it easier to explore and understand the specifications, thus reducing the risk of misunderstanding. Architecture diagrams with established shapes and icons are examples of such powerful views.

3.5 Quantitative improvement: Shorter Development Time

The goal “Reduce the time for development and verification by 10%” requires two subsequent and identical projects to measure precisely. However, this goal was deemed as met by qualitative reasoning regarding the efficiency improvements expected by deployment of project results.

With document-based collaboration as baseline, it is clear that less re-work is required on information exchange when models are used, in particular when the basis is a common exchange format (EAST-ADL).

Model based engineering represents large efficiency improvement for verification. Provided requirements are formulated in a non-ambiguous and testable way, they can be used both for specification and testing. The traceability provided by architecture models means that the right requirements can be identified for a specific verification task. Other efficiency gains for verification comes from clear interface definitions and the opportunity to define plant and environment together with models of the subject systems.

Agile development and short loops is often seen as a prerequisite for shorter development time. Model based engineering is a prerequisite for frequent iterations among stakeholders, as the sheer information management would take up too much time in a document based setting.

Because automotive embedded systems are large, complex and coupled, each engineer needs to integrate with several legacy systems and signals. It has been assessed that as much as 20%-35% of engineering time is spent on seeking information. With model based engineering, system specifications are formalized and seekable or browsable, providing faster access to at least that part of the information needed.

The initial modelling effort may be larger compared to document-based specifications, but as discussed above, it is well compensated for by the potential for automatic and rigorous analyses and inspections provided by models.

4 Key System Technologies

Synligare has developed a set of technologies supporting model based, collaborative development. Below, these will be characterized based on a set of criteria related to technology readiness level assessment used at Volvo. The technologies covered are

1. Diagram exchange
2. Model based Graphical visualization
3. Model aware Place and Route
4. Property calculations
5. Model based calculations of metrics
6. Model based diff and merge
7. Requirements Allocation Assistant
8. Model based views
9. Fault Propagation Model generation and analysis
10. Model Based Version Manager.

Table 1. Characterization of the technology Diagram exchange based on sgraphml format

Technology:	Diagram exchange based on sgraphml format
Intended purpose:	Sgraphml diagram exchange format allows exchange of model-aware diagrams across modeling tools.
Inputs and expected outputs	Sgraphml and corresponding model file following the AUTOSAR M3 principles is both output from the source tool and input to the target tool.
Environmental and functional constraints	Model file containing architecture model/system description must be an XML file complying with AUTOSAR M3 principles for representation
Benefits:	A portable format for diagram exchange has several benefits: - It represents an infrastructure for handling graphical views enabling improved tooling for views. Adequate graphical views enables more effective communication and understanding of engineering information. - Separation of view information from the system description/architecture model - Ability to preserve the work spent on organizing system description in views
Standards and Regulations:	Sgraphml is an extension to the de-facto standard graphml. The model representation is based on AUTOSAR M3 principles, i.e. arxml or eaxml.
Scalability:	The format has been validated using diagrams with a size and complexity corresponding to what is suitable to have in a single view.

Technical Risk:	The main risk of the technology is lack of support in tools. This risk is mitigated by the fact that this exchange format can be used as an intermediate format and supported in two steps.
ISO26262 related Qualification Need:	The generic Tool Confidence Level is TCL2, based on Impact: TI2, there is a risk that tools producing diagram exchange files introduce diagram failures that may cause undetected errors in developed items Error Detection: TD2, there is a medium degree of confidence that such failures are detected by downstream activities.

Table 2. Characterization of the technology Model based Graphical visualization

Technology:	Model based Graphical visualization
Intended purpose:	The purpose of the technology is to provide visualization of engineering information with icons and shapes based on the represented element kinds, and to select presentation content based on model content. The latter includes exploitation of meta-model based associations and containments.
Inputs and expected outputs	The input is an EAST-ADL model and the output is a diagram reflecting the content of the model, including its semantics.
Environmental and functional constraints	The input model shall be compliant with the EAST-ADL metamodel.
Benefits:	Presentation of engineering information according the syntax and semantics of the model based representation, makes diagrams non-ambiguous and understandable by domain experts.
Standards and Regulations:	The visualization technology uses EAST-ADL syntax and semantics and the underlying AUTOSAR M3 principles. AUTOSAR models are thus representable with the same approach.
Scalability:	The visualization principles have been validated using diagrams with a size and complexity corresponding to what is suitable to have in a single view.
Technical Risk:	There is no technical risk associated with a model based graphical visualization technology.
ISO26262 related Qualification Need:	The generic Tool Confidence Level is TCL2, based on Impact: TI2, there is a risk that tools producing graphical views introduce failures that may cause undetected errors in developed items Error Detection: TD2, there is a medium degree of confidence that such failures are detected by downstream activities.

Table 3. Characterization of the technology Model aware Place and Route

Technology:	Model aware Place and Route
Intended purpose:	The purpose of the technology is to automatically organization diagram layout in a way that respects the meaning of different elements. For example, elements of a hardware architecture and a set of requirement may reside in the same diagram, but shall be placed differently.
Inputs and expected outputs	The input is an EAST-ADL model and an associated sgraphml diagram. The output is an updated sgraphml diagram, where diagram entities are organized according the element kinds.
Environmental and functional constraints	The input model shall be compliant with the EAST-ADL metamodel and sgraphml metamodel respectively.
Benefits:	Presentation of engineering information according the syntax and semantics of the model based representation, makes diagrams non-ambiguous and understandable by domain experts.
Standards and Regulations:	Syntax and semantics is assumed to follow EAST-ADL and sgrapghml, respectively.
Scalability:	Automatic diagram layout has been validated using diagrams with a size and complexity corresponding to what is suitable to have in a single view.
Technical Risk:	There is no technical risk associated with Architecture aware Place and Route.
ISO26262 related Qualification Need:	The generic Tool Confidence Level is TCL2, based on Impact: TI2, there is a risk that tools manipulating diagrams introduce failures that may cause undetected errors in developed items Error Detection: TD2, there is a medium degree of confidence that such failures are detected by downstream activities.

Table 4. Characterization of the technology Model Based Property calculations

Technology:	Model Based Property calculations
Intended purpose:	This technology allows mode-based property annotations to be summed over a product hierarchy in order to assess properties such as cost, weight or energy consumption. The subject of analysis may be a subsystem, product or entire product line.
Inputs and expected outputs	The input is an EAST-ADL model representing the product line/product/system/subsystem depending on scope. A requirement corresponding to the expected property value defines what to compute and the model elements need to be annotated with values corresponding to the property kind. Optionally, different values are provided for each applicable mode. The output is the total value in each mode.
Environmental and functional constraints	The input model shall be compliant with the EAST-ADL metamodel and a modeling pattern for property annotations.

Benefits:	Being able to calculate properties such as energy consumption and cost makes it possible to assess which candidates are best among alternatives or checking if all requirements are met. Because well-defined syntax and semantics are used, analysis is rigourous and automatic. The latter can be used for optimization.
Standards and Regulations:	Syntax and semantics is assumed to follow AUTOSAR or EAST-ADL for structure and EAST-ADL for annotations.
Scalability:	The annotation approach has been validated with small-medium sized models, but the low complexity of the analysis suggests that there is no scalability issue.
Technical Risk:	Model annotations are made manually by engineers. Because the analysis is rigorous and automatic there is a risk that too much confidence is put in the results, even if modeling mistakes and uncertain input data may threat validity. Careful validation of the input models is required to mitigate this risk.
ISO26262 related Qualification Need:	The generic Tool Confidence Level is TCL2, based on Impact: TI2, there is a risk that tools calculating property values introduce failures that may cause undetected errors in developed items Error Detection: TD2, there is a medium degree of confidence that such failures are detected by downstream activities.

Table 5. Characterization of the technology Model based calculations of metrics

Technology:	Model based calculations of metrics
Intended purpose:	The purpose of this technology is to establish metrics of architecture models. Such metrics allow assessment of the state of engineering data, and thus the product or process progress. Metric calculations do not concern product properties like cost or power consumption.
Inputs and expected outputs	The input is an EAST-ADL model and the output is a set of diagrams or numbers representing the selected metric. Examples of current metrics are Henry-Kafura structural complexity and requirement allocation progress.
Environmental and functional constraints	The input model shall be compliant with the EAST-ADL metamodel.
Benefits:	Being able to establish model metrics allows assessment of the current state of engineering data. A complexity metric characterizes the quality of the model, while a completeness metric provides a progress assessment. This can be used to follow up engineering work and to increase the quality of the models, which indirectly improves the product itself.
Standards and Regulations:	Syntax and semantics is assumed to follow EAST-ADL.
Scalability:	Metrics calculations scale linearly with model size and would therefore only slowly reach any limitations. If the scope increases from individual products to entre product lines, aspects like navigation and data management would still be the more challenging concerns.

Technical Risk:	Metrics like requirement allocation completeness assume a specific modeling pattern to be used. Careful validation of the input models is thus required to mitigate this risk. Another risk is to use metrics without full understanding of its meaning. For example, if a problem is complex by nature, it may be inappropriate to enforce changes to the solution to reach a lower model complexity index.
ISO26262 related Qualification Need:	The generic Tool Confidence Level is TCL1, based on Impact: TI1, there is no risk that metrics calculation tools introduce failures that may cause undetected errors in developed items

Table 6. Characterization of the technology Model based diff and merge

Technology:	Model Based diff and merge
Intended purpose:	The purpose of this technology is to compare and highlight differences between models on the basis of model syntax, i.e. the metamodel. A target model may be updated based on the identified differences between source and target models, automatically or manually per identified deviation.
Inputs and expected outputs	The input are two EAST-ADL models or subtrees within the same model. The output is the set of tree entries that deviates.
Environmental and functional constraints	The input model shall be compliant with the EAST-ADL metamodel.
Benefits:	Comparing text files is not sufficient for model based development, since small or large differences in the file may correspond to no, small or large differences in the model. For example, changing the order of elements in the textfile may not influence the model at all. By analyzing differences in the model, engineers are provided with a syntactically and semantically relevant presentation of differences between models.
Standards and Regulations:	Syntax and semantics is assumed to follow AUTOSAR or EAST-ADL.
Scalability:	Model diff and merge has been validated with small-medium sized models without scalability issues.
Technical Risk:	There is no technical risk associated with model based diff and merge.
ISO26262 related Qualification Need:	The generic Tool Confidence Level is TCL2 based on Impact: TI2, there is a risk that use of tools comparing and merging models introduces failures that may cause undetected errors in developed items Error Detection: TD2, there is a high degree of confidence that such failures are detected by downstream activities.

Table 7. Characterization of the technology Requirements Allocation Assistant

Technology:	Requirements Allocation Assistant
Intended purpose:	The purpose of this technology is to assist in linking requirement to structural entities. Traceability in the structural model is related to the traceability of the requirement model, which can be exploited when finding suitable target elements. The suggestions are based on Realization links from structural elements to more abstract structural elements and derivations from requirements to more abstract requirements. It is also possible to use searching and filtering functions to assist finding the right target entity for a specific requirement.
Inputs and expected outputs	The input is an EAST-ADL model with requirements and an EAST-ADL model with functional or hardware hierarchy. The output is an updated EAST-ADL model with satisfy relations between requirements and structure.
Environmental and functional constraints	The input model(s) shall be compliant with the EAST-ADL metamodel and contain both requirements and components.
Benefits:	Allocation of requirements to a large and complex functional or hardware structure is potentially complex and error prone. By helping users finding the right target element, less time is spent on amortizing requirements over architectural models.
Standards and Regulations:	Syntax and semantics is assumed to follow AUTOSAR or EAST-ADL.
Scalability:	Requirement allocation assistant has been validated with small-medium sized models without scalability issues.
Technical Risk:	There is no technical risk associated with Requirements Allocation Assistant
ISO26262 related Qualification Need:	The generic Tool Confidence Level is TCL1, based on Impact: TI2, there is a risk that tools allocating requirements to structure introduce failures that may cause undetected errors in developed items Error Detection: TD1, there is a high degree of confidence that such failures are detected by downstream activities.

Table 8. Characterization of the technology Model based views

Technology:	Model based views
Intended purpose:	Model based views have the purpose to present model content according to the syntax and semantics of the model.
Inputs and expected outputs	The input is an EAST-ADL model and the output is a dynamic view that changes content depending on which model element is in scope, and is updated based on model updates.
Environmental and functional constraints	The input model(s) shall be compliant with the EAST-ADL metamodel.

Benefits:	Complex models can be understood easier by presenting content according to its inherent semantics and according to actual relations in the model. For example, showing the related hazards when a safety goal is marked, provides context to the latter. Similarly, showing the voltage attribute of a set of sensors provides overview.
Standards and Regulations:	Syntax and semantics is assumed to follow EAST-ADL.
Scalability:	Model based views are largely independent of model size, as only few elements at a time are concerned.
Technical Risk:	There is no technical risk associated with model based views.
ISO26262 related Qualification Need:	The generic Tool Confidence Level is TCL1, based on Impact: TI2, there is a risk that tools presenting model content introduce failures that may cause undetected errors in developed items Error Detection: TD1, there is a high degree of confidence that such failures are detected by downstream activities.

Table 9. Characterization of the technology Fault Propagation Model generation and analysis

Technology:	Fault Propagation Model generation and analysis
Intended purpose:	The purpose of automatic generation of fault propagation models is to represent errors and how they propagate through each component. Automatic fault propagation analysis provides Fault Tree Analysis or Failure Modes and Effects analysis on the basis of a fault propagation model. The goal is to understand system vulnerabilities and identifying mitigations.
Inputs and expected outputs	The input is an EAST-ADL model representing functional or hardware architecture. The output is a structurally equivalent model representing fault propagation. The input for analysis is the fault propagation model, and the output is an FTA (fault tree analysis) or FMEA (failure modes and effects analysis).
Environmental and functional constraints	The input model(s) shall be compliant with the EAST-ADL metamodel.

Benefits:	Error propagation typically occurs along the logical or physical links across components. For this reason, a mirror of the functional or physical architecture is a good starting point for defining how errors occur and propagate. By automatically generating a separate propagation model, engineering judgment can be used to remove or add sources, connections and propagation logic. For example, there may be 100 signals between two subsystems, but the dependability analysis may suffice with a single failure mode and error propagation. On the other hand, two subsystems may be linked by a single logical or physical interface, but there may be several complex ways in which they may interfere with each other. Automatic fault propagation analysis on the basis of an integrated architecture model is a way to secure consistency between system representation and a critical system analysis activity.
Standards and Regulations:	Syntax and semantics is assumed to follow EAST-ADL.
Scalability:	Error propagation model generation and analysis has been validated on a medium sized system. Typically, the scope is limited to individual functions or systems, suggesting that scalability is not a concern in most cases. Analyzing complete vehicles or system of systems will be challenging from a tooling and methodology perspective. It typically requires abstraction and divide and conquer to be feasible.
Technical Risk:	This technology requires appropriate input models to produce useful results. Confidence in results is thus dependent on valid assumptions and correct representation of those assumptions.
ISO26262 related Qualification Need:	The generic Tool Confidence Level is TCL2, based on Impact: TI2, there is a risk that tools presenting model content introduce failures that may cause undetected errors in developed items Error Detection: TD2, there is a medium degree of confidence that such failures are detected by downstream activities.

Table 10. Characterization of the technology Model Based Version Management

Technology:	Model Based Version Management
Intended purpose:	With model based system engineering, model elements rather than files are relevant for configuration management. Model Based Version Management supports version annotation and management of individual model elements.
Inputs and expected outputs	The input is an EAST-ADL model with or without version annotations. The output is an EAST-ADL model with version annotations, possibly with incremented versions of one or several elements.
Environmental and functional constraints	The input model(s) shall be compliant with the EAST-ADL metamodel.

Benefits:	With increased granularity of version management, it is possible to work efficiently with product lines and variants, and to reuse engineering work in a rigorous manner. By supporting version annotations of elements represented by an open exchange format, the information can be shared across tools and organizations.
Standards and Regulations:	Syntax and semantics is assumed to follow EAST-ADL.
Scalability:	Version annotations use a pattern where a separate version annotation element is added for every version annotated element. For this reason, version information grows linearly with the size of the architecture.
Technical Risk:	System integrity may be jeopardized if flaws in version management cause incompatible system elements to be integrated. This can largely be mitigated by appropriate integration testing and analysis.
ISO26262 related Qualification Need:	The generic Tool Confidence Level is TCL1, based on Impact: TI2, there is a risk that tools manipulating element versions introduce failures that may cause undetected errors in developed items Error Detection: TD1, there is a high degree of confidence that such failures are detected by downstream activities.

5 Validator System

To validate Synligare results, an example system is being used, Adjustable Speed Limit with Traffic Sign Recognition. To illustrate the OEM-supplier collaboration, the Traffic Sign Recognition system is considered as a separate subsystem delivered by a supplier.

5.1 Adjustable Speed Limit

Adjustable Speed Limit is a Vehicle Feature that sets an electronic limit on the vehicle speed. By temporary limiting the maximal speed, accidental overspeed in restricted or sensitive areas is possible. Another scenario is to set the temporary speed limit to the currently allowed road speed.

