OETCS/WP2/D2.3 – 01/01

openETCS

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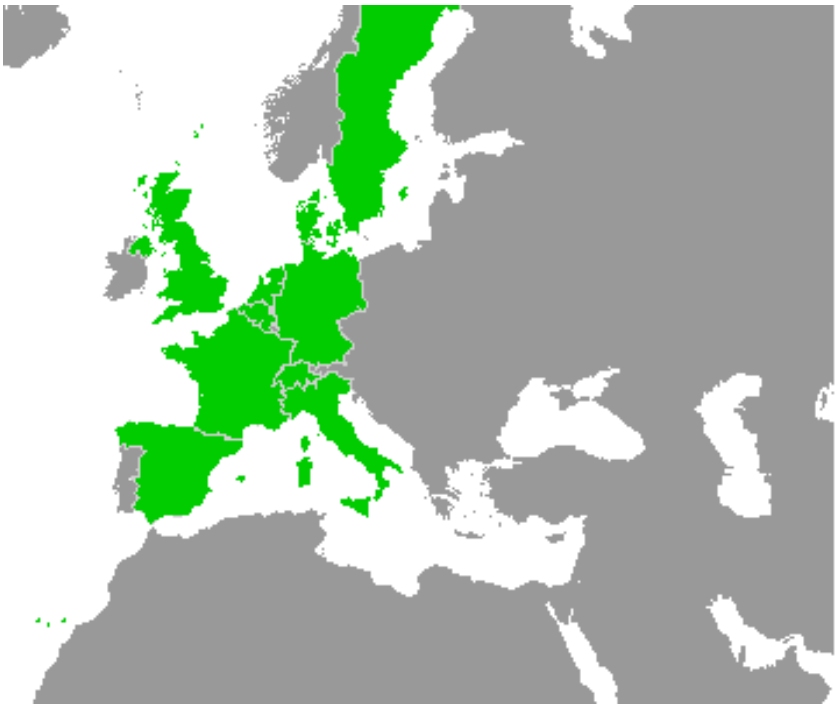
Work-Package 2: “Definition”

OpenETCS process

Definition of the overall process for the formal description of ETCS and the rail system it works in

Marielle Petit-Doche and Matthias Güdemann April 2013



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Definition of the overall process for the formal description of ETCS and the rail system it works in

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Definition

Prepared for ITEA2 openETCS consortium
Europa

Abstract: This document gives a description of the process to be applied in the OpenETCS project. In the first part, the document gives a description of the specification and design activities for a critical system. The second part presents an abstract description of the case study issued from SUBSET-026.

Table of Contents

Figures and Tables

Figures

Tables

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1 Introduction

The purpose of this document is to describe the specification and design activities for the OpenETCS project. The activities for safety, verification and validation are not in the scope of this document and will be described in WP4's documents.

To deal with a safety process, the specification and design activities shall follow the requirements of EN 50126, EN 50128 and EN 50129 and reflect usual activities for the development of railway critical systems (see D2.1 and D2.2). This description is linked to the set of requirements defined for the OpenETCS project in D2.6.

1.1 Motivation

This document describes the process to be applied during the OpenETCS project to achieve the main goals of the OpenETCS project:

A semi-formal reference specification for the ETCS requirements and architecture, completed by strictly formal models of sub-parts

The first goal of the project is to propose a semi-formal specification of the ETCS on-board functionalities according to UNISIG SUBSET-026, baseline 3.

The purpose of this model is:

- to enhance the understanding of the subset;
- to be able to animate the model for testing and analysing purpose at system level;
- to provide information on the completeness and soundness of the SUBSET-026;
- to be used as a reference semi-formal specification for the implementation of an on-board unit (by the OpenETCS project team and by industrial actors);

The output is a model, at least semi-formal, understandable by many formal approaches (SCADE, Simulink, B tools, OpenETCS tool chain...) that can be given to all railway actors, and if possible associated to SRS documents in the ERA database.

Thus, strictly formal models can be designed from this semi-formal model which allows for formal proofs of sub-parts of SUBSET-026. This will allow improving the understanding of the system, and will provide elements for verification and validation using formal proof.

The final goal is that industrial actors work with this model instead of the natural language specification. The objective is to cover as much as possible of the functionality of the on-board unit described in SUBSET-026 and to show the capabilities of analyses of a complex system using formal approaches.

Define the safety case concept for the full model and apply it on a subset of the on-board unit

The safety strategy and the safety case concept required for the full validation of the product, compliant to the CENELEC standards shall be taken into account in all steps of the specification and design process. This will allow industrial actors to reuse the models and processes to develop certifiable products.

In particular the definition of the process shall take into account specification as well as verification and validation of the safety properties on the models. The outputs of WP4 (safety plan, safety case concept, verification plan and validation plan) will complete the description of the safety process.

