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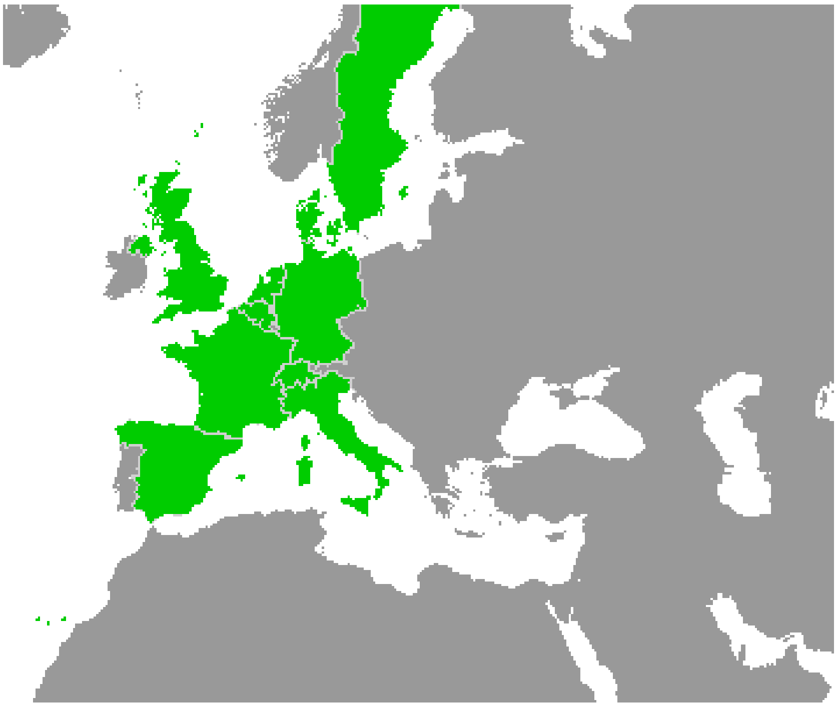
Work-Package 7: “Toolchain”

Event-B Model of Subset 026, Section 3.13

Matthias Güdemann
Systerel, France

April 2013



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Model Description

Prepared for openETCS@ITEA2 Project

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This document describes a formal model of the requirements of section 3.13 of the subset 026 of the ETCS specification 3.3.0 [Eur12]. This section describes the speed and distance monitoring subsystem of ETCS.

The model is expressed in the formal language Event-B [Abr10] and developed within the Rodin tool [Jas12]. This formalism allows an iterative modeling approach. In general, one starts with a very abstract description of the basic functionality and step-wise adds additional details until the desired level of accuracy of the model is reached. Rodin provides the necessary proof support to ensure the correctness of the refined behavior.

In this document we present an Event-B model of the speed and distance monitoring subsystem of ETCS. At first, we describe shortly the background of Event-B, then the overall approach taken to model this section and finally present the model in detail.

The section 3.13 of the SRS gives a very detailed description of the calculation of many necessary values for speed and distance monitoring. As Event-B is a system modeling approach, we give an abstract model of the system. The calculations are abstracted as functions and the system ensures the correct parameter flow to the functions. We illustrate the model decomposition capabilities of Event-B and Rodin by decomposing the overall model into different functional parts.

For a short introduction on Event-B and the usage of Rodin with models on github see https://github.com/openETCS/model-evaluation/blob/master/model/B-Systerel/Event_B/rodin-projects-github.pdf?raw=true

Table 1. Glossary

1 Modeling Strategy

The section 3.13 of the SRS describes the speed and distance monitoring together with the necessary parameters and data. The model starts with an abstract modeling of dataflow of the various intermediate calculated values. This model is partitioned into functional parts, the model is decomposed using shared variables and the respective sub-models are refined until the basic calculation functions are reached.

2 Model Overview

The overview of the speed and distance monitoring is shown in Fig. 1 from the SRS.