Adjustable Speed Limit can be combined with both Advanced and Standard Cruise Control. At any given time, speed will not exceed

- Cruise Control Setspeed (or ACC)
- Legal speed limit
- Temporary Speed Limit

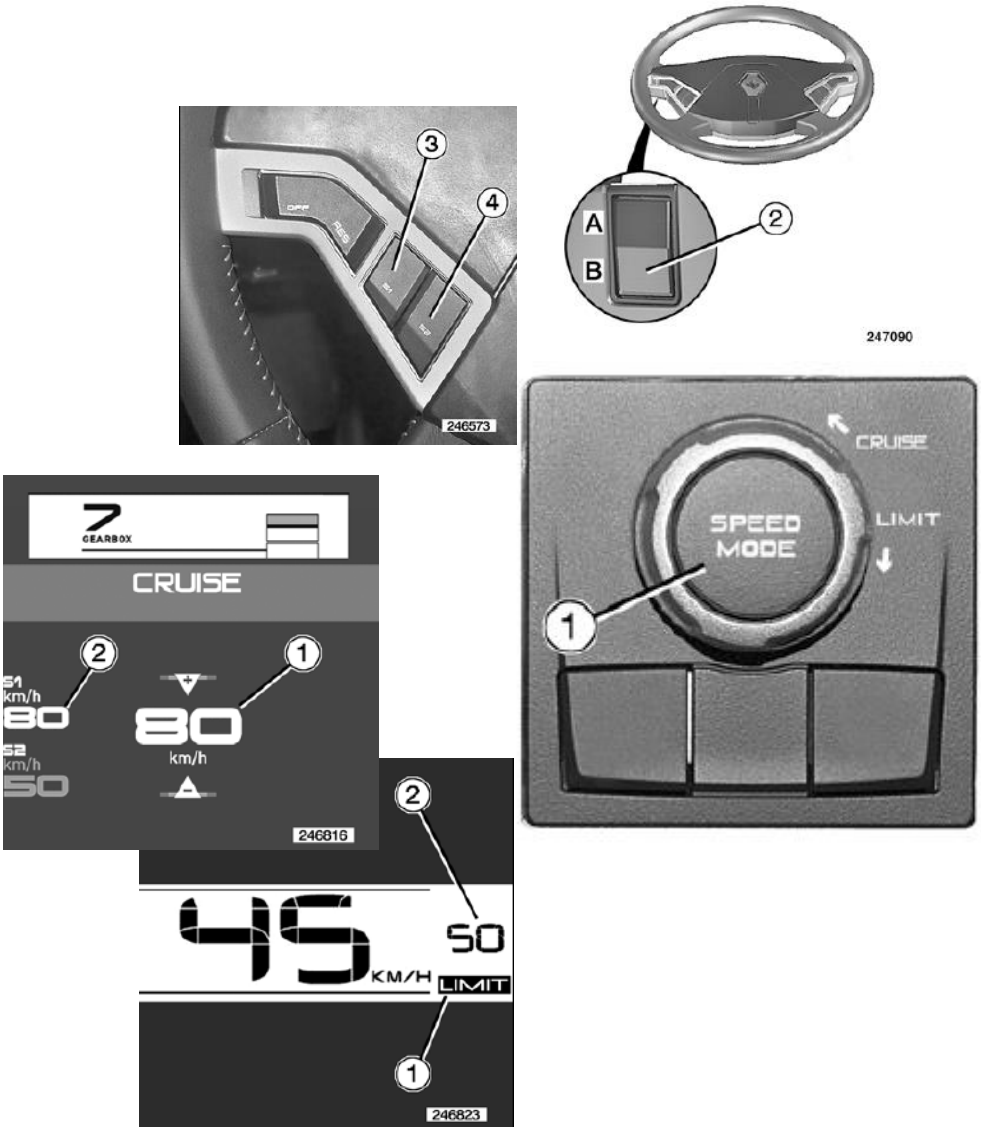


Figure 1. User interface of Adjustable Speed Limit

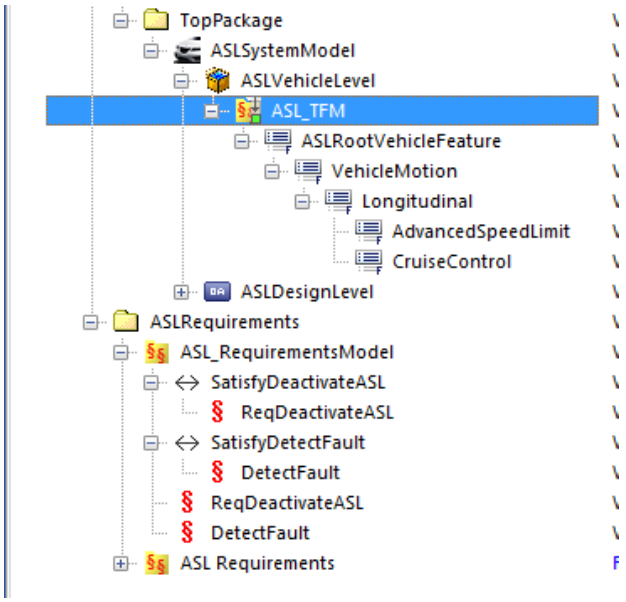


Figure 2. Feature Tree of Adjustable Speed Limit

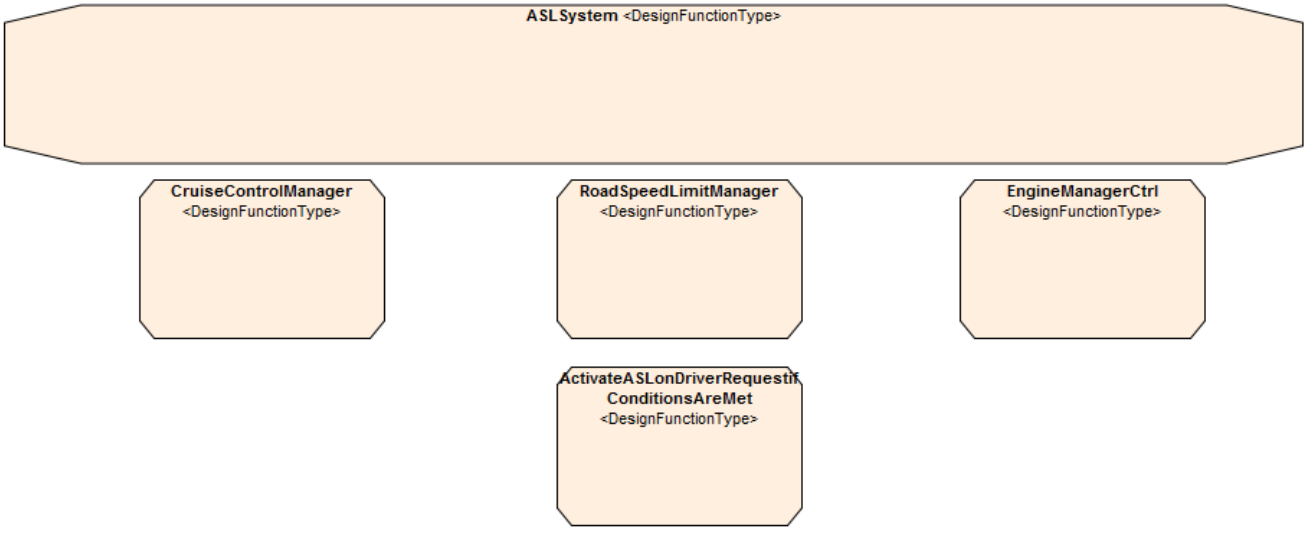


Figure 3. Top level functional Components of Adjustable Speed Limit

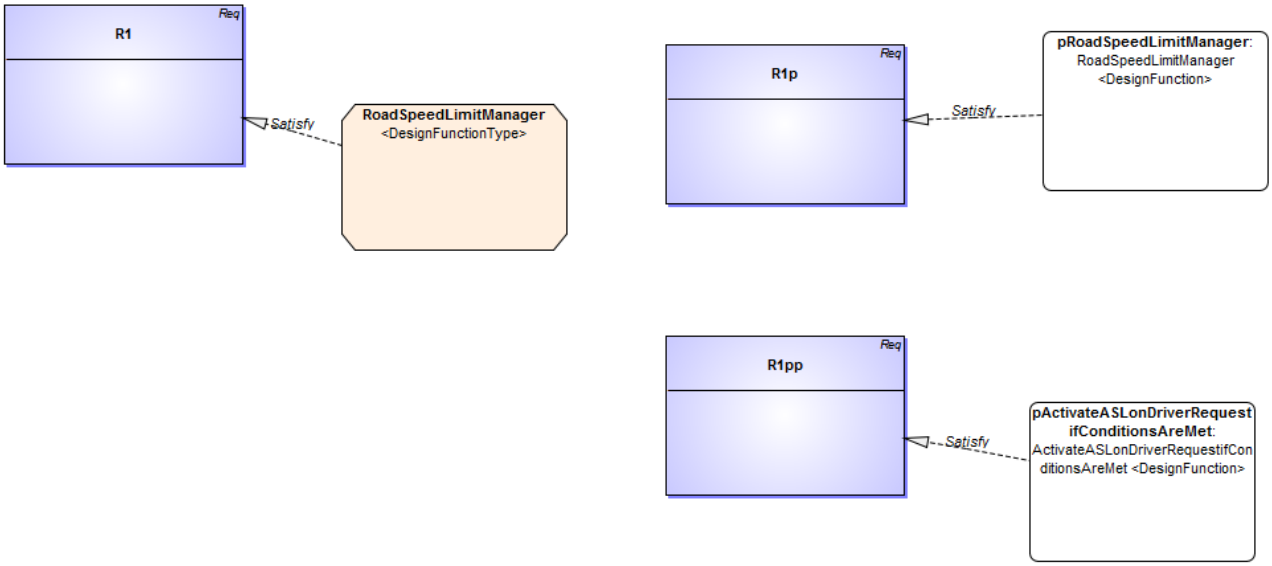


Figure 4. Requirements

6 Validation Scenario

In this section a validation scenario covering Synligare concepts and tools will be presented. The scenario was used to exercise tooling and illustrate project results.

6.1 Overview

The Synligare methods and prototypes have been validated by pursuing a set of engineering activities on the example system described in Chapter 5. Some of the characteristics of the scenario are:

- Supplier-OEM collaboration
- Functional Safety
- Representation of Synligare technologies
- Illustration of how project objectives are met

Figure 5 shows the main steps of the validation scenario.

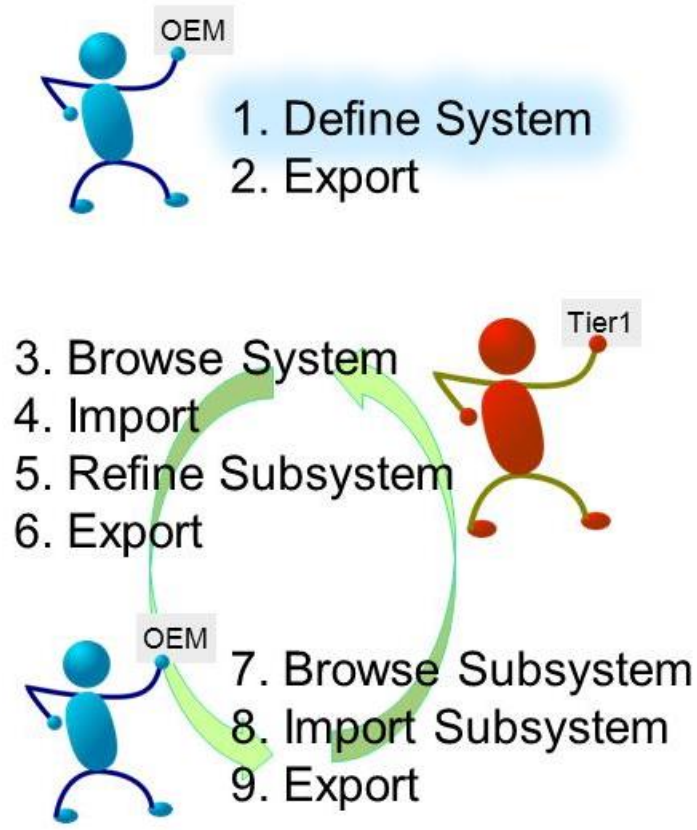


Figure 5. Main steps of validation scenario

The overall scenario reflects a system development effort where a legacy ststem is extended with new functionality. The OEM has the overall design responsibility, supported by a Tier1 for one part of the system. The next sections will cover the core and dependability related scenario steps.

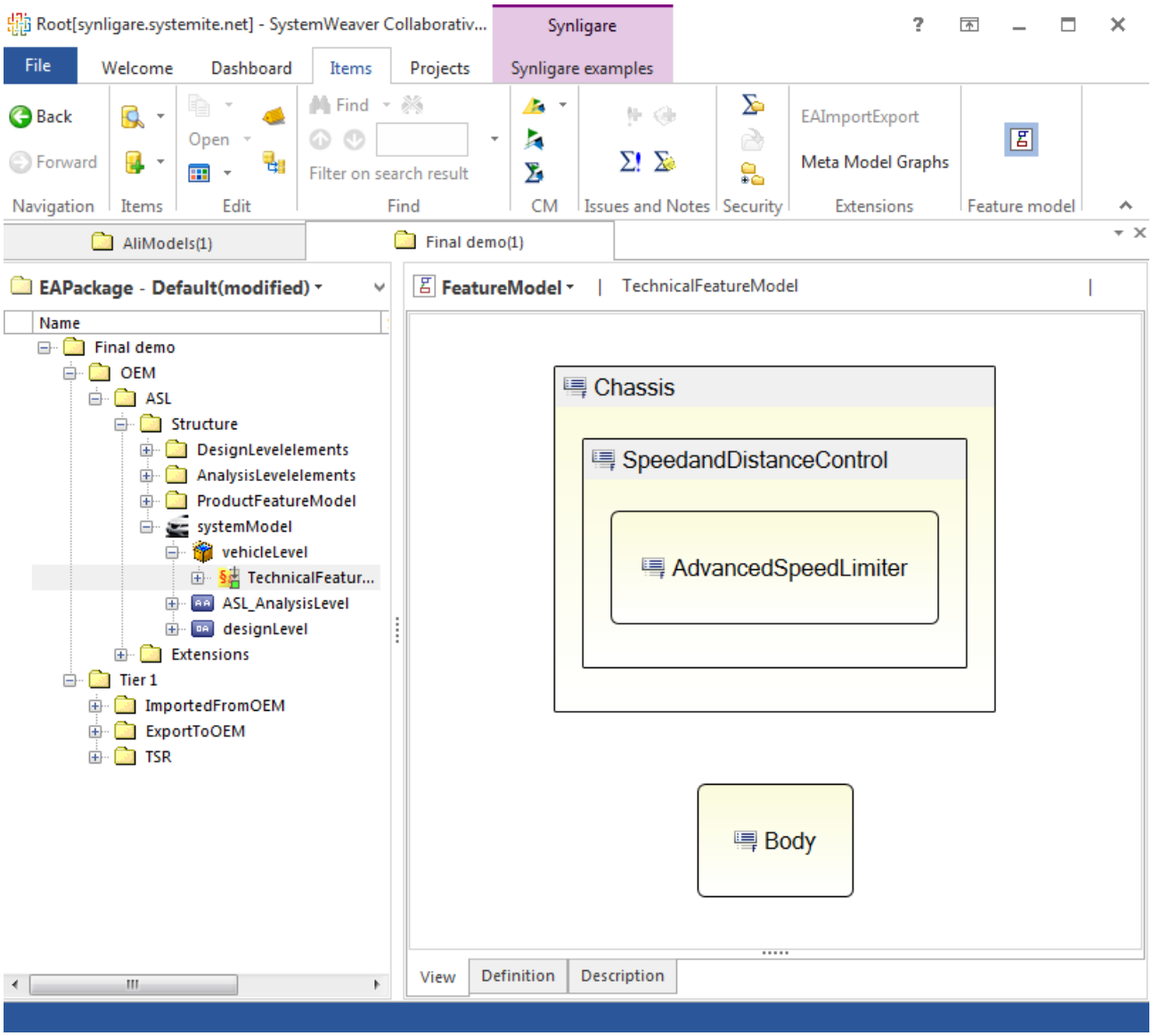
6.2 Core Scenario

The core scenario covers collaborative function development assuming that a new capability, Traffic Sign Recognition, is added to an existing system, Advanced Speed Limiter.

6.2.1 OEM Views on Original System

Below are some views of the legacy Advanced Speed Limiter system, starting with Vehicle level and going down to the more concrete design level. In this part of the scenario, SystemWeaver was used, and 10 views were selected on the three abstraction levels Vehicle, Analysis and Design Level:

- Vehicle Level: Technical Feature Model in tree and diagram view
- Analysis Level: Functional Analysis Architecture with Neighborhood view
- Design Level: Functional Design Architecture with Neighborhood view
- Design Level: Hardware Design Architecture with Neighborhood view
- Design Level: Allocation of Design Functions to nodes in diagram view
- Design Level: Function - Feature mapping in list view
- Design Level: Function - Feature mapping in diagram view
- Design Level: Function Metrics
- Design Level: Hardware Metrics
- Requirement Allocation View



1.

Figure 6. Vehicle Level: Technical Feature Model in tree and diagram view in SystemWeaver

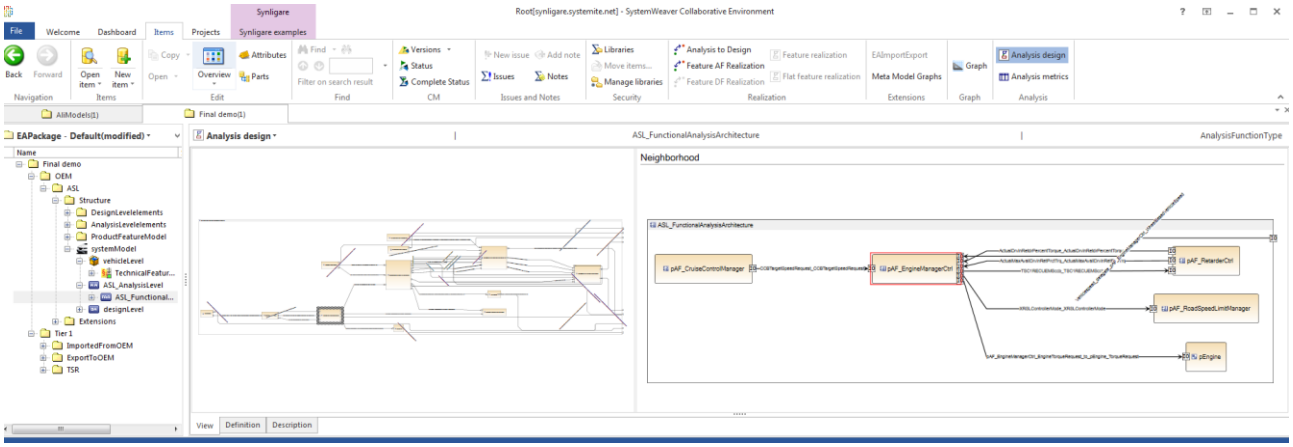


Figure 7. Functional Analysis Architecture with Neighborhood view in SystemWeaver

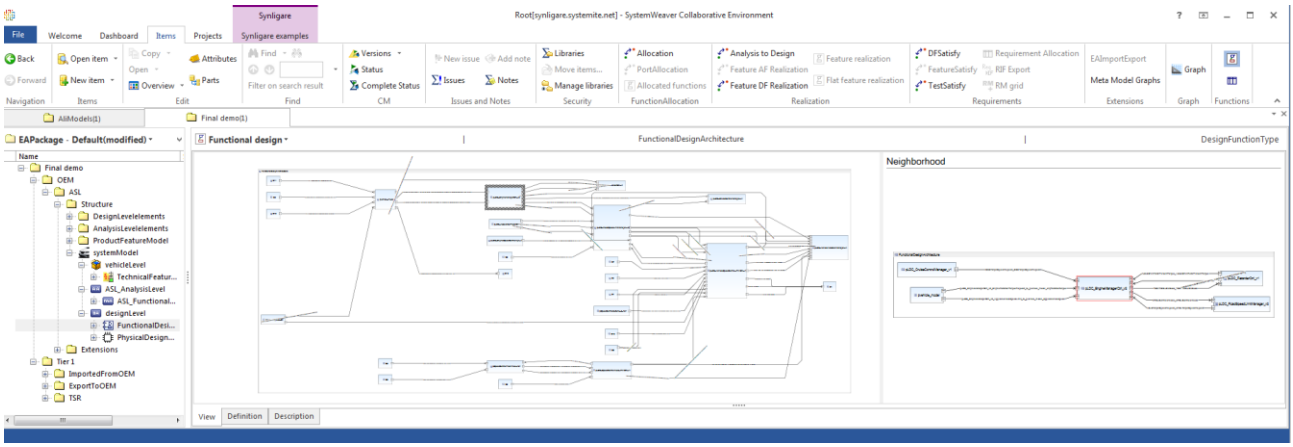


Figure 8. Design Level: Functional Design Architecture with Neighborhood view in SystemWeaver