Provide a tool chain and process/methodologies for developing an on-board software that can fulfil the CENELEC requirements for SIL4 software

The design process of the system and the associated tools of the tool chain, shall be suitable to provide a certifiable product. For this purpose all steps of the process and the choice of the methods and tools shall be justified to ensure a safe approach to build an ETCS system.

The full safety process required to make OpenETCS *certifiable* according to CENELEC 50126, 50128 and 50129 shall be described in detail. The safety process will detail precisely which activities are required, why they are required, and the choices that are made to claim that a safe design process is guaranteed.

The use of formal methods, supported by tools, is highly recommended in this safety process for specification, design, verification and validation of the certifiable product.

The tool chain should include model editors, code generators, verification tools (including formal provers), validation tools (including test generators, simulators,..), document generation, version management, maintenance facilities, ...

Provide an executable software package generated from the specification of on-board ETCS

An executable software of the specification shall be provided, as well as a non vital implementation of the on-board unit for laboratory test, simulation and as reference.

The output is the result of a functional implementation for the ETCS requirements and architecture which can be used by the industrial as reference.

%% Does this executable take into account real-time constraints ? API ? from which model it is derived ? %% %%at which level of the V-cycle ? system ? software ?%%

Besides this executable software, the tool chain can be used to generate certifiable executable software from the formal model of sub-parts of the on-board unit.

1.2 Contents of this Document

As the Quality Plan D1.3 focuses on means to apply during the OpenETCS project (for example open source approaches or Scrum organization) the aim of this document is to define the main steps which are necessary within the OpenETCS project to produce a certifiable system according to the CENELEC standards. Safety, verification and validation activities are described in the outputs of WP4.

%%Give the references of WP4 deliverables%%

The first part of this document focuses on the description of the mandatory steps of a life-cycle to design a critical system according to the CENELEC standards, as described in figure 1.

Comment.

Form Marc Berhens : Strictly formal model shall be as semi-formal model in the safety process and in the functionnal process

The proposed process for the OpenETCS project shall describe:

- how to design a semi-formal model of the on-board unit system from the SRS SUBSET-026 ;
- how to design some subsets of the SRS SUBSET-026 within a safety process;
- how to produce a running model of the application software of the on-board unit.

For the 2 first objectives, the semi-formal model shall take into account the safety constraints to apply to the design of a critical railway system.

The second part of this document describes the system to design during the OpenETCS project, as well as the scope of the safety activities on this system.