The on-board system comprises only the middle layer. The upper layer gives train related inputs as parameters, the lower layer track related inputs. The system itself takes the current position, speed and acceleration of the train and computes commands for the train interface and for the driver machine interface. For the train interface, this consists of the command for the service and emergency brakes. For the driver machine interface this consists of the status indication for the driver.

The Event-B modeling starts with machines describing the dataflow of all inputs, outputs and intermediate values of the model. For example, the values that are calculated for *T_brake_service* in *Traction / Braking Models* are written into a variable by an event that calculates then and these values and are read as input by the event that calculates *T_bs* for *SBI* limit.

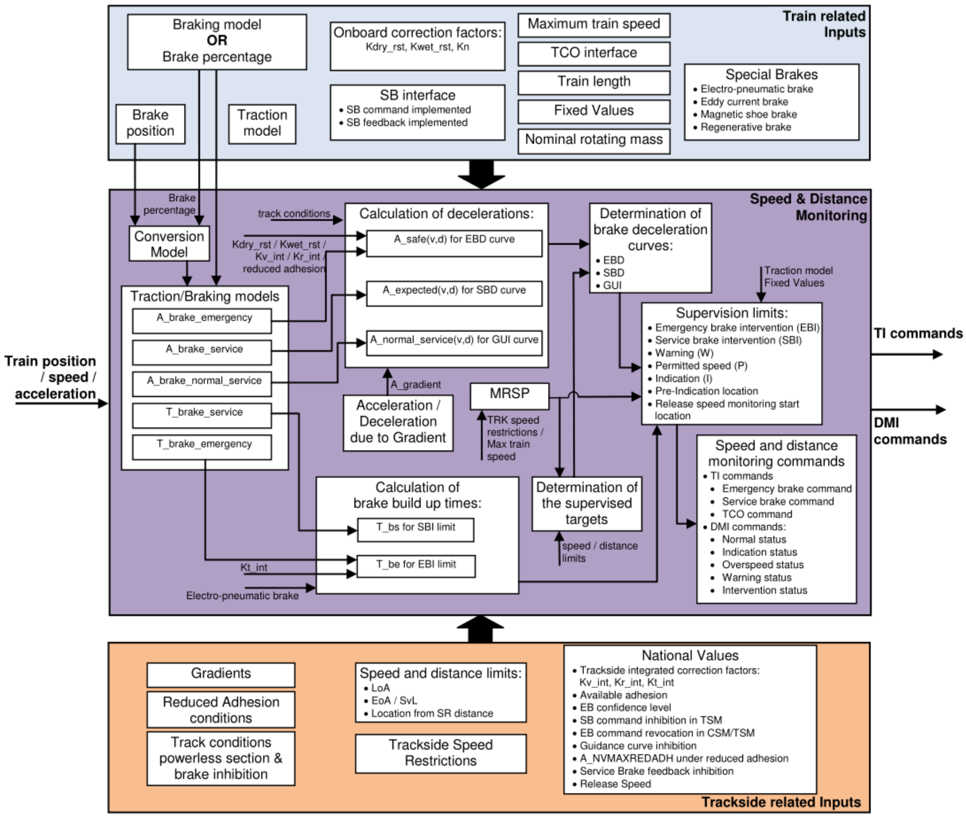

Train related Inputs
Braking model OR Brake percentage
Onboard correction factors: Kdry_rst, Kwet_rst, Kn
Maximum train speed
TCO interface
Train length
Fixed Values
Nominal rotating mass
Special Brakes
• Electro-pneumatic brake
• Eddy current brake
• Magnetic shoe brake
• Regenerative brake
SB interface
• SB command implemented
• SB feedback implemented
Brake position
Traction model
Speed & Distance Monitoring
Brake percentage
Conversion Model
track conditions
Kdry_rst / Kwet_rst / Kv_int / Kr_int / reduced adhesion
Calculation of decelerations:
A_safe(v,d) for EBD curve
A_expected(v,d) for SBD curve
A_normal_service(v,d) for GUI curve
Determination of brake deceleration curves:
• EBD
• SBD
• GUI
Traction model Fixed Values
Supervision limits:
• Emergency brake intervention (EBI)
• Service brake intervention (SBI)
• Warning (W)
• Permitted speed (P)
• Indication (I)
• Pre-Indication location
• Release speed monitoring start location
TI commands
DMI commands
Train position / speed / acceleration
Traction/Braking models
A_brake_emergency
A_brake_service
A_brake_normal_service
T_brake_service
T_brake_emergency
A_gradient
Acceleration / Deceleration due to Gradient
MRSP
TRK speed restrictions / Max train speed
Calculation of brake build up times:
T_bs for SBI limit
T_be for EBI limit
Kt_int
Electro-pneumatic brake
Determination of the supervised targets
speed / distance limits
Speed and distance monitoring commands
• TI commands
• Emergency brake command
• Service brake command