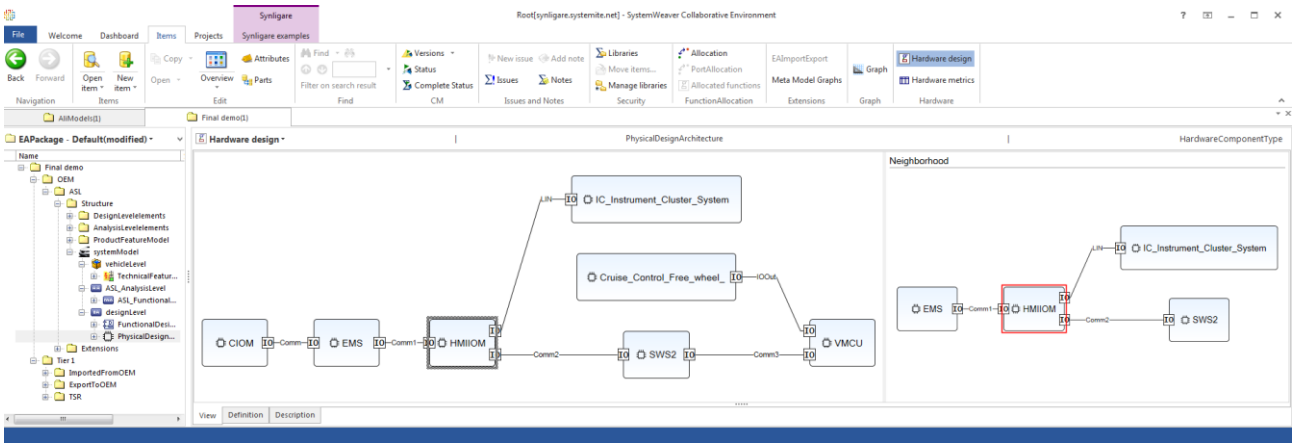


Figure 9. Design Level: Hardware Design Architecture with Neighborhood view in SystemWeaver

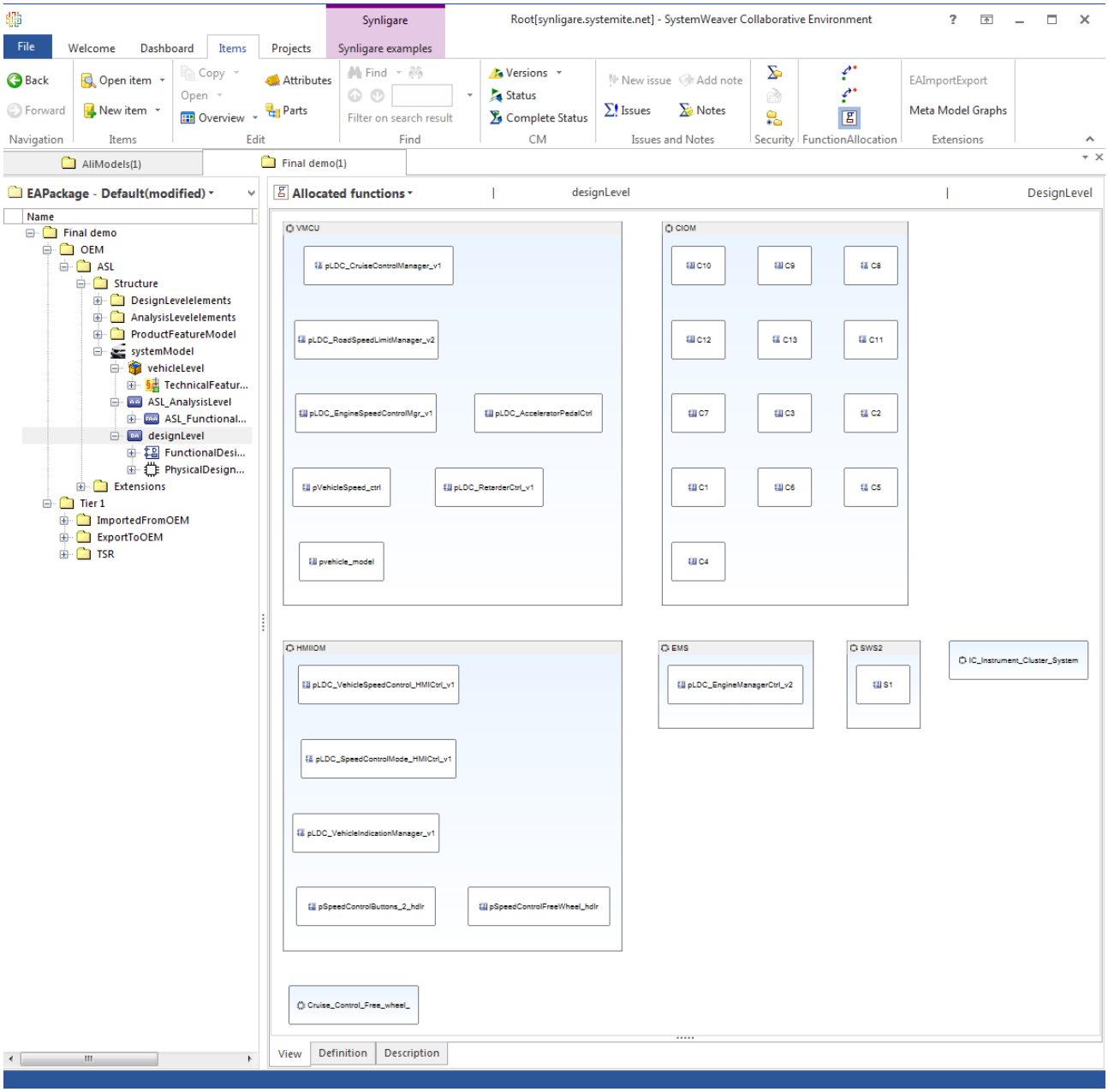


Figure 10. Design Level: Allocation of Design Functions to nodes in diagram view in SystemWeaver

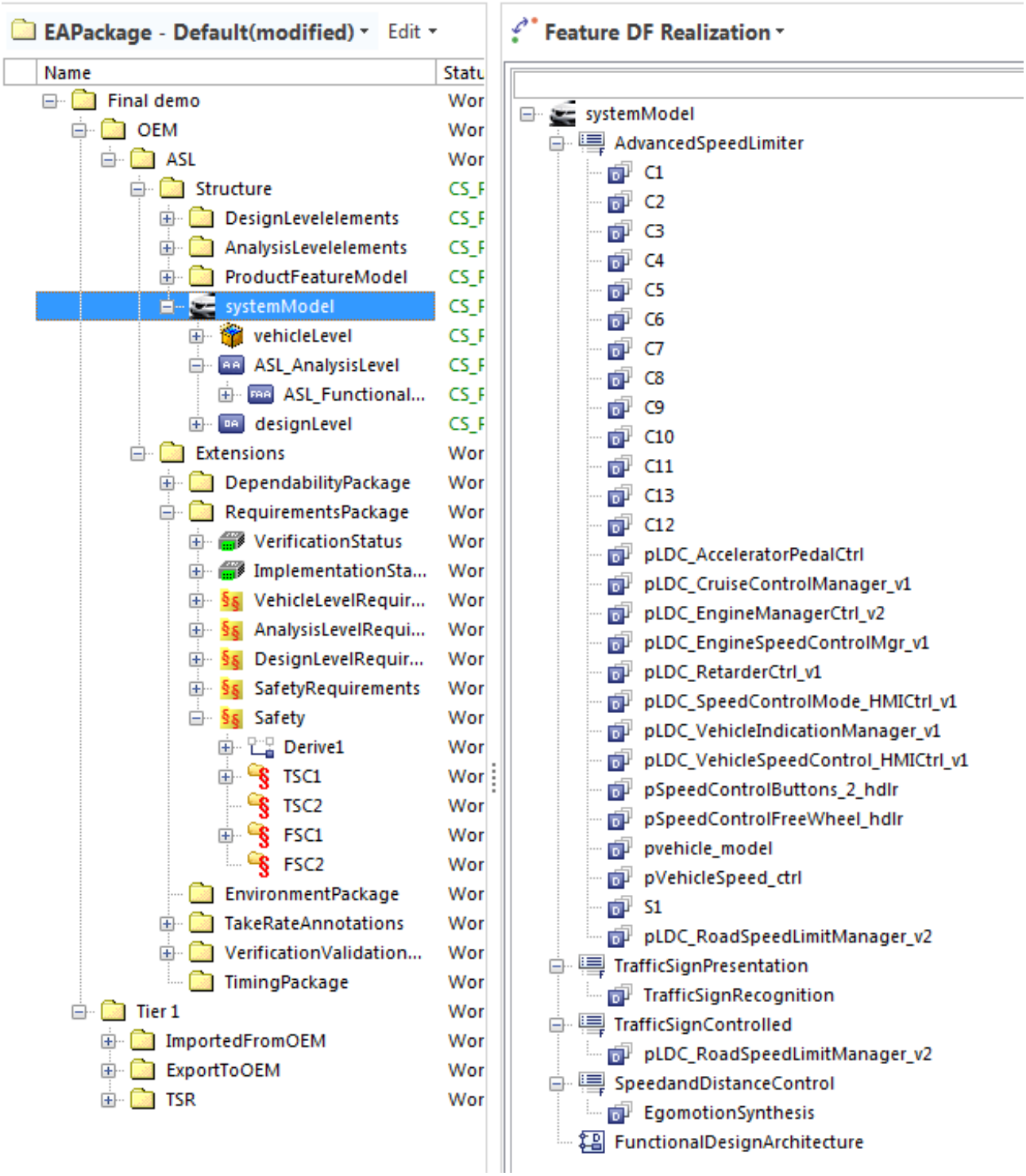


Figure 11. Design Level: Function - Feature mapping in list view in SystemWeaver

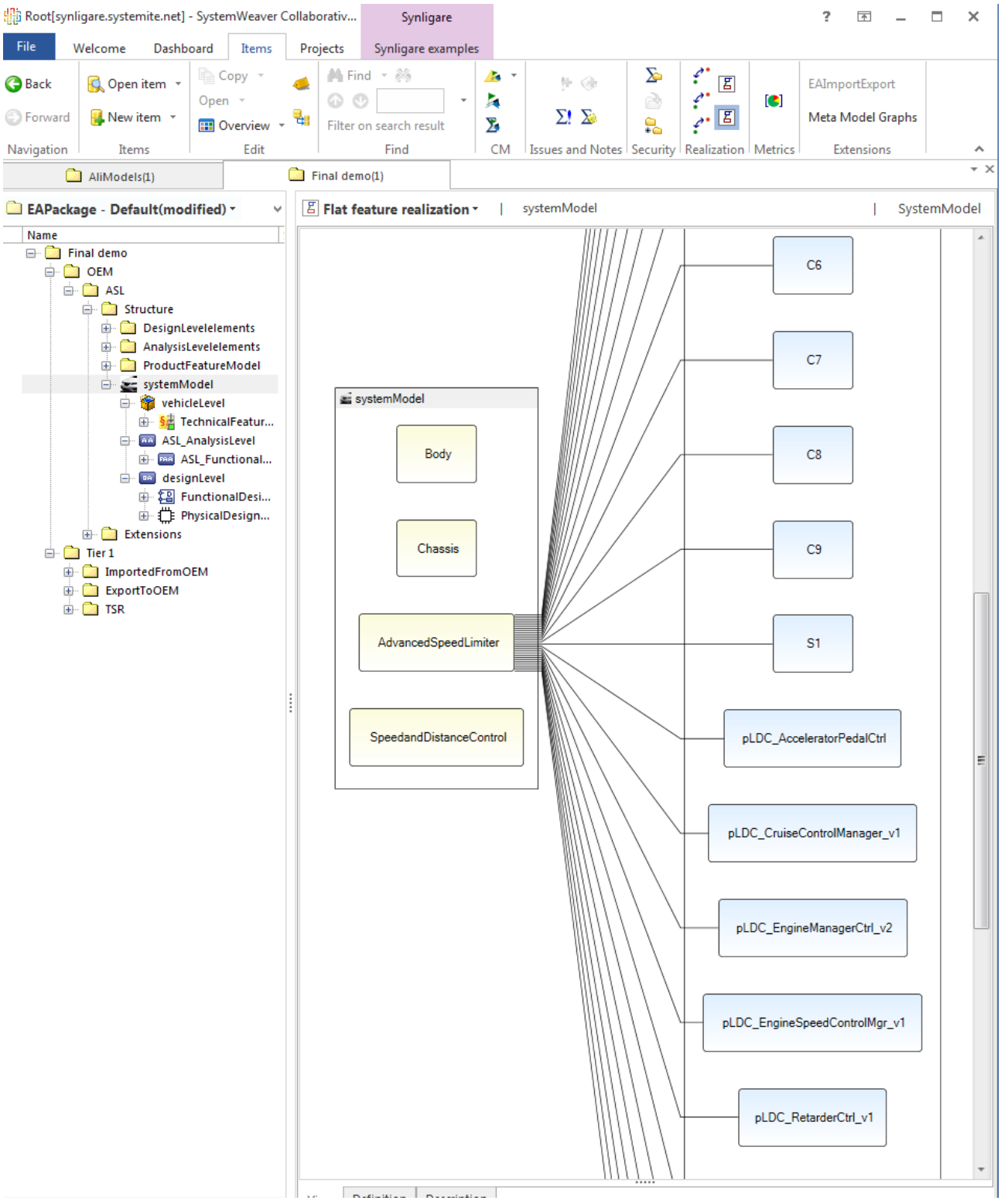
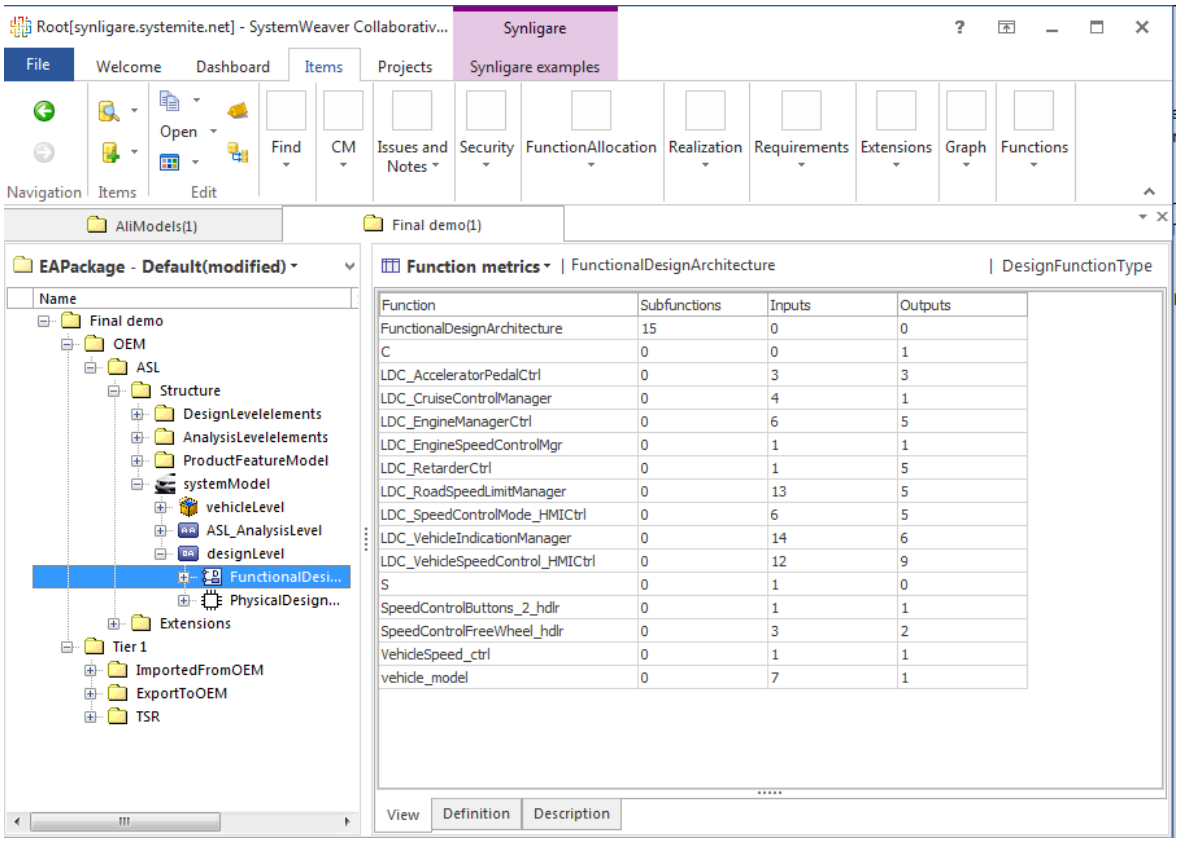
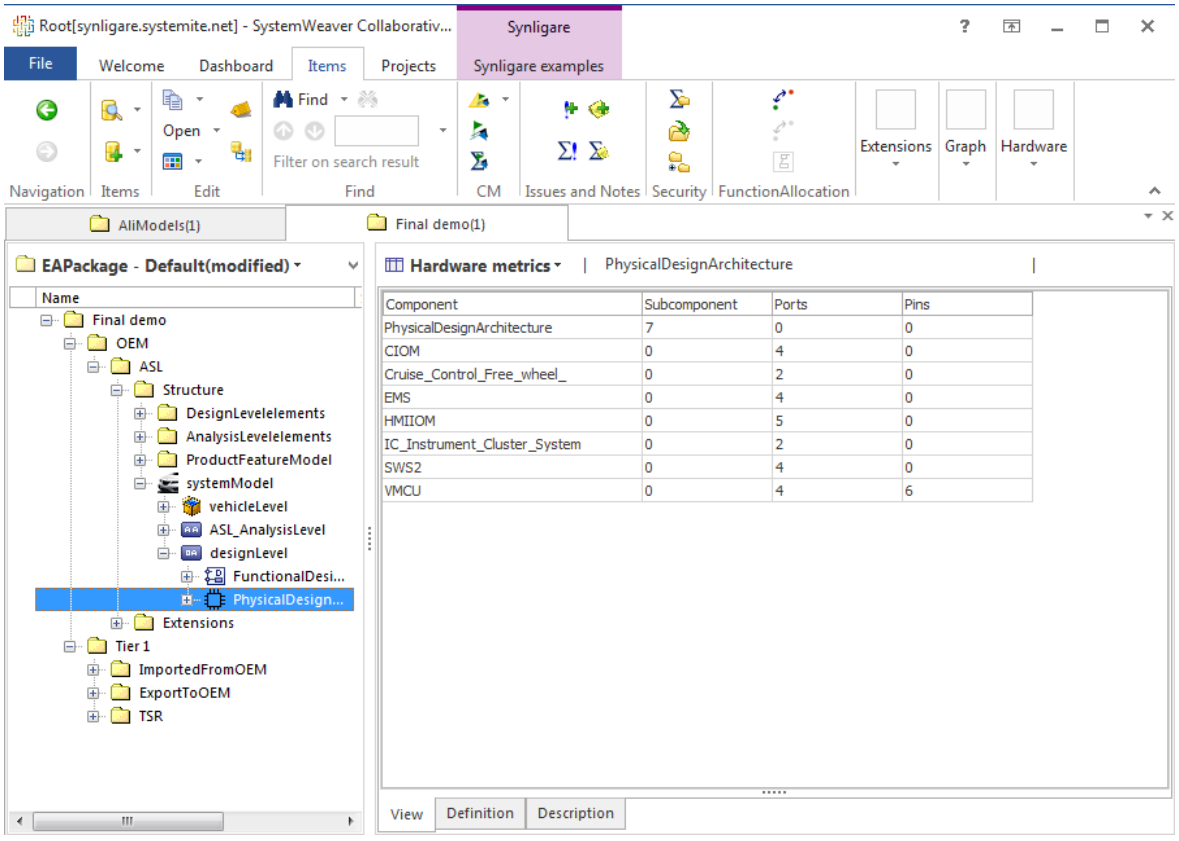


Figure 12. Design Level: Function - Feature mapping in diagram view in SystemWeaver



Function	Subfunctions	Inputs	Outputs
FunctionalDesignArchitecture	15	0	0
C	0	0	1
LDC_AcceleratorPedalCtrl	0	3	3
LDC_CruiseControlManager	0	4	1
LDC_EngineManagerCtrl	0	6	5
LDC_EngineSpeedControlMgr	0	1	1
LDC_RetarderCtrl	0	1	5
LDC_RoadSpeedLimitManager	0	13	5
LDC_SpeedControlMode_HMICtrl	0	6	5
LDC_VehicleIndicationManager	0	14	6
LDC_VehicleSpeedControl_HMICtrl	0	12	9
S	0	1	0
SpeedControlButtons_2_hdlr	0	1	1
SpeedControlFreeWheel_hdlr	0	3	2
VehicleSpeed_ctrl	0	1	1
vehicle_model	0	7	1