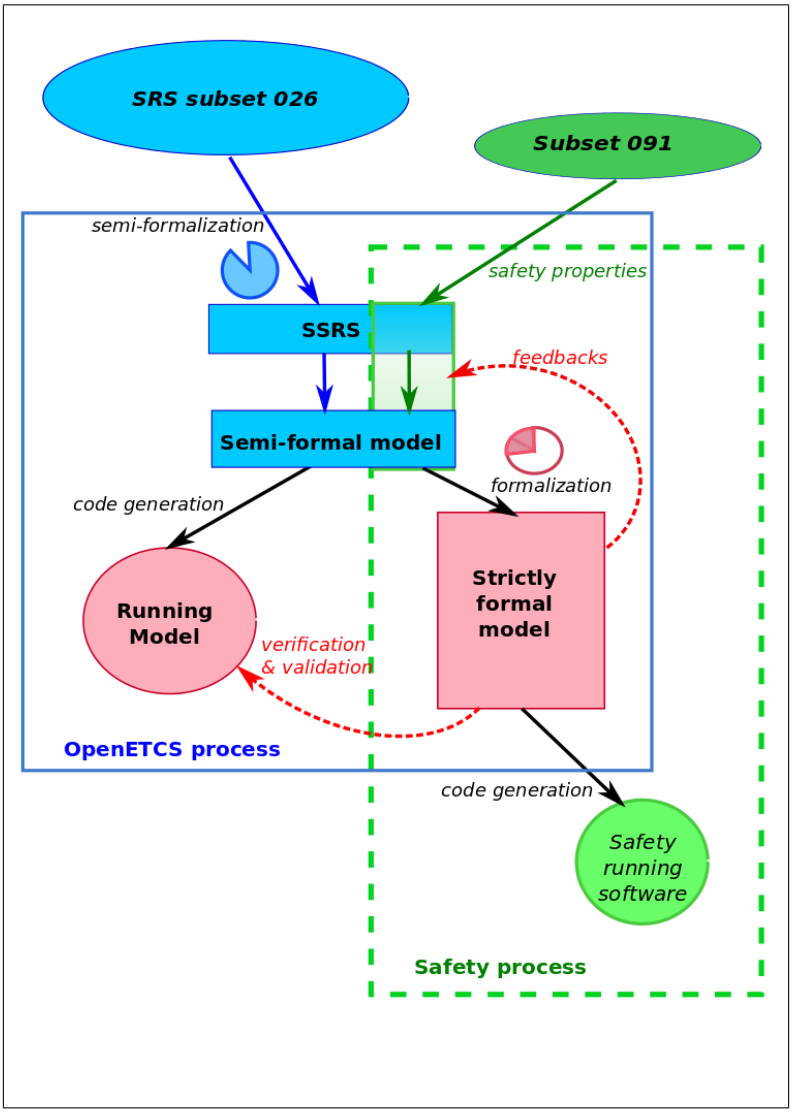

Figure 1. OpenETCS process

2 Reference Documents

- CENELEC EN 50126-1 — 01/2000 — *Railways applications — The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS) — Part 1: Basic requirements and generic process*
- CENELEC EN 50128 — 10/2011 — *Railway applications – Communication, signalling and processing systems – Software for railway control and protection systems*
- CENELEC EN 50129 — 05/2003 — *Railway applications — Communication, signalling and processing systems — Safety related electronic systems for signalling*
- FPP — *Project Outline Full Project Proposal Annex OpenETCS* – v2.2
- SUBSET-026 3.3.0 — *System Requirement Specification*
- SUBSET-076-x 2.3.y — Test related ERTMS documentation
- SUBSET-088 2.3.0 — *ETCS Application Levels 1 & 2 - Safety Analysis*
- SUBSET-091 3.2.0 — *Safety Requirements for the Technical Interoperability of ETCS in Levels 1 & 2*

- CCS TSI — *CCS TSI for HS and CR transeuropean rail has been adopted by a Commission Decision 2012/88/EU on the 25th January 2012*
- D1.3 – Project Quality Assurance Plan
- D2.1 – Report on existing methodologies
- D2.2 – Report on CENELEC standards
- D2.6 – Requirements for OpenETCS

3 Conventions

The requirements are prefixed by "R-zz-x-y", and are written in a roman typeface, where "R" stands for "Requirement", "zz" identifies the source document,"x" is the version number and"y" is the identifier of the requirement. All the text written in italics is not a requirement: it may be a note, an open issue, an explanation of the requirements, or an example.

The placeholder " %%xxx%% " is used to indicate an unfinished paragraph or section which is to be defined or confirmed.

4 Glossary

API Application Programming Interface

FME(C)A Failure Mode Effect (and Criticity) Analysis

I/O Input/Output

OBU On-Board Unit

QA Quality Analysis

RBC Radio Block Center

RTM RunTime Model

SIL Safety Integrity Level

THR Tolerable Hazard Rate

V&V Verification & Validation

5 OpenETCS Process

5.1 Overall Description

To pursue the goals given in the introduction, the development cycle for the project is presented in this document.

In order to minimise the number of different models and unused steps, the proposed process shall take into account the safety concepts from the early steps, i.e., the sub-system requirement specification (SSRS) and the semi-formal definition of the model instead of the SRS. Thus, these elements can be used in the safety process to deduce formal models as shown in figure 1.

The two most important elements of the system life-cycle of EN 50129 and the Software development life-cycle model of EN 50128 are the separation of the life-cycle into well-defined phases

