Digitalization and automation for driverless regional trains: The *safe.trAIn* research project

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Federal Ministry for Economic Affairs and Climate Action

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safe·trAIn

Motivation and Context

Potential of digitalization and artificial intelligence for central aspects of rail transport

Tremendous pressure to **significantly reduce CO_2 emissions** in transport (the transport sector is expected to reduce its emissions by 40 to 42% compared to 1990 to 98 to 95 million tons of CO2 in 2030

see https://www.bundesfinanzministerium.de/Content/DE/Standardartikel/Themen/Schlaglichter/Klimaschutz/2019-09-20-Eckpunkte-Klimaschutz-Download.pdf?__blob=publicationFile&v=5

Rail capacity

Flexibility and comfort for the passenger

Cost efficiency

Availability

Steps in the introduction of highly and fully automated driving

Manual operation Supervision by driver	Highly automatic operation Limited driver action	Fully automatic operation No supervision by driver	
GoA 1 Manual train operation with driver Supervision and control train operation (SCO)	**GoA 2** Automatic train operation with driver Semi-automated train operation (STO)	**GoA 3** Automatic train operation without driver Driverless train operation (DTO)	**GoA 4** Automatic train operation without staff Unattended train operation (UTO)
Provision of driving recommendations for energy-optimized train runs			
Driver drives completely manually	Automatic train operation after driver interaction	Automatic train operation	
Obstruction detection by driver		Automatic obstruction detection (obstacle detection, platform protection)	
Manual train dispatching by driver or train attendant			Central or automatic train dispatching
Train monitoring and intervention in emergency situations by driver or train attendant			Central monitoring or automation functions for handling of train disturbances and emergency situations

GoA Grade of Automation

Potential of “Fully Automated Operation”

Automatic obstacle and hazard detection as well as the reduction of unproductive times (paths from the train driver (TF) to and from the vehicle)

Densification of the timetable, e.g., by splitting vehicles that would otherwise run in multiple traction or additional connections in off-peak times

Increased flexibility in timetable design

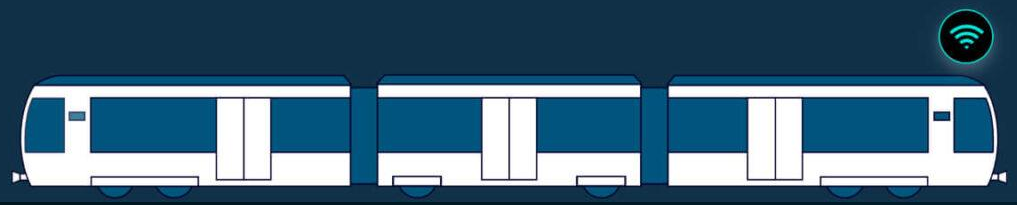
Faster achievement of normal operation in the event of malfunctions, as replacement vehicles are provided more rapidly

Metro Traffic

- One operator for infastructure and trains
- Passenger transport only
- Identical trains with similar properties
- Simple infastructure closed and access restricted
- Integrated systems - complete solution from one manufacturer

Mainline

- One operator for infastructure and trains
- Mixed transport i.e. regional, express & freight transport
- Different trains with different properties
- Very complex infastructure open and publicly accessible
- Network-wide interoperability - signal solutions from different manufacturers



Automation in the Railway Domain

Narrow/ constrained | Somewhat constrained | Wide/ unconstrained

ODD[2]

GoA[1]