Figure 13. Design Level: Function Metrics in SystemWeaver



Component	Subcomponent	Ports	Pins
PhysicalDesignArchitecture	7	0	0
CIOM	0	4	0
Cruise_Control_Free_wheel_	0	2	0
EMS	0	4	0
HMIIOM	0	5	0
IC_Instrument_Cluster_System	0	2	0
SWS2	0	4	0
VMCU	0	4	6

Figure 14. Design Level: Hardware Metrics in SystemWeaver

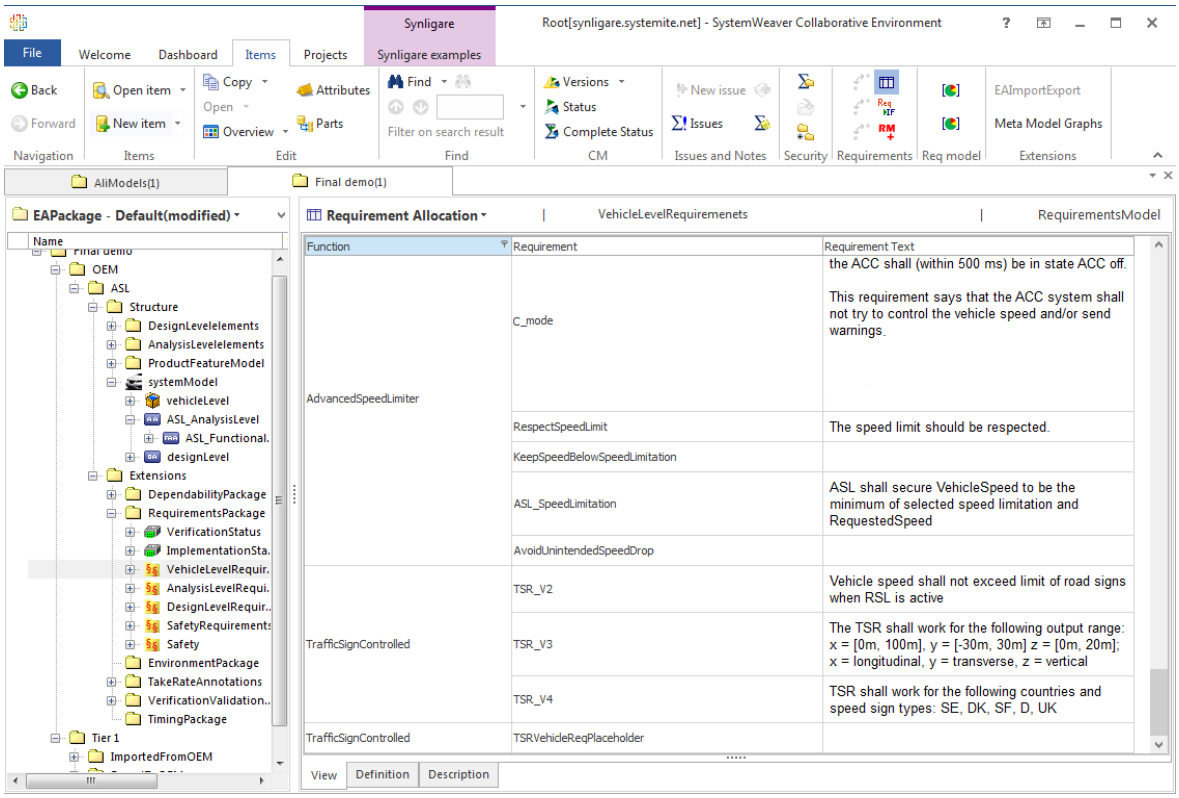


Figure 15. Requirement Allocation View

6.2.2 OEM Metrics on Original System

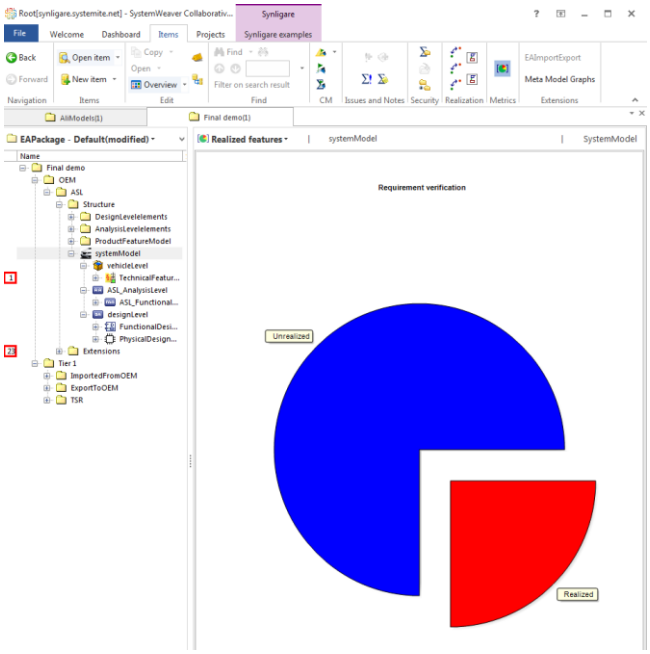


Figure 16. Metric: Ratio of realized vs. non-realized Features (SystemWeaver)

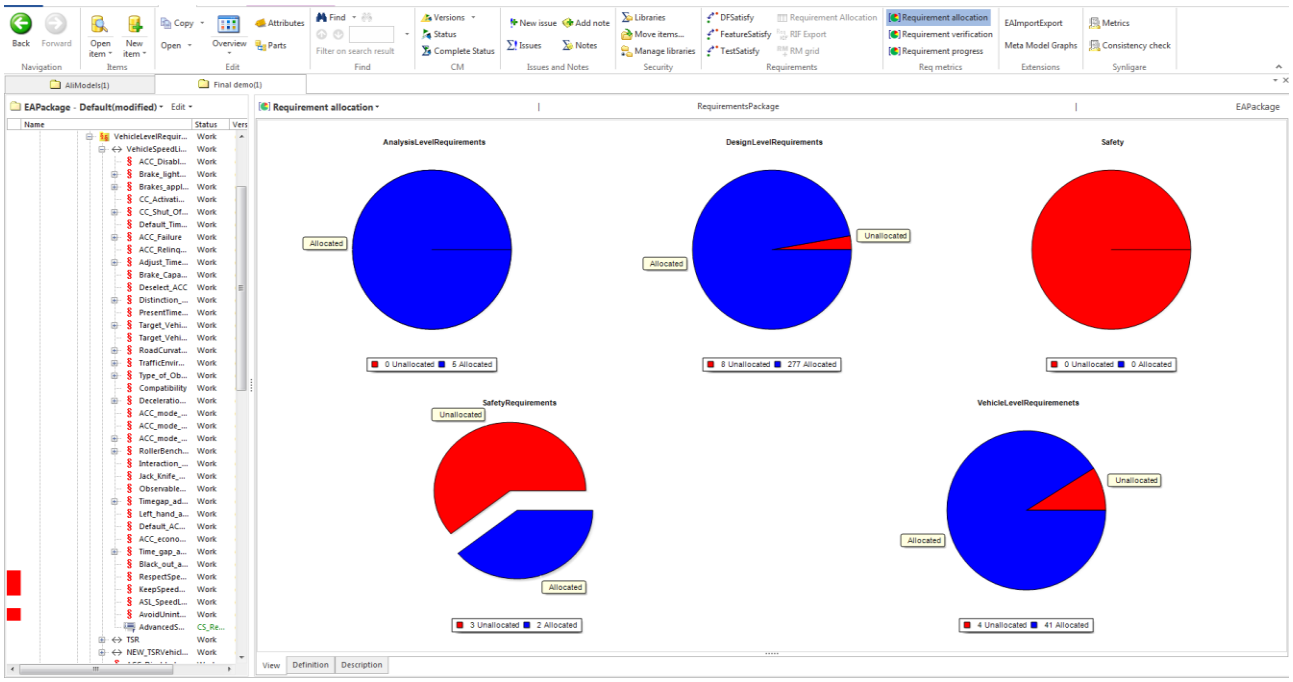


Figure 17. Configurable Metric Dashboard: Ratio of allocated requirements (SystemWeaver)

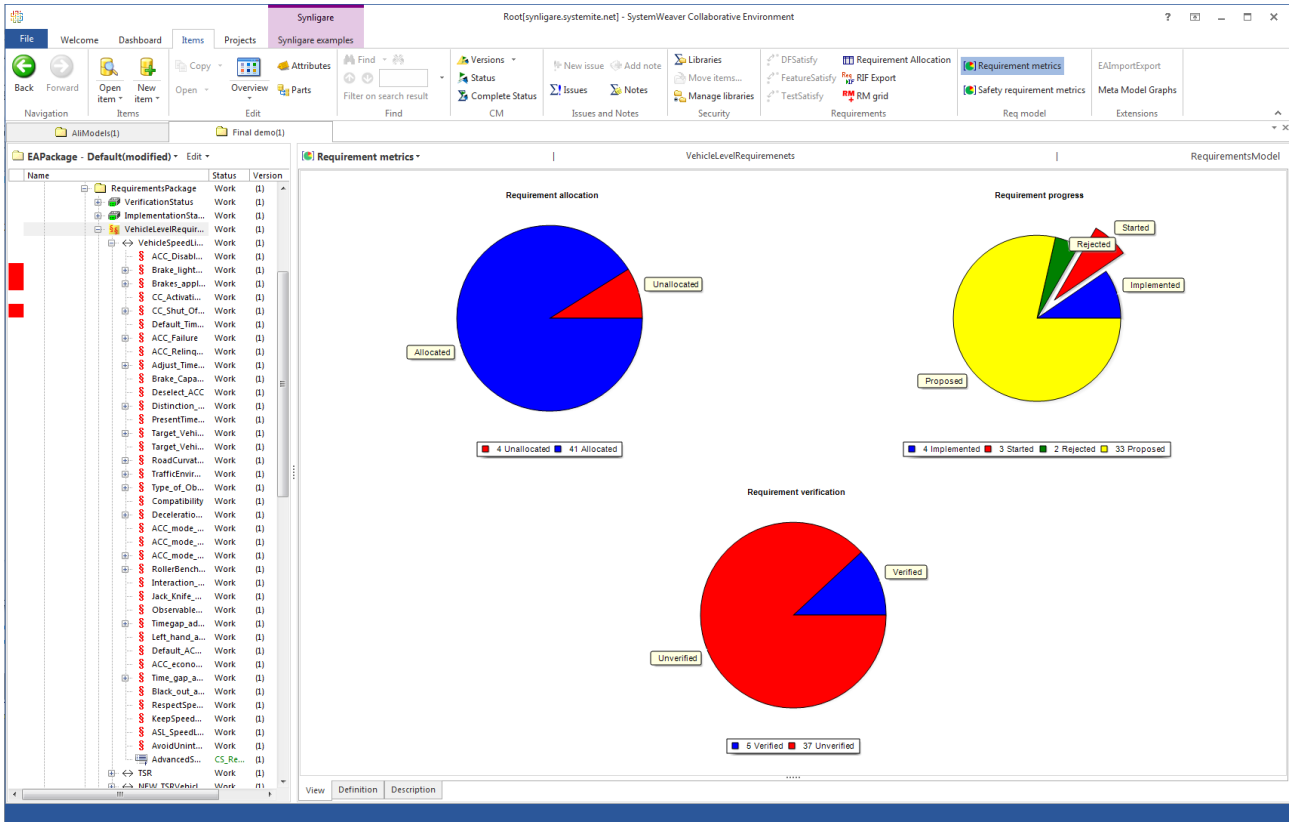


Figure 18. Configurable Metric Dashboard: Requirements' states (SystemWeaver)

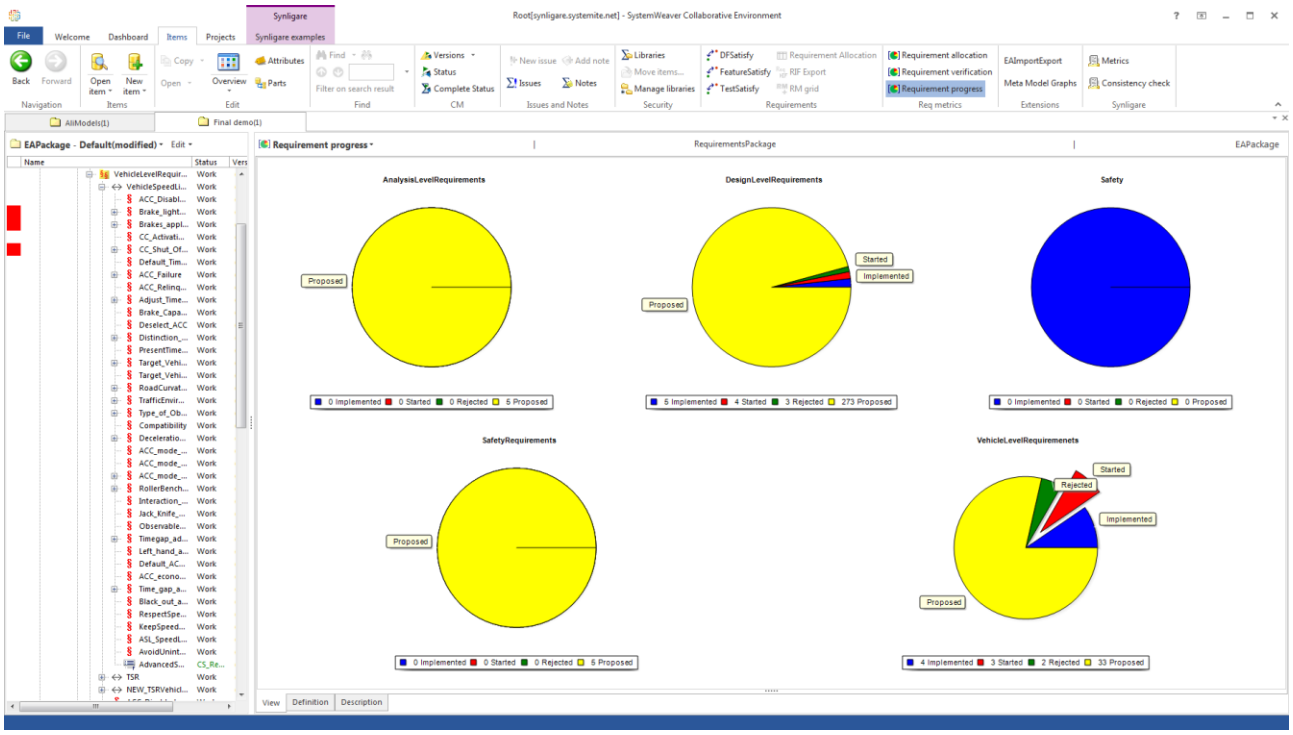


Figure 19. Configurable Metric Dashboard: Requirements' states (SystemWeaver)

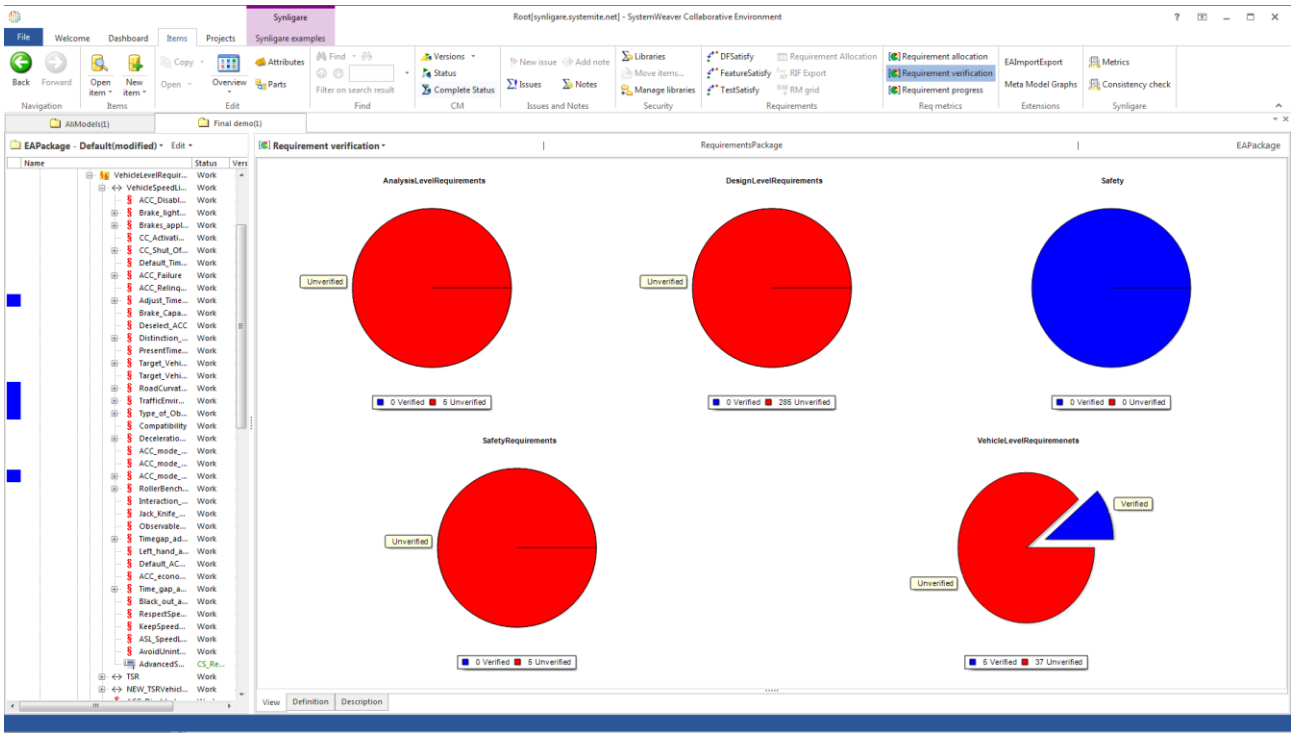


Figure 20. Configurable Metric Dashboard: Ratio of verified requirements (SystemWeaver)

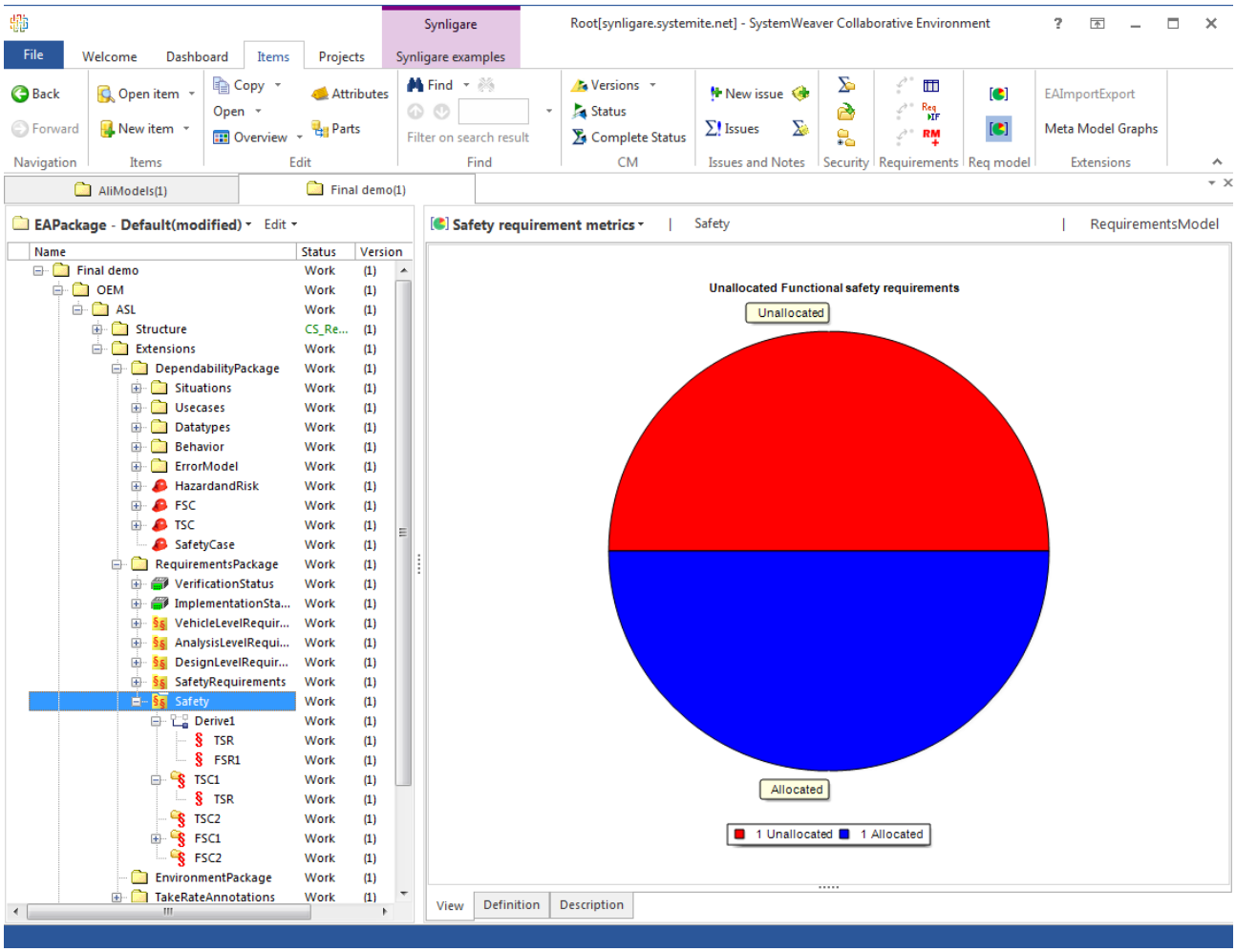


Figure 21. Configurable Metric Dashboard: Safety requirements (SystemWeaver)

6.2.3 OEM – Tier1 iteration

Below, the Advanced Speed Limiter has been extended with Traffic Sign Recognition. Only external interfaces are defined, since the component is developed by a Tier1 supplier.