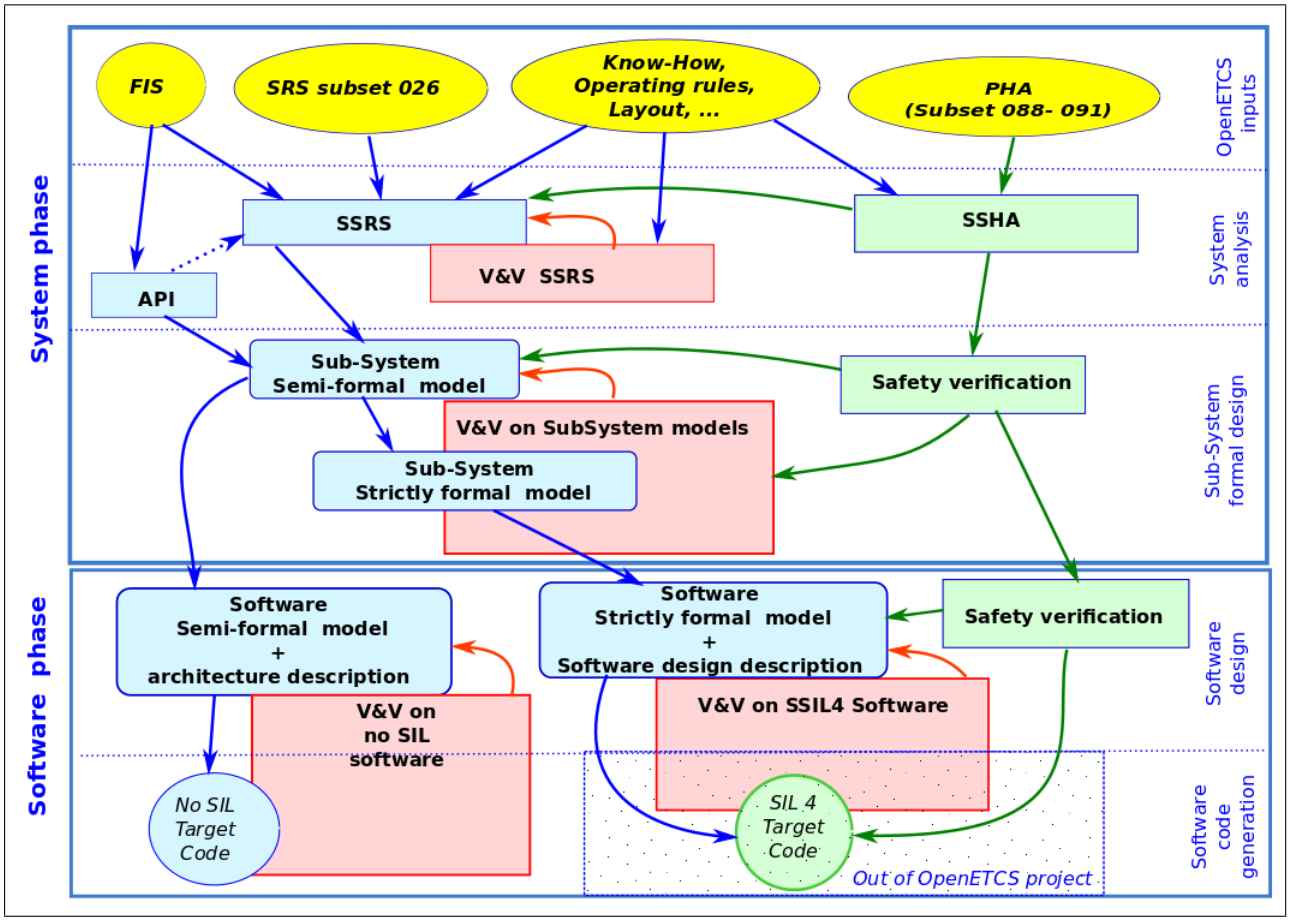

Figure 2. Whole process

and the focus on the production and recording of extensive documentation of the development process. This allows facilitation of safety, verification, validation and assessment activities and confidence in the use of good practises to develop a critical system. To achieve this, an appropriate life-cycle must be defined for OpenETCS, following the constraints provided by the CENELEC standard, and appropriate roles and responsibilities must be assigned to the participants.

Figure 2 described the main phases and main activities of the OpenETCS process. Input elements of the project are in yellow, specification and design activities in blue, verification and validation activities in red, safety activities in green.

Two main phases are defined :

System phase to analyse the input documents and provide a model of the on board unit according SUBSET-026 and safety strategy:

- First system analysis shall provide a sub-system requirement specification (SSRS) to define the scope of the system to design and its structure, completed with an abstract Application Programming Interface (API) to give the main interfaces of the system and interaction between software and hardware items. Sub-system hazard analyses (SSHA) allow the definition of safety properties.
- Secondly, a model, at least a semi-formal, is designed to describe sub-system architecture and requirements. This model can be completed with a formal model to focus on some functions or properties.

Software phase to design the software and then generate applicative code of the sub-system. Two approaches are developed together from the same sub-system model:

- on one part to complete the semi-formal model to obtain a functional code covering as much as possible of the SSRS
- on the other part to provide method and tools to obtain a SIL4 code and to apply this approach on a subset of the SSRS.

In the sequel, the main lines of this figure are going to be detailed. However, we are going to focus on specification and design activities only.

5.2 OpenETCS inputs

5.3 System Analysis

5.4 Sub-System formal design

5.5 Software design

5.6 Software code generation

5.7 System Development Phase

Objectives

The aim of this phase is to have a clear definition of the system to design:

- a set of system requirements which describe the functionality of the system as the expected results concerning performance, maintainability, safety, reliability,...
- the description of the architecture of the system
- interface descriptions

Safety activities are necessary to define the safety requirements of the system and to define which functions are considered vital or non-vital respectively.

This step is not explicitly defined in EN 50128 but is defined in EN 50129.

Documents

According the CENELEC standards, the documents to produce in this phase are:

- the *System Safety Plan* which explains the overall approach to ensure safety in the developed system
- the *System Requirements Specification* which describes all requirements of the system
- the *System Safety Requirements Specification* which focuses on the safety aspects
- the *System Architecture Description and Software / HW interface definition* which specify how the Software and the HW interact as well as the location of the boundary between the two

System Safety Plan and *System Safety Requirements Specification* shall be produced by the safety managers (WP4) and are out of the scope of this document.

The main input of the OpenETCS project is the SUBSET-026 3.3.0, which can be considered as the *System Requirement Specification* (see R-WP2/D2.6-01-011).