0/1


Metro Berlin


High-speed: PZB/LZB/ETCS


Commute: PZB/LZB/ETCS


Siemens Tram Assist


BOStrab Tram Operation: “Driving by sight

2


Metro Munich


Thameslink ATO over ETCS

No product available today – R&D

3


Metro Sofia CBTC


London Docklands LRT


Mireo2021


Alstom “Real-labor” BS


Thales R&D

4


U-Bahn Nürnberg Dirverless


Metro Paris CBTC


Rio Tinto AutoHaul Australia: ATO over ETCS


Depot: AStriD


Shunting


Highly automated Commute: BerDiBa


AST Demonstrator

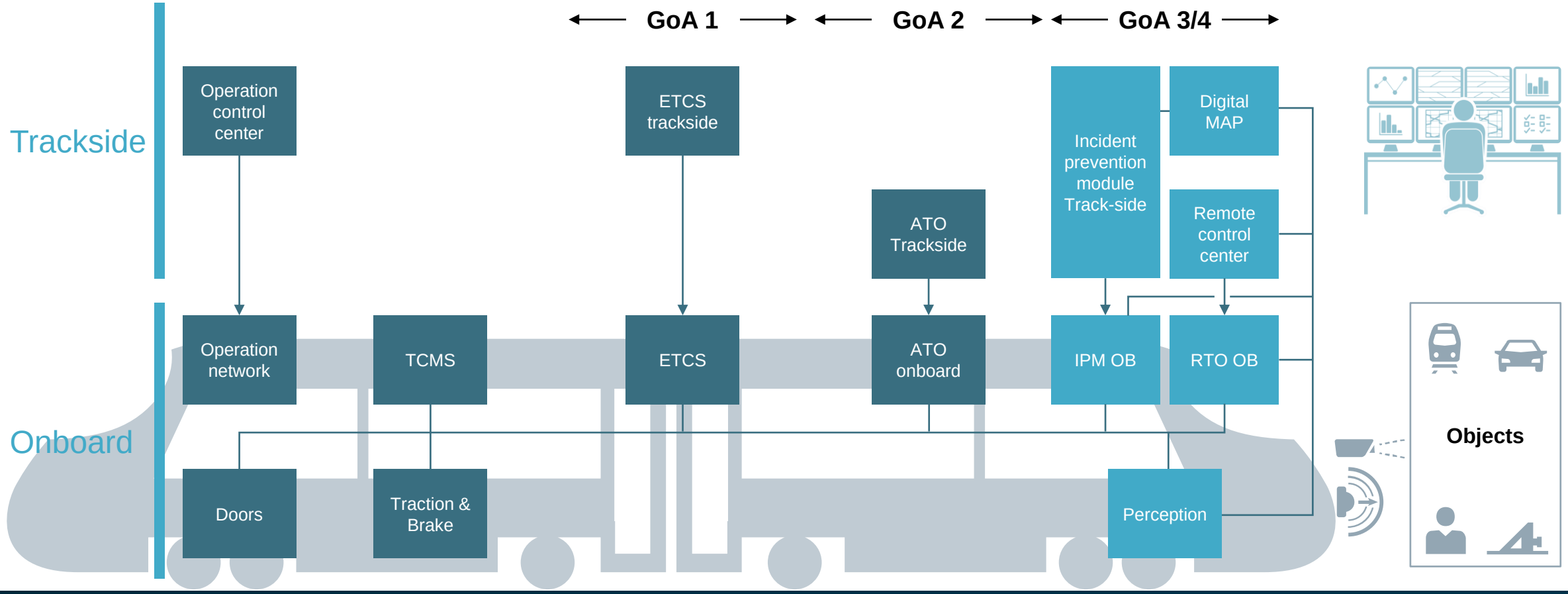
Less

Technical Challenge

More

1 GoA = Grade of Automation (IEC 62290) | **2** ODD = Operational Design Domain = Operation conditions under which an autonomous system is specifically designed to function

Establishment of a system for GoA 3/4 operation



Technical key challenge: Obstacle/object detection in a natural environment

Up to GoA 2 components Added components for GoA 3/4

Getting approval for a perception system is challenging!
Obstacle detection/AI

According to the current state of the art, we assume that e.g., obstacle detection can only be implemented using the methods of ML (Machine Learning – a field of AI Artificial Intelligence).

Legislation

New: European AI ACT- high-risk application

Transparency

High-perfor-mance systems are highly intrans-parent

Processes und tools

No established tools and processes

New error domain in assessment

Requirements for assessment

Unclear regarding trans-parency, robustness

Research regarding transparency

Extensive research with little progress

Examples

Project Objectives

Integrated Development

…of guidelines and methods for the safety assurance of artificial intelligence in autonomous regional trains by the development

A Safe AI-based functions for a driverless regional train

B Method to enable the assurance of AI-based functions in terms of safety

C Guidelines and concepts to enable certification of AI-based functions in the railway domain

Proof

Of the feasibility of the guidelines and methods with a real case study

Related Projects

safe.trAIn takes up the results of current research and development activities and develops them further

Rail

Shift2Rail (Partner: DB, SNCF, Alstorm, CAF, …)

- X2Rail, LYnx4Rail, Connecta
  - Conceptual development for GoA2-GoA4
- Tauro
  - Concepts for a future automated and autonomous European railway traffic