To spot the difference, a diff-and-merge plugin was used in the EATOP environment, and a similar functionality is available in SystemWeaver.

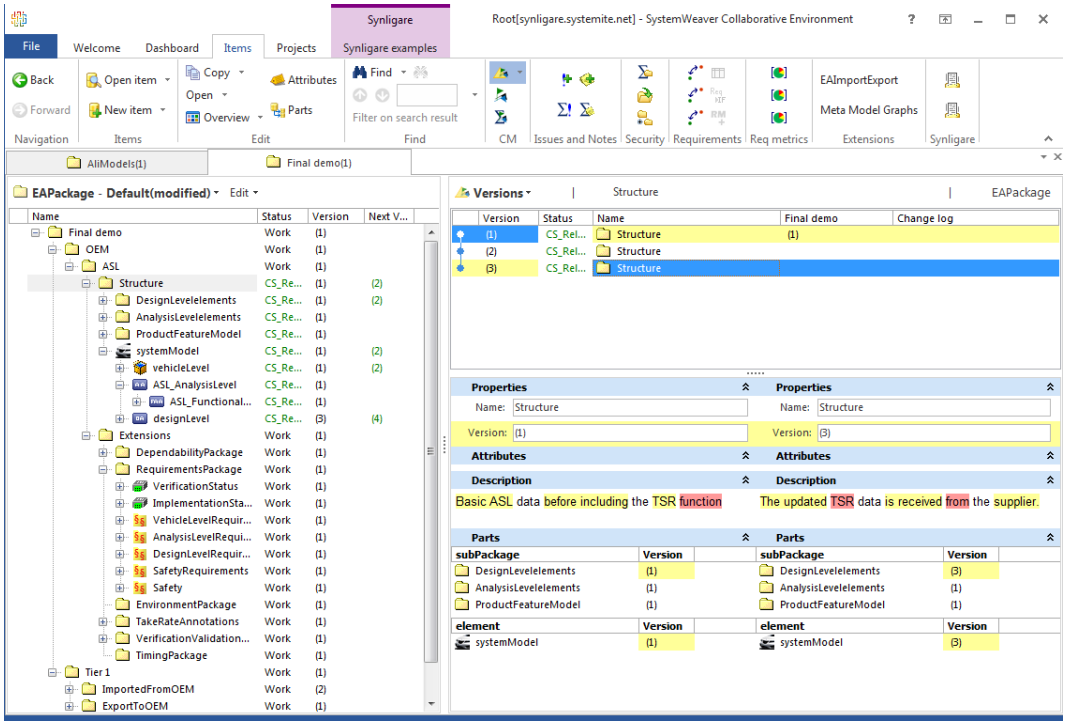


Figure 22. Variant and Version Support in SystemWeaver

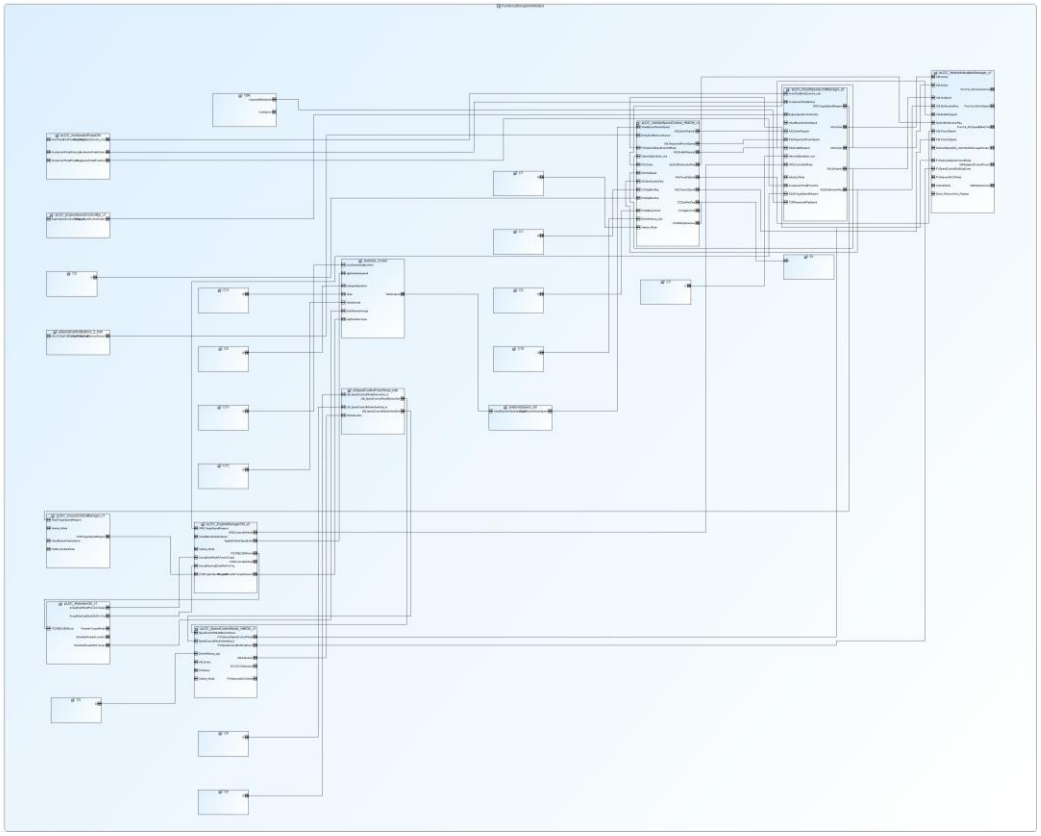


Figure 23. Function Design Architecture with Added Traffic Sign Recognition component (EATOP).

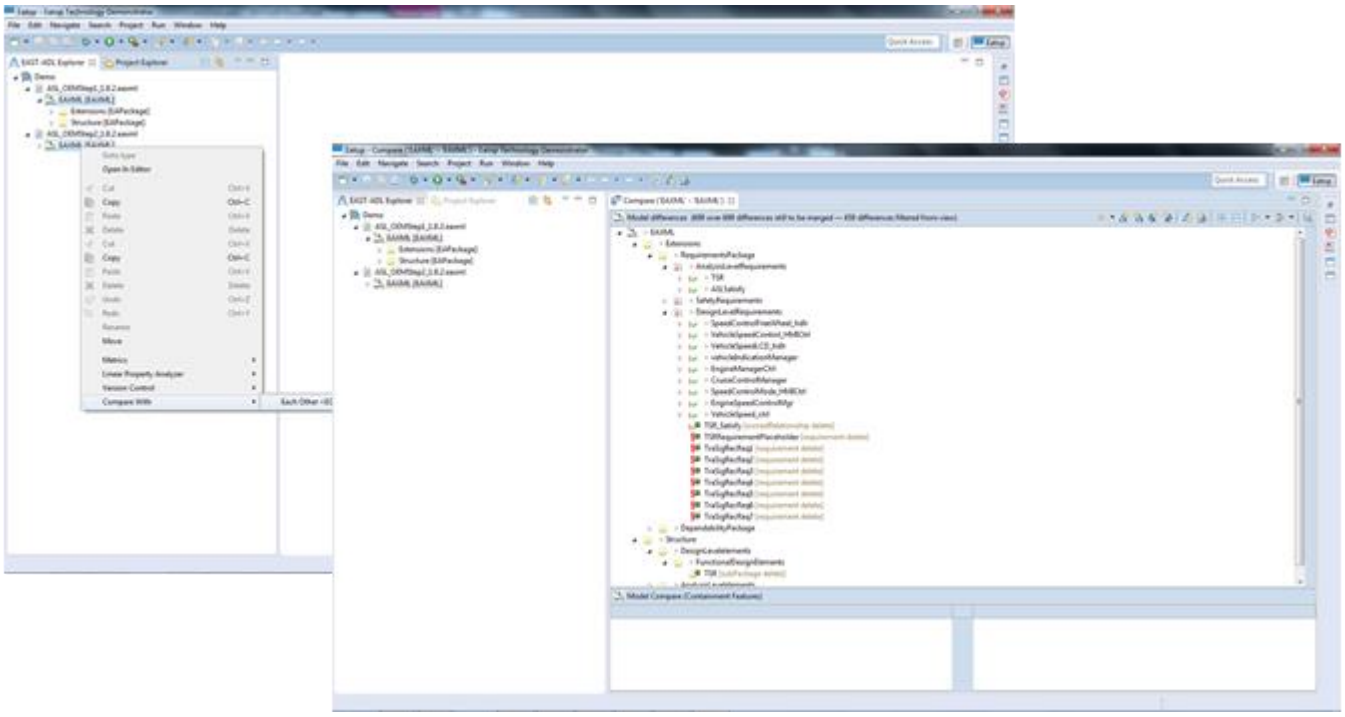


Figure 24. Diff and merge plugin used by requirement engineer to detect changes to the system model (EATOP).

The next step is to distribute requirements to the system elements.

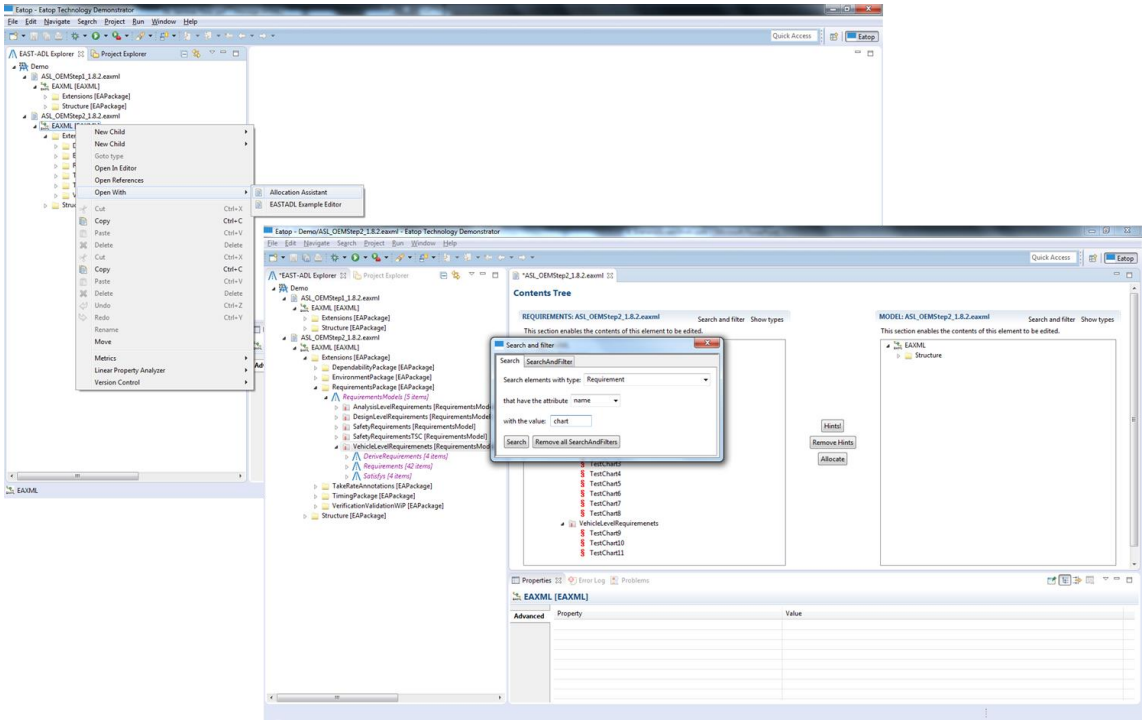


Figure 25. Requirement allocation assistant used to allocate requirements to components

After allocating requirements, the requirement metric is checked for completeness.

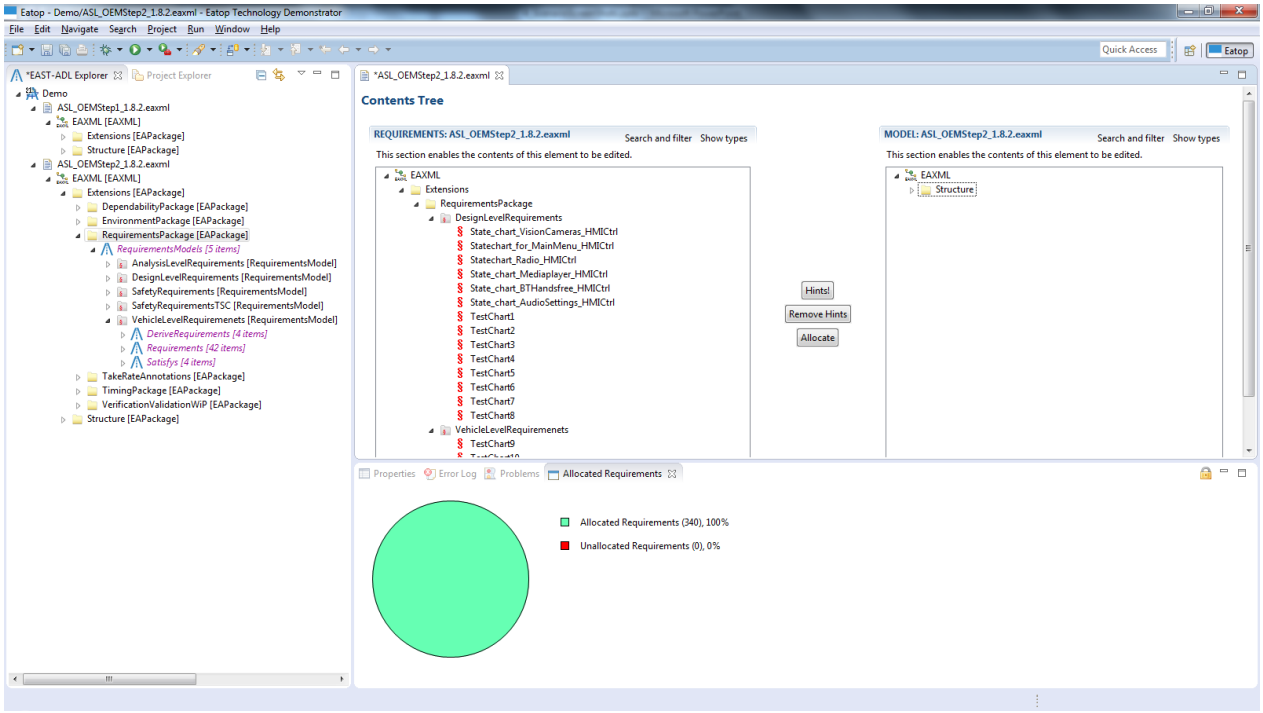


Figure 26. Requirement allocation metric.

In the next step the Tier 1 receives the model and adds internal structure to the Traffic Sign Recognition component. This is done after importing the structure to EnterpriseArchitect. There is now a difference between the legacy TrafficSignRecoognition component, and the one requested by the OEM that requires changes by both parties: The OEM has overlooked EgoMotionData which is a necessary input and the Tier1 previously did not supply a separate “Confidence” output.