However, this document is not sufficient to produce a model of the on-board unit software. Thus a *Sub System Requirement Specification* shall be produced during this phase, in particular to define the structure of the system and to manage the requirement allocation (see R-WP2/D2.6-X-12).

External interfaces are partially provided by the UNISIG documents. However interfaces between ETCS units and application programming interfaces (API) have to be defined for the OpenETCS project.

Detailed Description

Figure 3 describes the detailed steps of the System Development Phase.

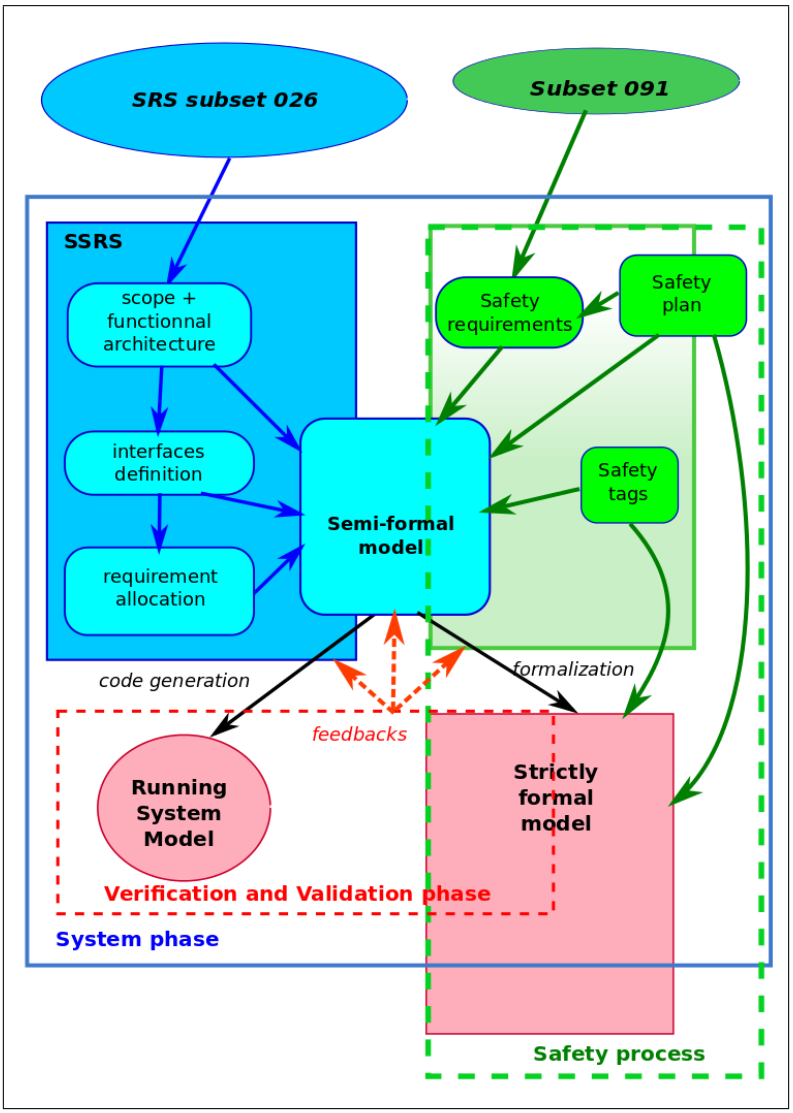

Figure 3. System phase description

The first part is the definition of the *Sub System Requirement Specification* (SSRS, the blue rectangle in figure 3) which shall allow:

- to clearly define the scope of SUBSET-026 to take into account for the design (only on-board functionalities are designed, track-side functionalities are out of the scope of the project) (see R-WP2/D2.6-X-12.1.4),
- to define the interfaces of the system: external interfaces and software/hardware interfaces (see R-WP2/D2.6-X-12.1.5, R-WP2/D2.6-X-12.1.6),
- to provide a functional architecture of the system with inputs and outputs of each function identified (see R-WP2/D2.6-X-12.1),
- to allocate SRS requirements to each function (see R-WP2/D2.6-X-12.2),
- to classify Safety versus Non-Safety items (functions, input/output, requirements, ...) from the safety analyses results (see R-WP2/D2.6-X-13),
- to facilitate safety, design, verification, validation and maintenance activities.

These tasks need some interactions with safety activities (dashed green rectangle in figure 3), for example to define safety tags on functions, requirements,...

To cover the OpenETCS project objective of formal models, a semi-formal model of the system specification is defined from the requirements of SUBSET-026 together with the architecture and interface description of the SSRS.

This semi-formal model can be completed with strictly formal models to improve the understanding of the system and to provide elements for verification and validation activities (dashed red rectangle on figure 3). System validation can be performed on a running model generated from the semi-formal model.