• TCO command
• DMI commands:
• Normal status
• Indication status
• Overspeed status
• Warning status
• Intervention status
Gradients
Reduced Adhesion conditions
Track conditions powerless section & brake inhibition
Speed and distance limits:
• LoA
• EoA / SvL
• Location from SR distance
Trackside Speed Restrictions
National Values
• Trackside integrated correction factors: Kv_int, Kr_int, Kt_int
• Available adhesion
• EB confidence level
• SB command inhibition in TSM
• EB command revocation in CSM/TSM
• Guidance curve inhibition
• A_NVMAXREDADH under reduced adhesion
• Service Brake feedback inhibition
• Release Speed
Trackside related Inputs

Figure 1. Speed and Distance Monitoring Overview ([Eur12] p. 85)

This approach is conducted for each intermediate value of the system until a single machine is created with one variable for each intermediate value as well as for each input and output. On this level of modeling, all events only define the necessary input values and write a new value to their output variable. This value is provided as event parameter on this abstraction level.

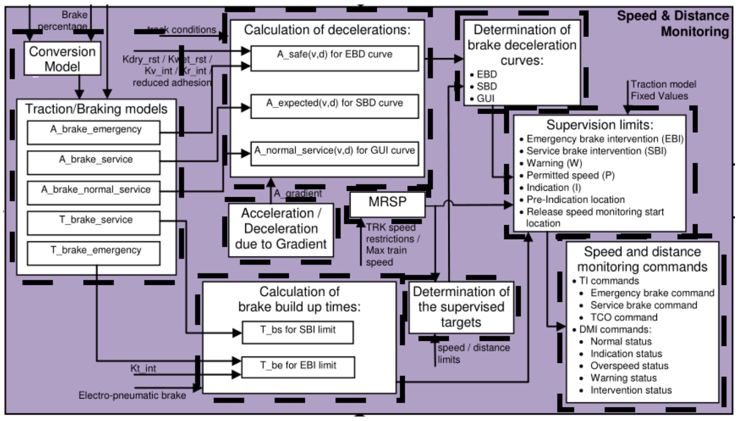
The next step is to decompose the single machine into different sub-machines, in general one machine for each functional part of the model. This allows for model structuring and complexity reduction for each machine. For this we use the Rodin decomposition plug-in [1] using the shared-variable decomposition approach [SPHB11]. This approach splits the set of events of a machine into several disjoint sets and assigns one such set to each sub-machine. It also allows to distribute the variables over several machines, effectively implementing a shared variable distributed system.

The borders for the subsystem decomposition are shown in Fig. 2. The dashed lines show the separate sub-machines. The dataflows that cross these lines are represented by the shared variables of the decomposed model.

Each of the sub-machines with its shared variables is then further refined until the desired level of detail is reached. The overview of these refinements is shown in Fig. 3.

The context hierarchy also reflects this structuring. The contexts define the data types for the intermediate values, as well as the functions that calculate these values. These functions are generally not further refined in the Event-B model, as this is not part of the system modeling.