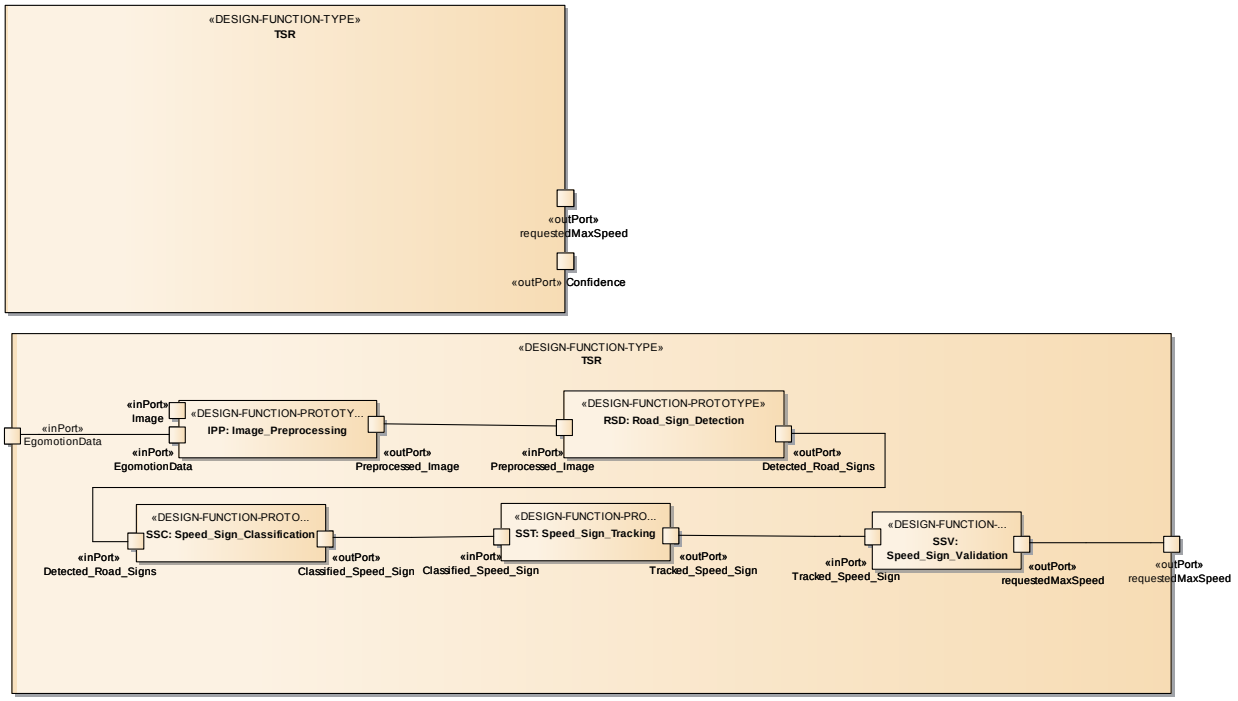


Figure 27. Imported Component Specification from OEM (top) vs. Legacy component at Tier1 (bottom) (EnterpriseArchitect)

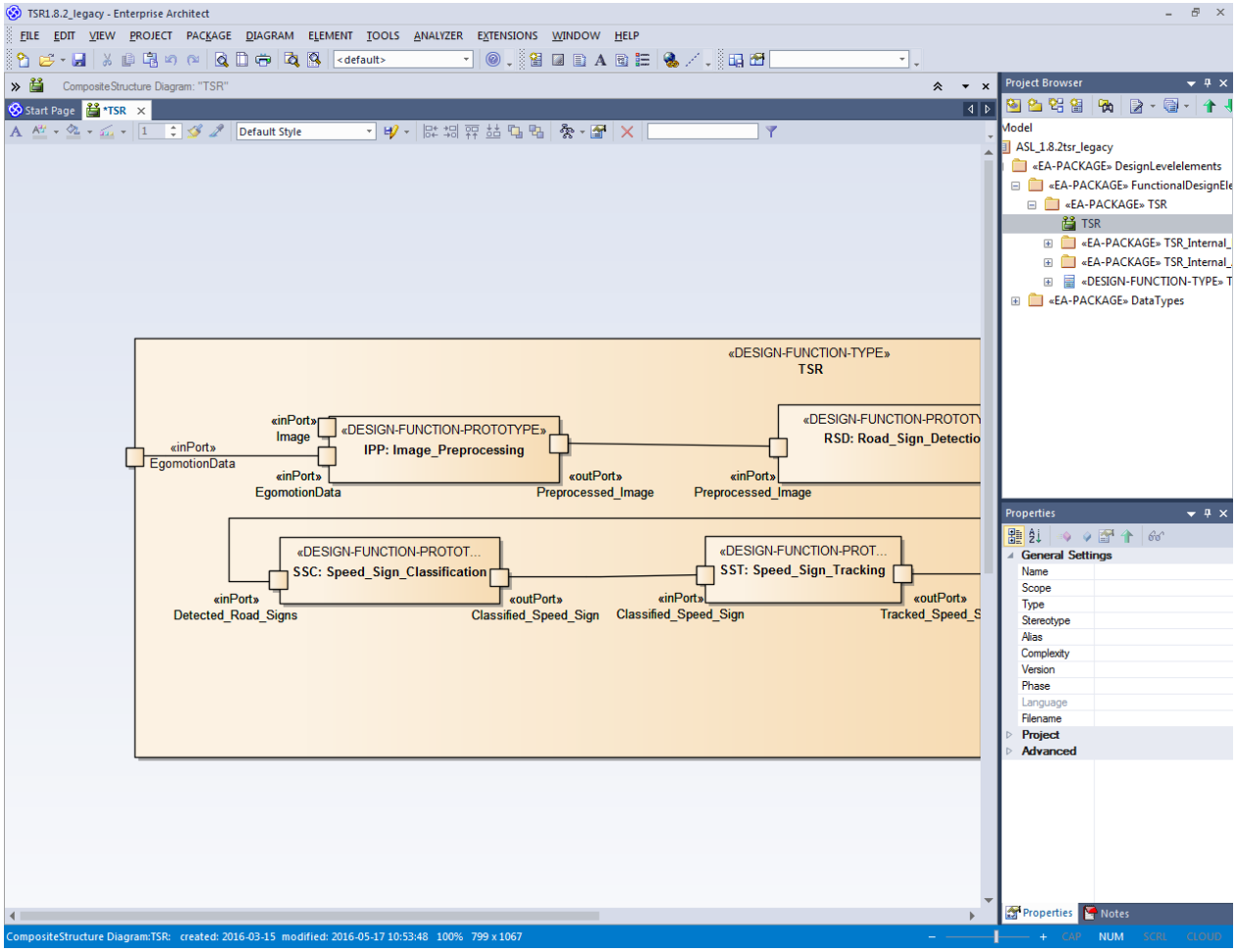


Figure 28. Traffic Sign Recognition in Enterprise Architect

On receiving and importing the new component specification, the OEM sees the added interface and updates the design accordingly, see below.

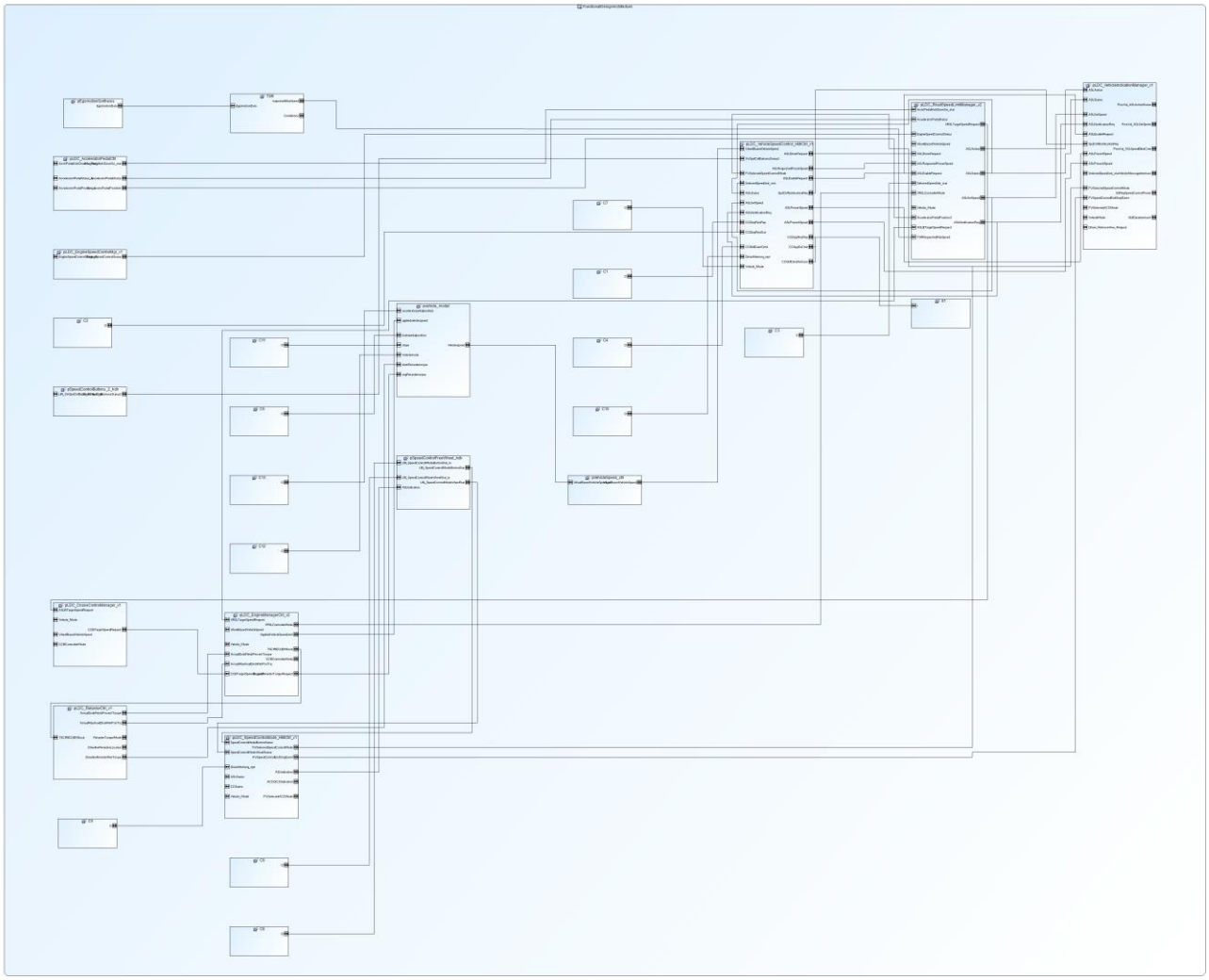


Figure 29. Updated Advanced Speed Limiter with EgoMotionData component added.

6.3 Dependability Scenario

The dependability scenario covers exchange of dependability related information between OEM and supplier.

6.3.1 Hazard and Risk Analysis

Hazard and risk analysis is performed on solution-independent information and represented on Vehicle level in EADST-ADL. Below we show diagrams and other views from SystemWeaver and their counterparts in EATOP.

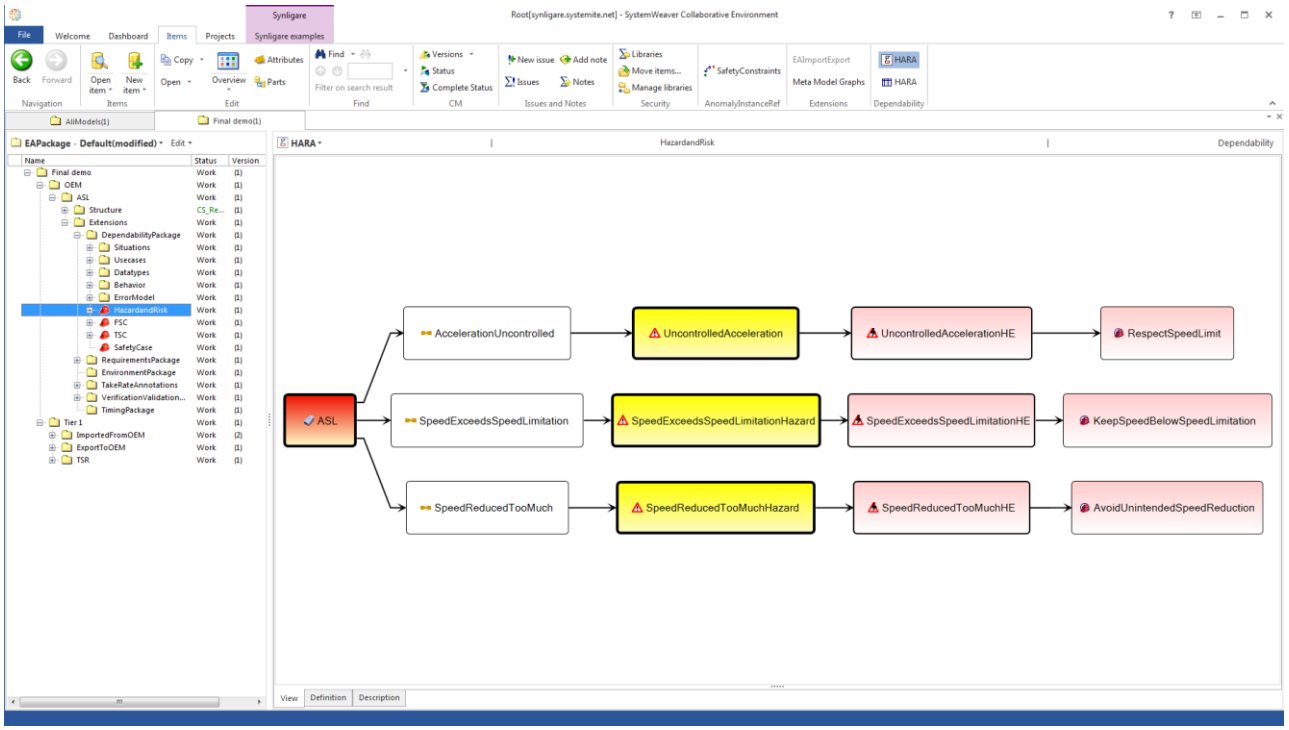


Figure 30. Hazard and Risk related elements in diagram view (SystemWeaver)

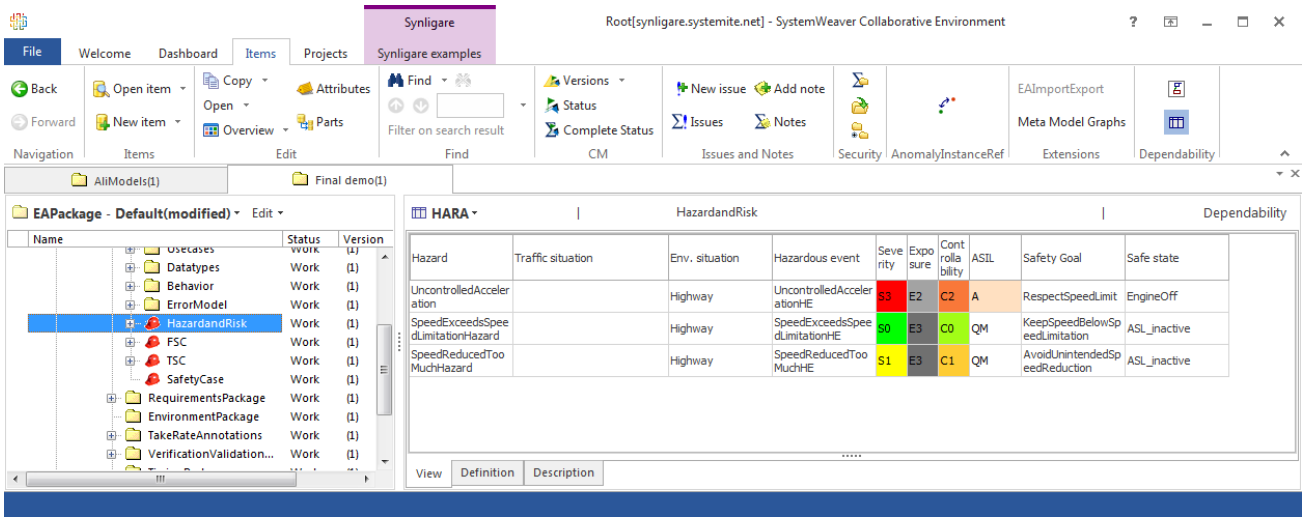


Figure 31. Hazard and Risk related elements in table view (SystemWeaver)

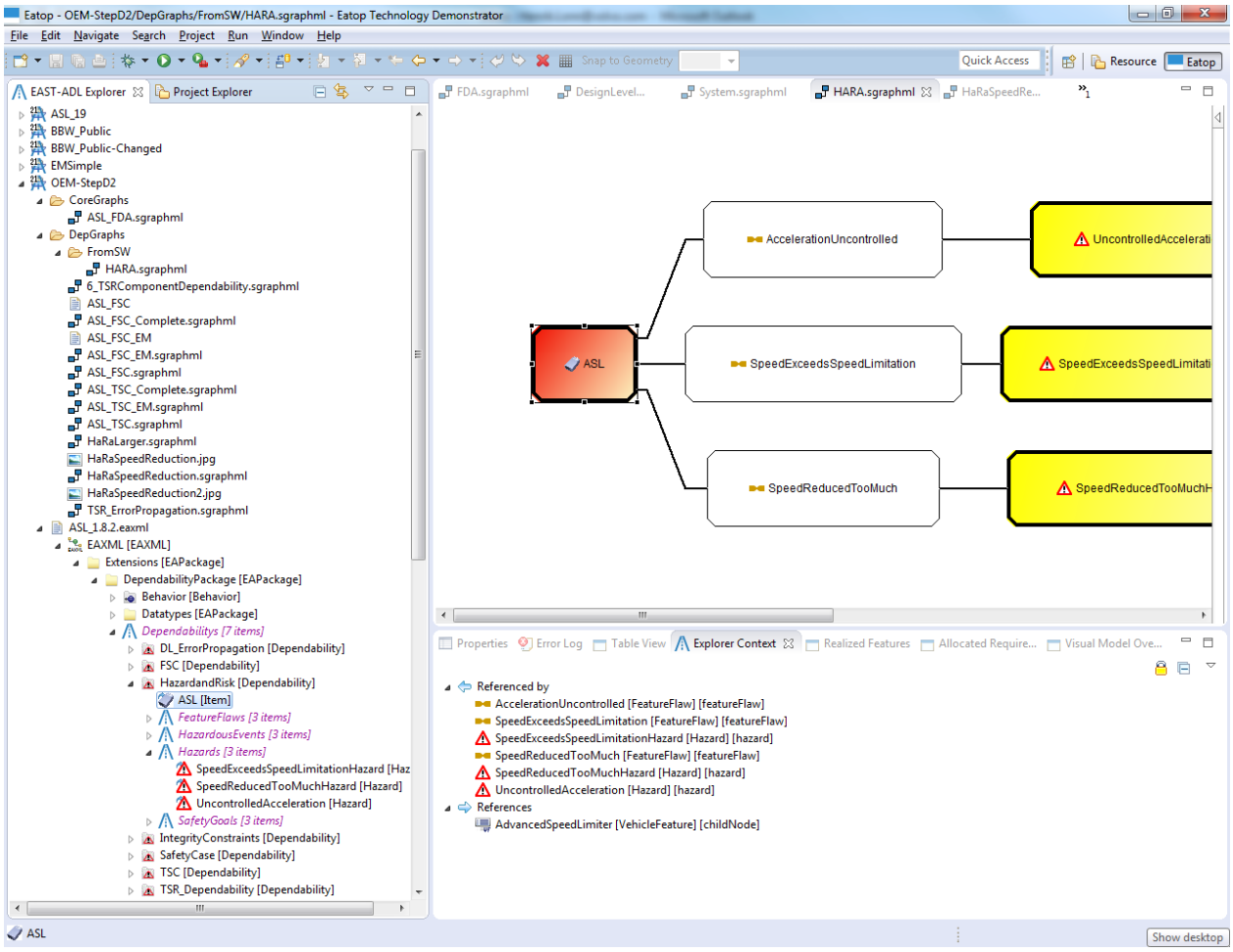


Figure 32. Hazard and Risk, diagram imported from SystemWeaver (EATOP).