Means and tools

The SSRS and interfaces definition shall be described as documents. However these documents can be completed by a semi-formal model to describe the functional architecture of the on-board unit (see R-WP2/D2.6-X-12.1.2):

- to define the scope of the application to design (see R-WP2/D2.6-X-12.1.4),
- to split the main function of the system into independent functions (see R-WP2/D2.6-X-12.1.1),
- to describe the data flow between functions (see R-WP2/D2.6-X-12.1.3),
- to describe the abstract interfaces of the sub-system and its environment, with respect to the existing input documents (see R-WP2/D2.6-X-12.1.5 and R-WP2/D2.6-X-12.1.6).

The semi-formal model shall be, at least, modelled in a semi-formal language (see R-WP2/D2.6-X-14.1). It shall be consistent with the SSRS (see R-WP2/D2.6-X-14.2), especially all the requirements of the SSRS shall be covered by the semi-formal model or justification shall be provided.

The semi-formal model shall reflect the functional architecture defined in SSRS. In particular the language used to design the semi-formal model shall allow it to be modular and extensible (see R-WP2/D2.6-X-17).

In view of validation activities, the means of description of the semi-formal model shall allow to execute or simulate it (see R-WP2/D2.6-X-33).

Parts of the subsystem shall be modelled strictly formally (see R-WP2/D2.6-X-16). This formal model shall be derived from the semi-formal one (see R-WP2/D2.6-X-16.2), as straightforward and automated as possible (see R-WP2/D2.6-X-16.4). Thus, the semi-formal model shall be designed (language and structure) in order to allow the design and validation of the strictly formal model (see R-WP2/D2.6-X-16.3); and to be easily translatable to other languages (see R-WP2/D2.6-X-30).

The expressiveness of the language used to design the semi-formal and formal models shall allow formalisation of the classical objects used in the description of a critical system (see R-WP2/D2.6-X-31 and R-WP2/D2.6-X-32):

- state machines
- time-outs
- truth tables
- arithmetics
- braking curves
- logical statements
- messages and fields

In view of verification activities, traceability between documents and models shall be provided (see R-WP2/D2.6-X-12.3 and R-WP2/D2.6-X-14.3) :

- between SSRS and SRS
- between semi-formal model and SSRS
- between strictly formal model and semi-formal model

In practice, interpretations, additions and omissions of requirements shall be tracked and justified (see R-WP2/D2.6-X-12.3.1 and R-WP2/D2.6-X-14.3), as well as exportedFIXME: je ne comprends pas “exported” exigence and derived requirements (see R-WP2/D2.6-X-12.3.2 and R-WP2/D2.6-X-14.???).

In view of safety activities, the languages used for the models shall allow a declarative, simple and formal expression of the safety properties (see R-WP2/D2.6-X-29 R-WP2/D2.6-01-020). The modelled safety properties shall be validated on the semi-formal model by test and on the strictly formal model by proof (see R-WP2/D2.6-X-24). Logical properties can be added to simplify the models but shall be validated just as the properties (see R-WP2/D2.6-X-34).