[1] http://wiki.event-b.org/index.php/Decomposition_Plug-in_User_Guide


Speed & Distance Monitoring
Brake percentage
Conversion Model
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Kdry_rst / Kwet_rst / Kv_int / Kr_int / reduced adhesion
Traction/Braking models
A_brake_emergency
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A_brake_normal_service
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Calculation of decelerations:
A_safe(v,d) for EBD curve
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A_gradient
Acceleration / Deceleration due to Gradient
MRSP
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Determination of brake deceleration curves:
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Traction model Fixed Values
Supervision limits:
• Emergency brake intervention (EBI)
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• Permitted speed (P)
• Indication (I)
• Pre-Indication location
• Release speed monitoring start location
Speed and distance monitoring commands
• TI commands
• Emergency brake command
• Service brake command
• TCO command
• DMI commands:
• Normal status
• Indication status
• Overspeed status
• Warning status
• Intervention status
Calculation of brake build up times:
T_bs for SBI limit
T_be for EBI limit
Kt_int
Electro-pneumatic brake
Determination of the supervised targets
speed / distance limits

Figure 2. Decomposition of System

Figure 3. Machine Decomposition Overview

3 Model Benefits

The modeled section of the SRS provides many details for calculation of various values. The main content from a system modeling point of view is the model. So while in this case the same benefits from using Rodin as for [Mat13a, Mat13b] are present, the main advantage here is the model structuring facility.

- **Model Decomposition** The shared variable model decomposition [SPHB11] allows for decomposing an Event-B model and for separate refining of the machines of the resulting sub-models while retaining correctness of the refinement proofs.

4 Detailed Model Description

4.1 Context 0 - Train Inputs, TI and DMI command

CONTEXT c0_train_ti_dmi_commands
SETS

t_locations all possible locations on track
t_speed train speed measurement
t_acceleration train acceleration
t_TI_commands track interface commands
t_DMI_commands driver machine interface commands

t_time

t_train_modes

CONSTANTS

$c\_emergency\_brake$

$c\_service\_brake$

c_TCO traction cut off

$c\_no\_command$ empty command

c_normal

$c\_indication$

$c\_overspeed$

$c\_warning$

$c\_intervention$

c_v0

c_a0

c_l0

c_a_brake0

c_T_brake0

AXIOMS

axm1 : $partition(t\_TI\_commands, \{c\_no\_command\}, \{c\_emergency\_brake\}, \{c\_service\_brake\}, \{c\_TCO\})$

axm2 : $partition(t\_DMI\_commands, \{c\_normal\}, \{c\_indication\}, \{c\_overspeed\}, \{c\_warning\}, \{c\_intervention\})$

axm3 : $c\_v0 \in t\_speed$

axm4 : $c\_a0 \in t\_acceleration$

axm5 : $c\_l0 \in t\_locations$

axm6 : $c\_a\_brake0 \in t\_speed \to t\_acceleration$

default brake profile

axm7 : $c\_T\_brake0 \in t\_time$

default brake buildup time

END

4.2 Machine 0 - Basic Communication

Implemented Requirements

- each session allows for communication between two entities (cf. §3.5.2.1)

References

[Abr10] Jean-Raymond Abrial. *Modeling in Event-B - System and Software Engineering*. Cambridge University Press, 2010.

[Eur12] European Railway Agency (ERA). System Requirements Specification - ETCS Subset 026. http://www.era.europa.eu/Document-Register/Documents/Index00426.zip, 2012.

[Jas12] Michael Jastram, editor. *Rodin User's Handbook*. DEPLOY Project, 2012.

[Mat13a] Matthias Güdemann. Event-B Model of Subset 026, Section 3.5, 2013.

[Mat13b] Matthias Güdemann. Event-B Model of Subset 026, Section 4.6, 2013.

[SPHB11] Renato Silva, Carine Pascal, Thai Son Hoang, and Michael Butler. Decomposition tool for event-b. *Software: Practice and Experience*, 41(2):199–208, 2011.