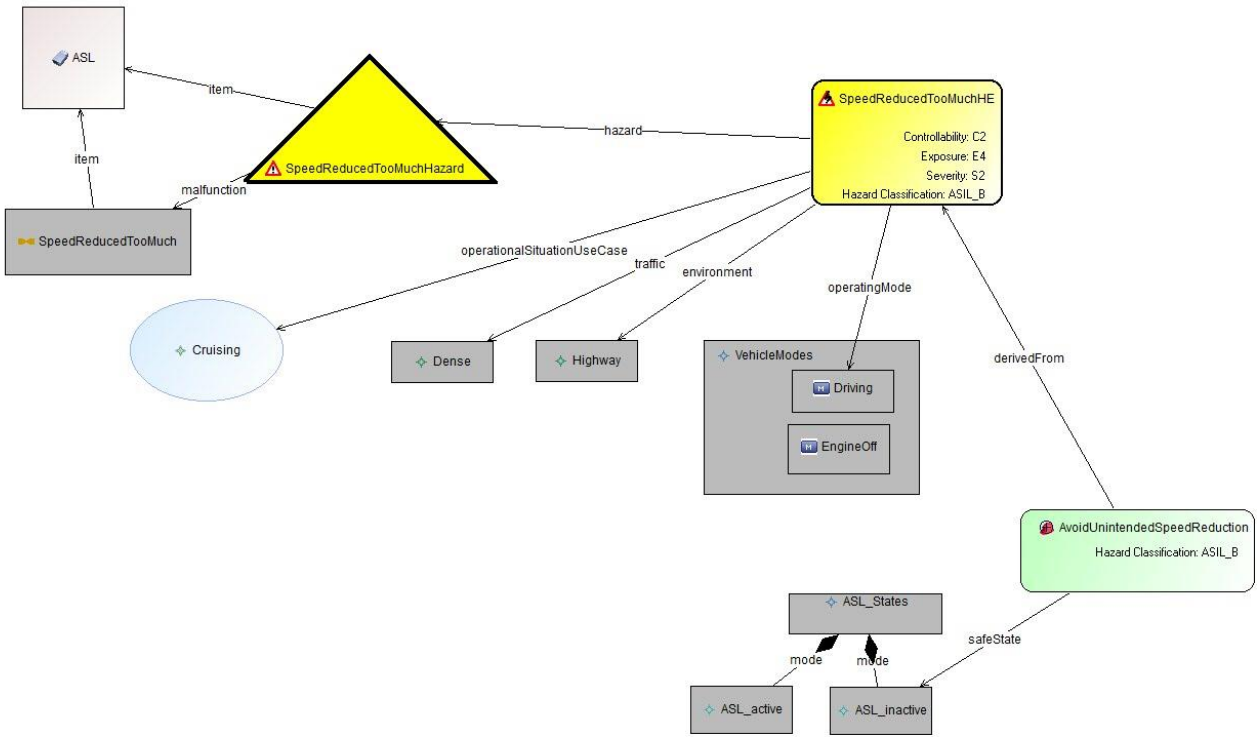


Figure 33. Diagram view: Item, Hazard, HazardousEvent, SafetyGoal (EATOP)

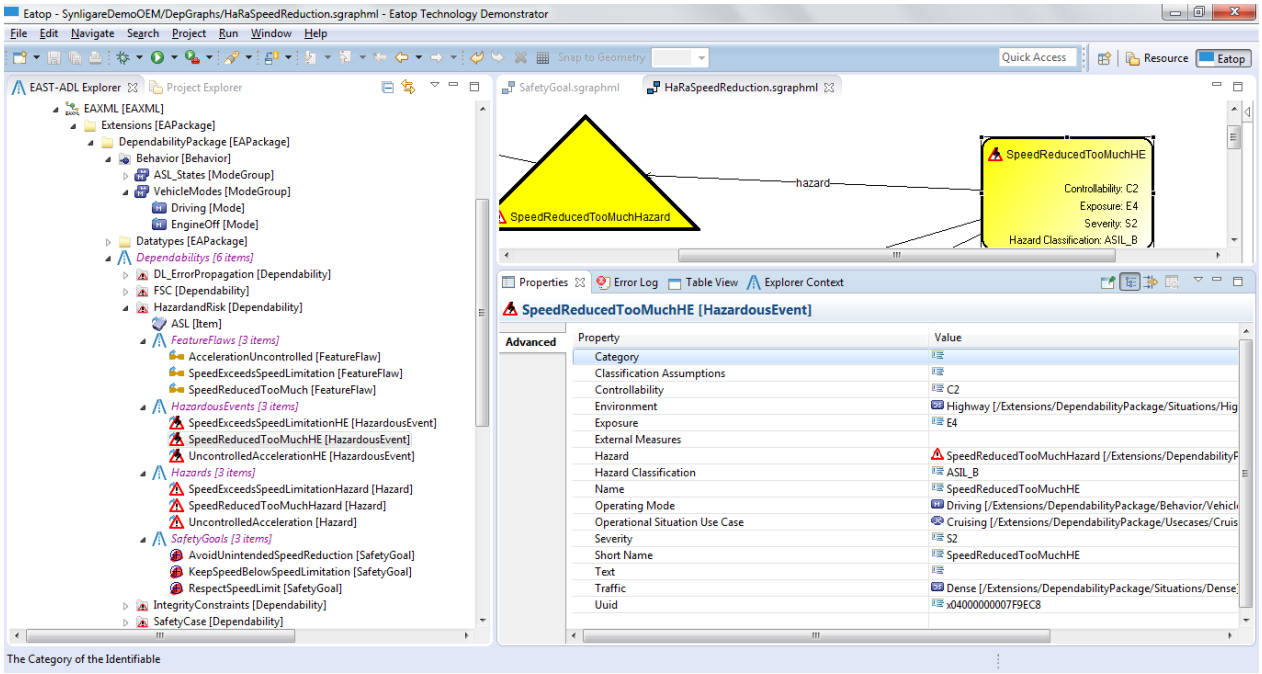


Figure 34. HazardousEvent, Property view (EATOP)

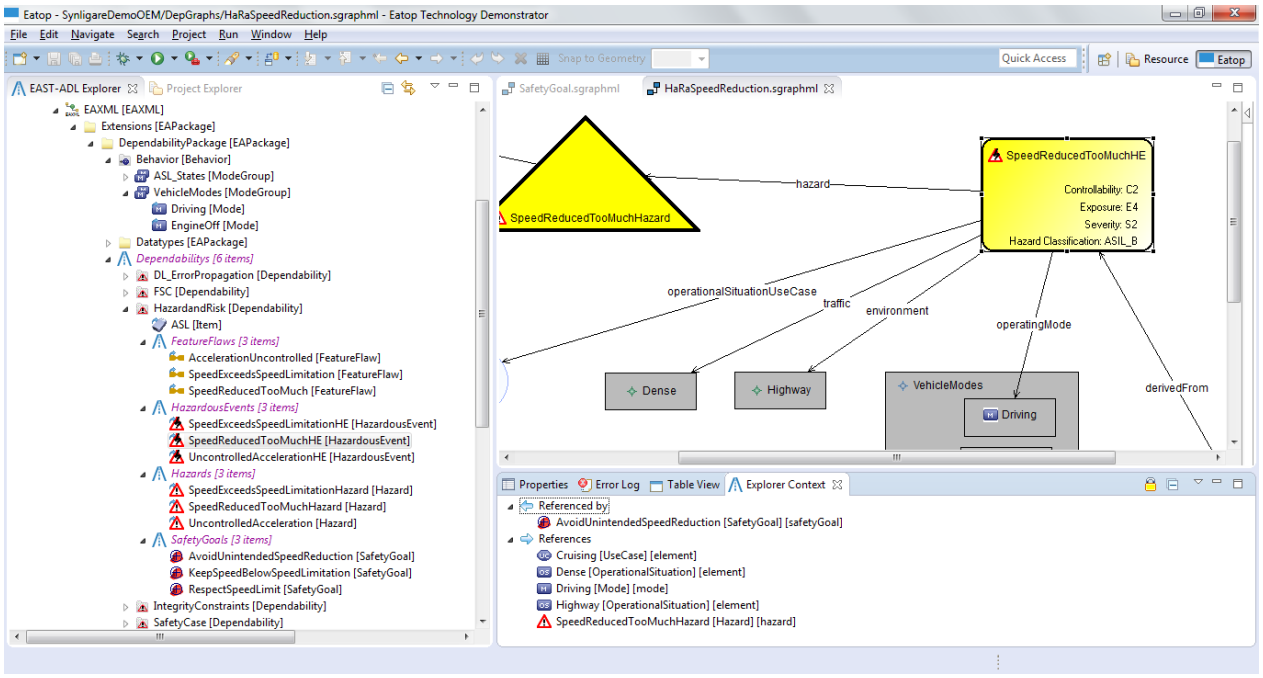


Figure 35. Hazardous Event, Context view(EATOP)

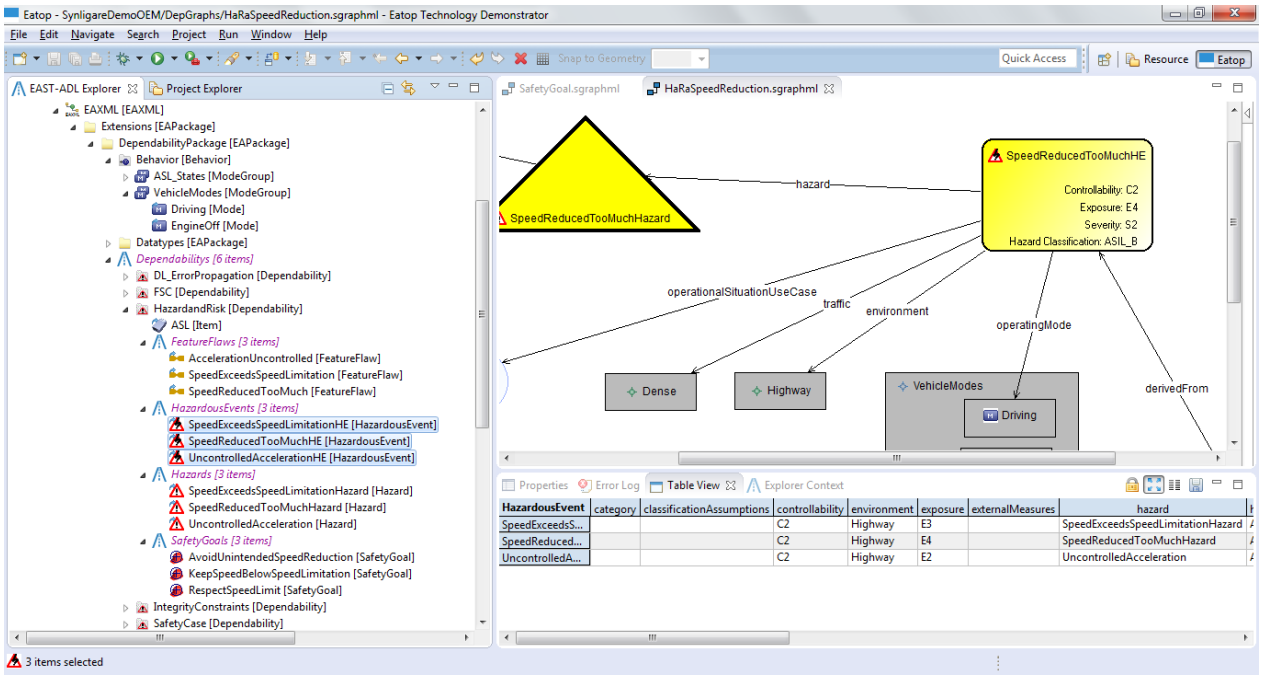


Figure 36. Hazardous Event, Table view (EATOP)

6.3.2 Functional Safety Concept

FunctionalSafetyConcept is based on artefacts on AnalysisLevel, i.e. the hardware and topology independent representation in EAST-ADL. Below, the requirements, constraints and error propagation constructs are shown in various diagram, tree and list views.

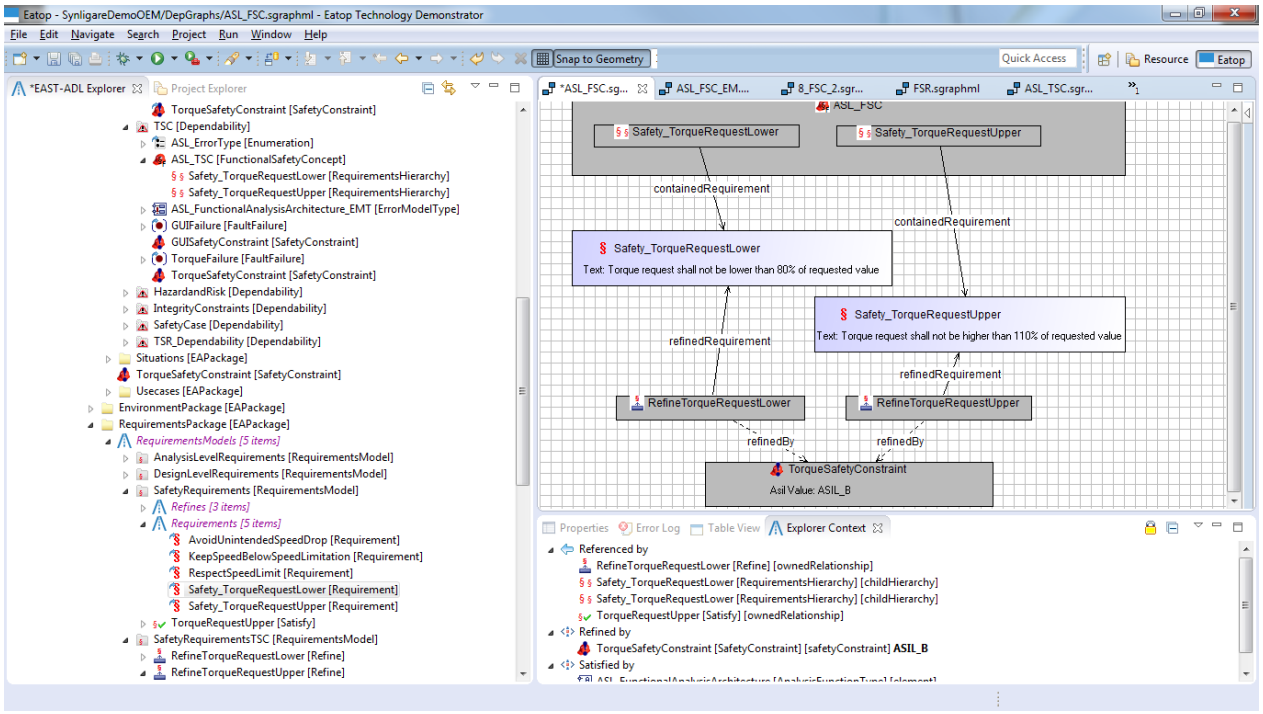


Figure 37. Functional Safety Concept: Context and diagram view (EATOP)

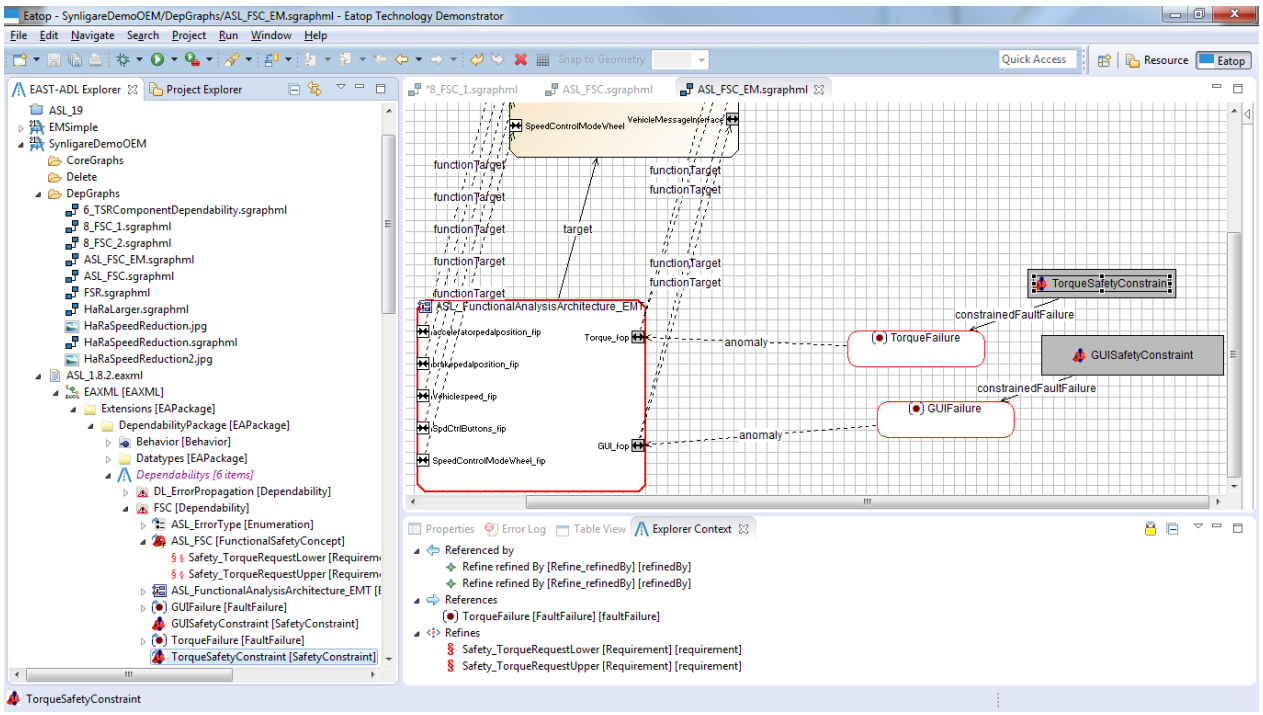


Figure 38. Functional Safety Concept, Error propagation and constraint annotation: Context and diagram view (EATOP)

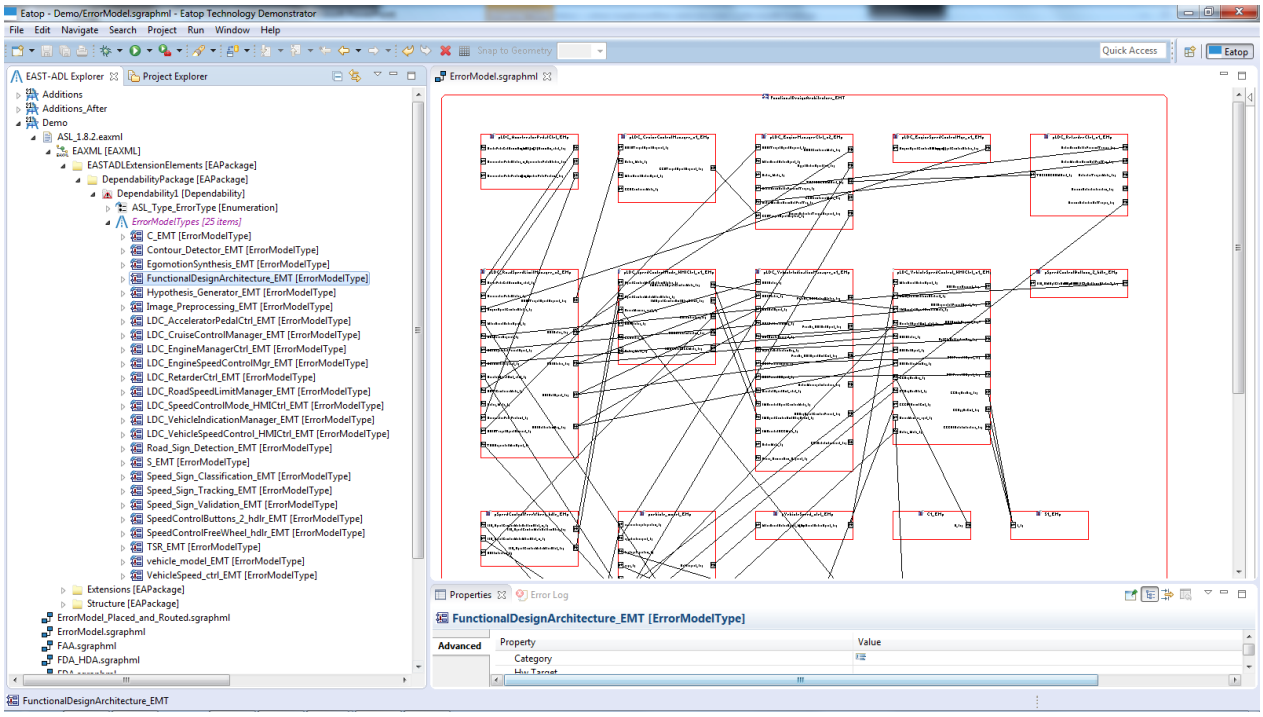


Figure 39. Generated Error Propagation Model (EATOP)