BerDiBa

- Digital twin for railway operations; Environment detection and obstacle detection in the railway domain using AI methods
- Participation of SMO in the consortium with TU Berlin (BBI)/DLR/DB Systemtechnik

ATO-Sense & ATO-Risk

- Development of a safety approach for automated rail vehicles

Automotive

KI-Absicherung:

- Methods to improve the performance of ML-based safety-critical functions (e.g., pedestrian detection)
- Generic strategies for deriving detailed acceptance criteria for ML-based automation function in cars
- Some methods can be transferred to safe.trAIn
- Knowledge transfer through joint project partners (Fraunhofer IAIS/IKS, Merantix Momentum, BIT Technology)

Planned Exploitation

Commercial Utilization

Automation solutions for the highly automated and driverless operation of rail vehicles

- Siemens collaborates closely with the railway companies DB and SNCF at EU level as part of Shift2Rail
- Development of tools for the development and validation of AI-based functions in the environment of safety-critical systems

Standardization

Safe.trAIn provides important contributions to current standardization activities

- **AI related standards:** ISO/IEC JTC 1/SC 42, ISO/TC 204, CEN/CENELEC JTC 21
- **Railway standards:** CLC/TC9X, IEC/TC9 with **EN50126, EN50657, EN50129**, TSI CCS 2022 of the ERA for offering rail vehicles on the market within Europe (CSM-RA)
- DIN VDE SPEC

- ISO/IEC TR 24028
- VDE-AR-E 2842-61
- DIN SPEC 92001
- ISO/IEC 20547
- ISO/IEC JTC 1/SC42
- DIN SPEC 13266
- DIN SPEC 13288
- UL4600
- ISO41228