5.8 Model Definition

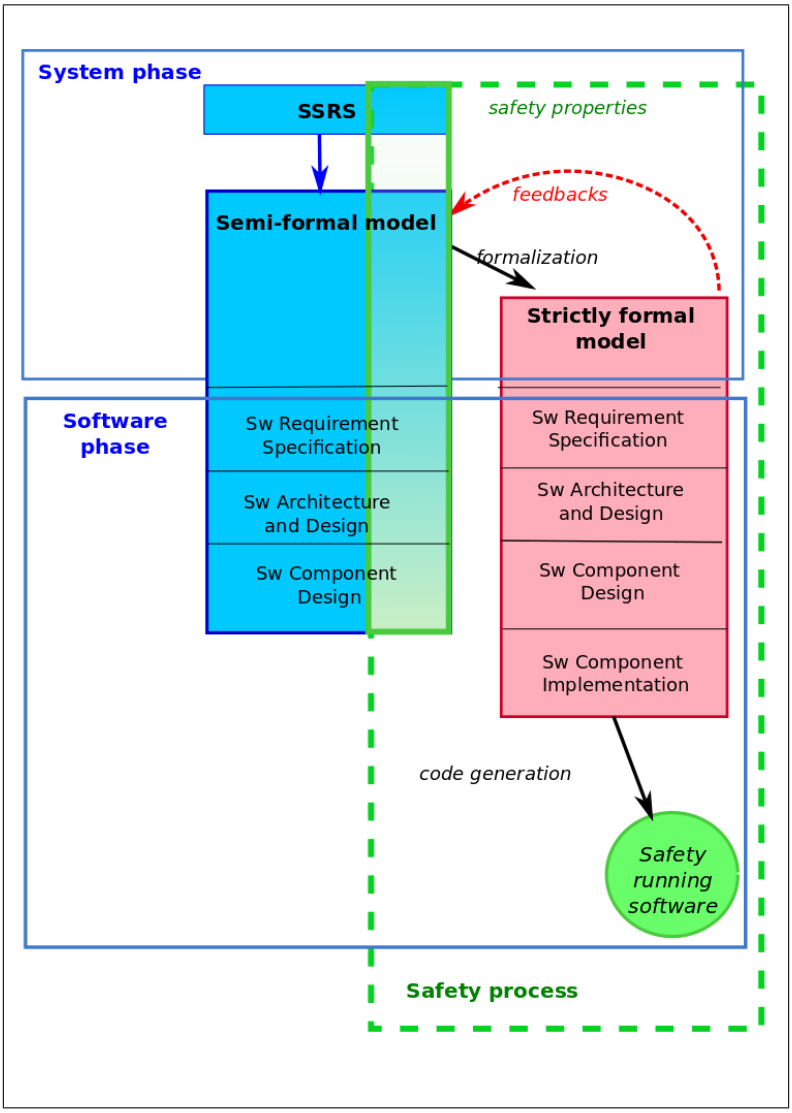

Figure 4. Software phase description

Objectives:

In this phase, the system requirements shall be refined to take into account software constraints.

The produced model shall cover the three software development phases according EN 50128 :

- Software Requirements Phase
- Software Architecture and Design Phase
- Software Component Design Phase

Documents:

From a design point of view, the outputs to produce in this phase are:

- the Software Requirements Specification
- the Software Architecture Specification

- the Software Design Specification
- the Software Interface Specification
- the Software Component Design Specification

Detailed Description:

The first step of this phase is to give an explicit description of software requirements according to system requirements and safety properties. The system architecture model from the preceding phase shall be extended with a model of the software. All software requirements shall be referenced in that model. In particular the *Software Requirement Specification* shall give a description of all the input/output of the software, as well as a description of the operational modes and behaviour. It shall provide all the elements to have testable requirements on a target platform. All functions to perform shall be clearly identified. All existing constraints between hardware and software will be taken into account (cf. §7.2.1.1 of EN 50128).

Then, a *Software Architecture Specification* shall be developed which allows meeting the software requirements and the necessary safety requirements without introducing unnecessary complexity. In this phase, there shall also be an evaluation of the Hardware / Software interaction, its influence on the safety aspects of the system and the evaluation of the usage of already existing Software. It shall also ensure the testability and the appropriateness for formal proofs of the resulting Software, in particular by minimising the complexity and the size of the safety relevant parts (cf. §7.3.1.1 to 7.3.1.5 of EN 50128).

The *Software Design Specification* shall give a description of the design choices, in particular software component decomposition, data description and requirement allocations. Interfaces between software components and the software environment are described in the *Software Interface Specification*.

Finally, the low level specification of each software components is defined in the *Software Component Design Specification* (cf. §7.4.1.1, §7.4.1.2 of EN 50128).

Means and tools

Comment. To be completed according requirement of EN50128 and D2.6 Use of formal methods to describe. To each level shall be develop the semi-formal model ?

5.9 Demonstrator

Objectives

Comment. What is the aim of the demonstrator ? to provide an executable model of the on-board unit What does that mean, Which functionalities have to be taken into account ? Which are the interfaces and API ? Does it take into account real-time, performance,... elements or just functional aspects ? What about safety ? What is the target platform ? Non safety code ?

Documents

%%input of the demonstrator : semi-formal model , at which level ?%%

Detailed Description

Open Issue. Manual versus automatic code generation ?

Means and tools

%%To detail according next meeting results%%

5.10 Concrete Code

Objectives

This code cannot be provided by the OpenETCS project : Safety activities are not conducted in the whole scope of the on-board unit subsystem, and elements of the target platform are not provided.

However, the description of how to produce such a code in a safe way is part of the OpenETCS project. This corresponds to the lower phases of the process according to E50128 :

- Software Component Implementation Phase
- Integration

Documents

According to EN50128, outputs of design for this phase are :

- Software Source Code and supporting documentation

Detailed Description

Open Issue. Manual versus automatic code generation ?

%%To detail according next meeting results%%

Means and tools

Comment. Shall be replaced by automatic code generation from formal models using refinement techniques.

5.11 Safety Activities

To respond to the goal of the OpenETCS project and to provide an environment capable to design in safety an on-board system unit, safety activities have to be planned at the beginning of the project and conducted along the process. This plan and the activities are out of the scope of this document and shall be managed in WP4.

However, as shown in figure **??**, design and safety activities require strong interactions together : safety properties shall be allocated to some functions and modelled during the design phases.

The higher level properties will be provided by the SUBSET-091 document, that we will consider here as a preliminary hazard analysis. In the scope of the subsystem, a sample of these properties are will be taken into account to show how to apply the OpenETCS process in a safety way.