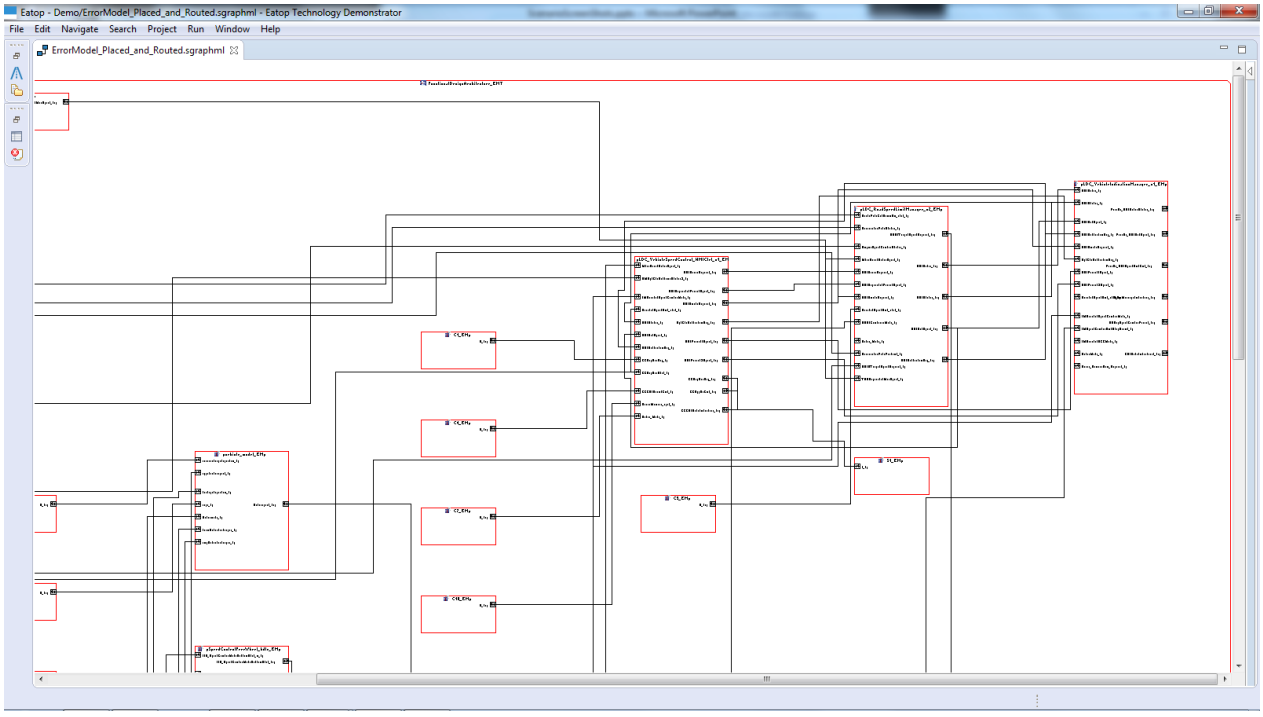


Figure 40. Error propagation model, autorouted diagram (EATOP)

6.3.3 Technical Safety Concept

TechnicalSafetyConcept is based on artefacts on DesignLevel, i.e. the hardware and topology aware representation in EAST-ADL. Below, the requirements, constraints and error propagation constructs are shown in combined views with diagram, tree and list views.

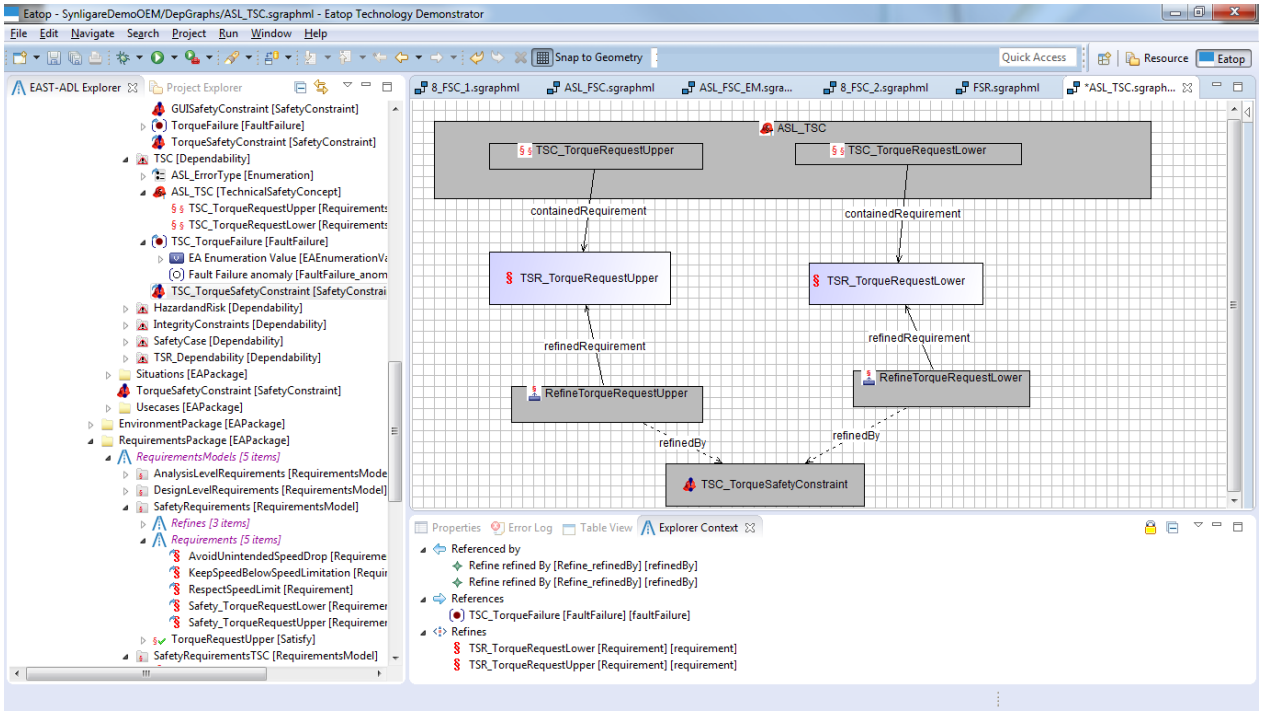


Figure 41. Technical Safety Concept, Overall Diagram View (EATOP)

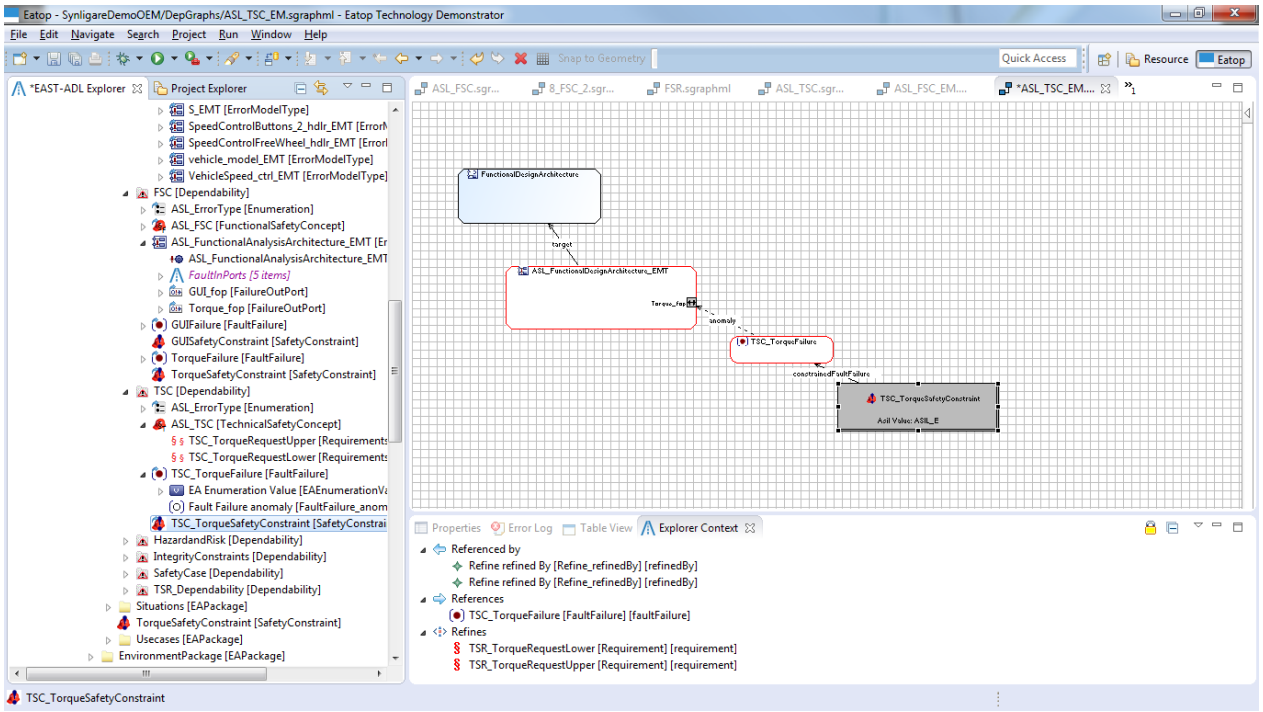


Figure 42. Technical Safety Concept, Error propagation and ASIL constraints in context view and Diagram View (EATOP)

6.3.4 Tier1 Technical SafetyConcept

Assuming that the tier1 is responsible for a part of the system, the OEM is not exposed to the internals of that subsystem or component. Below, the generatied fault propagation disgram and corresponding fault propagation analysis using HiP-HOPS are shown.

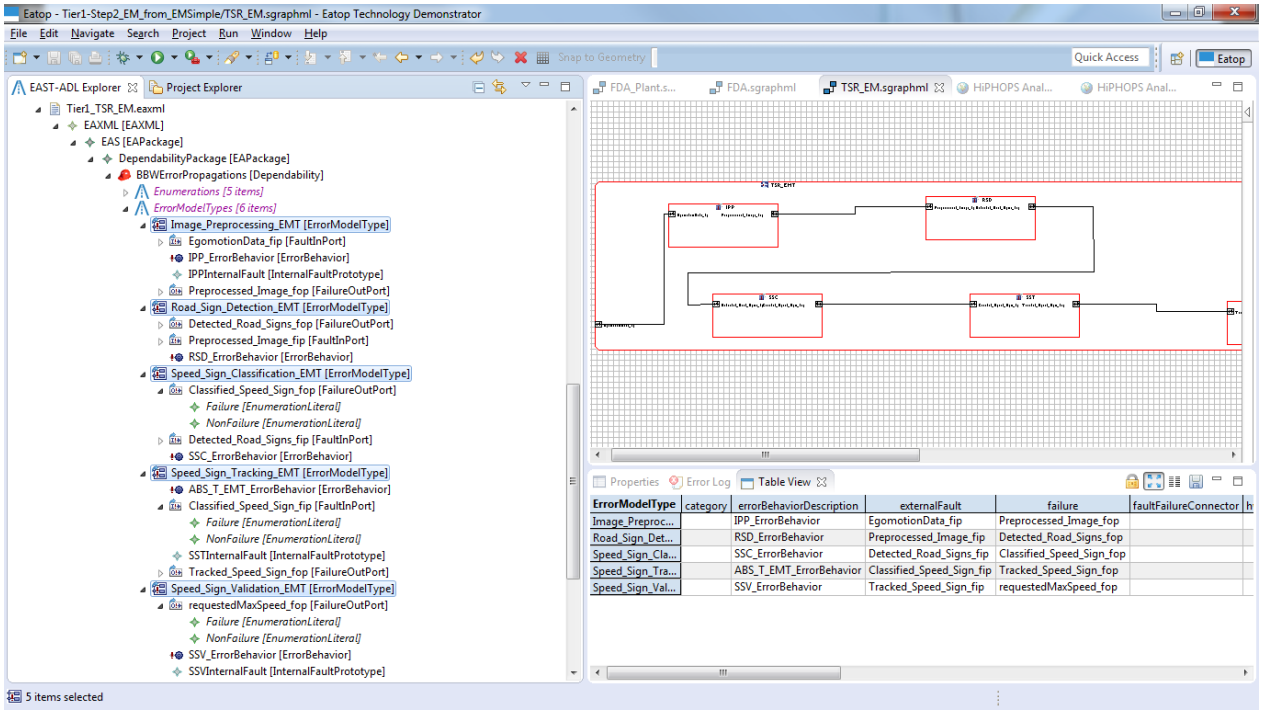


Figure 43. Tier1 autogenerated error propagation model (EATOP)

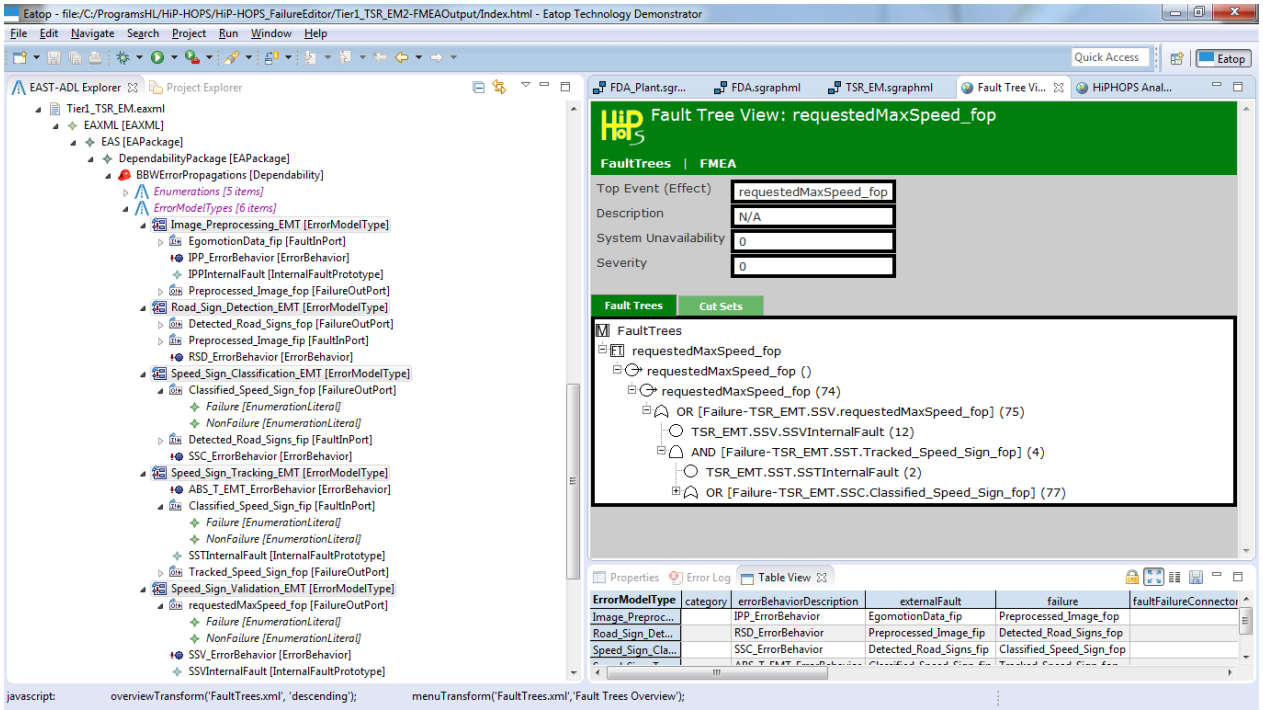


Figure 44. Fault Tree Analysis using HipHops

7 Summary and Conclusions

This document has described the Synligare project objectives how they have been addressed by the project. The conclusion is that they are all met by applying the technologies identified, detailed and prototyped.

In order to validate project results, example system development has been pursued. This was summarized in this document in terms of engineering activities performed as a validation scenario.

7.1 Reflection

There are a lot of challenges in a multi-company business environment like Synligare. We have learned that any project involving more than one company is a challenge and in Synligare we had representatives from three links in the value chain between the raw material and the final product in the hands of the end customer. The OEM, the Tier 1 and the Tier 2 were represented in the Synligare project and had the opportunity to play the “real game” in a small scale.

The OEM perspective is in the automotive industry governed by delivery plans and just in time delivery is the first and easiest quality measure that should be applied to multi-company business relations. Even small delays in delivery times are generally hiding other bigger quality issues and this is something that should be a trigger of systematic activities to find the root causes to the delay. In the Synligare context, we experienced small but significant delays early in the project and were able to handle them thanks to the early discovery of small delays of deliveries. The countermeasures were fixed deadlines and significantly higher sampling rate for the follow up loop in the project.

The Tier 1 perspective is the customer-supplier perspective. The OEM is at first sight the Customer and the Tier 2’s are the Suppliers – but this simplified view is only an illusion. The OEM is an important supplier of information in terms of requirements and expectations on the supplier chain, and the Tier 2 companies are important ‘information customers’ for the Tier 1. The conclusion is that all actors in the value stream are both customers and suppliers to more or less all other actors. The interdependence between all the links in the value chain has to be clear for all involved parties, regardless of where they are located in the chain. The automotive industry uses the lean concept in many areas inside each company but the lean concept is often forgotten in the relations between the companies. The OEM’s can create significant unnecessary labor in the supplier chain if they deliver their requirements late or in an incomplete state. Synligare has shown that requirements and models has to been associated to each other to avoid misunderstanding between the parties but the challenge of translating these blocks of requirements and models between different tools has also been highlighted. A standard language could have reduced this challenge and made Synligare redundant. On the other hand, other standardization initiatives (one example is Autosar) has shown that the winners in commercially driven standardization projects is the Tier 2 level, due to the concentration of expertise in the Tier 2 companies.

The Tier 2 perspectives are several and very dependent on the size and nature of the Tier 2 company. Small Tier 2 companies are either suppliers of products or services, and therefore easy victims for the divide and conquer strategies of the often significantly bigger purchasing departments of the Tier 1 companies. On the other hand, bigger and/or specialized Tier 2’s with good relations to the OEM’s can often hide behind unclear OEM requirements where they as they have the experts are the only trusted source of knowledge. Examples can be Tier 2’s that has delivered tools and/or services to the OEM and therefore has created a monopoly on these services or tools (and tools related services). This dilemma becomes clear when the automotive industry with its cost based purchasing philosophy meets the software industry and their value based pricing paradigm. Customer lock in using dependencies on (different) tools is common in the automotive supply chains and often not considered by the individuals that signs the agreements. On the other hand, customer lock in is the only way of handling the price competition strategy that the bigger players uses to create an effective supply chain (from the big company

perspective). The eco system of small and bigger companies needs a balance and fair cooperation is always more effective than unfair competition. Trustful relations and transparency between the actors in the value chain are therefore keys to success for the automotive industry, and how this trust building can be improved on national level needs to be studied more.

To summarize, Synligare has shown that the automotive industry has a lot of contributions when analyzing value streams between companies and the success factors in these business relations. Establishment and maintenance of lean, trustful and long term profitable customer-supplier relations are not created without effort but their value cannot be underestimated.

7.2 Conclusions

The project validation effort included applying tools developed in the project onto an example system identified and modeled by the project. On this basis, the project goals have been assessed. It was concluded that the five goals were fulfilled, based on the various project results and a related validation and refinement effort.

8 References

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[6] Synligare Consortium: Synligare Deliverable D3.2 Report on Tooling. http://www.synligare.eu/

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[8] Systemite AB: SystemWeaver. http://www.systemite.se

[9] HiP-HOPS: www.hip-hops.eu