%%To give a reference where is defined the scope and the subset of properties%%

5.12 Verification and Validation

Each of the system and software development phases shall have an appropriate test / validation counterpart, and thes activities have to be planned on the whole process according the requirement of EN50128 § 6.2 and 6.3.

This plan is out of the scope of the document and shall be defined in the WP4 process.

%%To add reference of WP4 deliverables%%

Comment. First requirements from VnV :

1. *Each design artifact needs a reference artifact which it implements. e.g. code to detailed model, detailed model to SRS model*
2. *The implementation relation shall be specified in detail. e.g. for state machine and a higher level state machine mapping of interfaces, states and transition is required. This includes additional invariants, input assumptions and further restrictions. This informaiton is the basis for verification activities.*
3. *The verifiability shall be incorporated within the model design. The samel applies to the code with explicit reaquirements of the standard (EN50128) to be met.*
4. *The findings from verification shall result in corrections.*
5. *Preliminary verification steps shall be performed and anticipated during model design and development.*

6 OpenETCS Case Study

%%This section is intentionally empty for the moment : %%

%%It will be completed with the results of the next meeting in Charleroi.%%

6.1 Scope of the OpenETCS Project

The EVC (European Vital Computer) is the heart of the ERTMS on-board system. This safety relevant computer implements the functions of the SRS subset 026 of UNISIG (for SRS versions beginning with baseline 3, published by ERA) in order to guarantee the safety of the train movements. The OpenETCS scope of application is related only to the EVC part of whole ERTMS system. The track-side part of the ETCS (the Radio Based Control) is excluded from the project activities, it is only considered through its interfaces with the On-Board part of ETCS.

A detailed specification of the system will be given during WP3 activities.

6.2 High Level Description of the Case Study

%%high level description of the OBU + link to reference documentation (subset 26) %%

Comment.

R-WP2/D2.3.0-X-1 *The model shall comply with all OBU ETCS mandatory requirements for ERTMS level up to 2, in the functional perimeter provided by the Functional Architecture.*

R-WP2/D2.3.0-X-1.1 *The model shall comply with the OBU part of SUBSET-26-3.3.0.*

R-WP2/D2.3.0-X-2 *The reference ETCS baseline shall be modified only by project decision, according to the QA Plan.*

R-WP2/D2.3.0-X-2.1 *All divergences with the chosen baseline shall be documented and tracked, according to the QA Plan.*

6.3 Environment and Abstract Architecture

%%high level description of the environment of the system%%

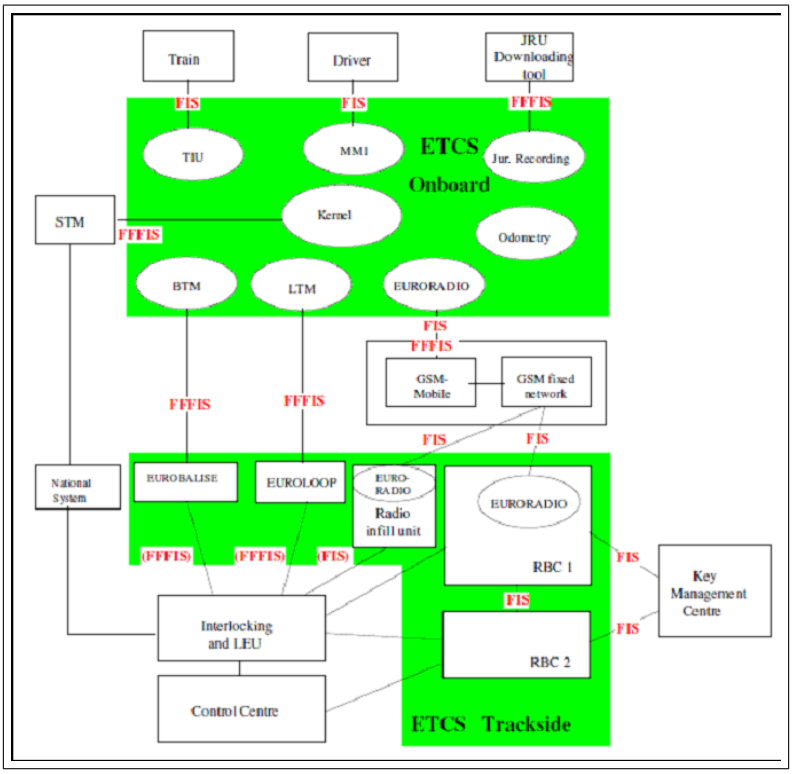

Figure 5. Architecture

6.4 Interfaces

%%high level description of the interfaces%%

6.5 Main functions

%%high level description of the main functions and data streams%%

6.6 Safety properties

%%reference document subset 091 to the list of safety properties%%