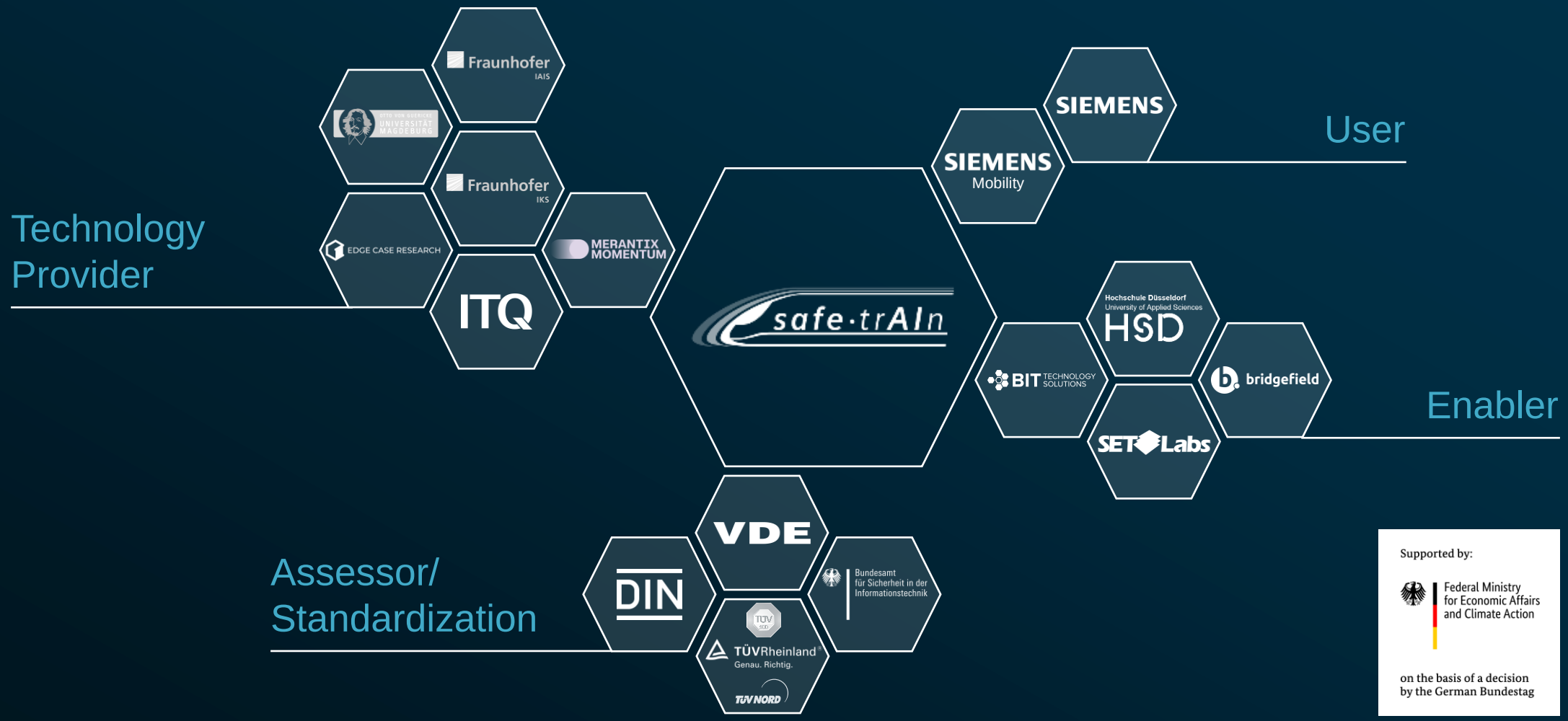
Safe.trAIn project

Standardization
- ISO/IEC JTC 1/SC 42
- ISO/TC 204
- CEN/CENELEC JTC 21
- CLC/TC9X
- IEC/TC9
- TSI CCS 2022

Tools for the development and validation of AI-based functions

Automation solutions for the highly automated and driverless operation of regional trains

Consortium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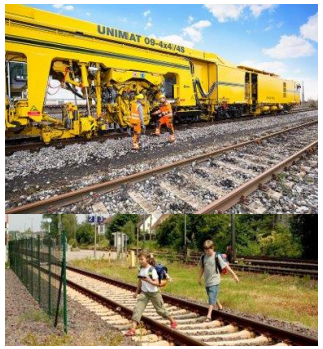
Obstacle detection task in safe.trAIn

Passenger in train

Person on track



Safety objectives

The obstacle detection system will prevent harm from passengers in the vehicle and persons on the track

The obstacle detection system will detect heavy obstacles on the tracks, a collision with which can potentially cause injuries and fatalities for **passengers in the train**

Heavy obstacles include, but are not limited to trees, rocks, cars, trucks, other trains, flooding, landslide…

Current safety objective of the rail operation acc. to german regulations (e. g. DB RIL 408.2341) The driver has to prevent harm from the train.

The obstacle detection system will detect persons on the tracks, a collision with which can potentially cause injuries and fatalities for the **person on the track**

Persons on the track include, but are not limited to workers, trespassers, playing kids, ...

Probably needed for public acceptence of driverless train operation.

Further aspects to consider

Action
Stopping vs. braking vs. honking

Collision
Obstacle in-gauge vs. off-gauge vs. neighboring track

Track context
Free track vs. station-starting vs. station-approaching vs. level crossing

…

Project goals – with main focus

Requirements

Project management

Standardization and dissemination

Methods to prove trustworthiness of AI-based functions

GoA 4 train architecture incorporating safe, AI-based functions

Virtual V&V platform, safety assessment

WP 2: Overview/Preliminary Results

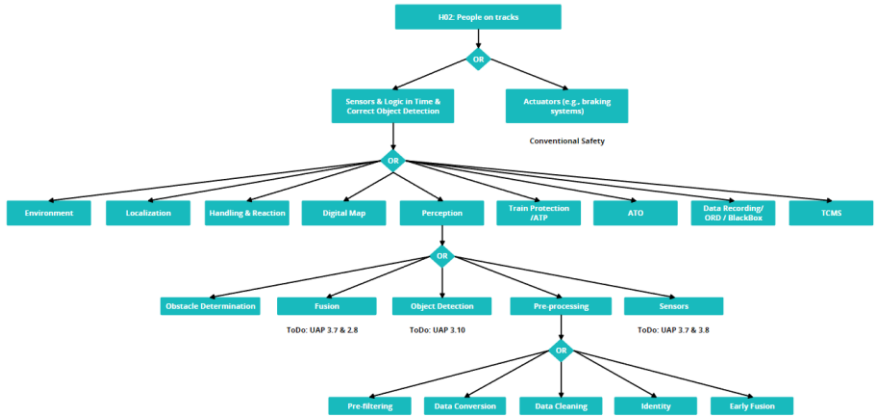
WP 2: Methods to prove trustworthiness of AI-based Functions

Goal:

Development of methods to ensure and verify the trustworthiness of AI functions, optimized for the use case of a driverless regional train and the criteria which need to be fulfilled for the safety assessment

- State-of-the-art analysis focused on different aspects of safety assurance methods for DNN
- Sub-work packages tackling the different aspects of safety assurance methodology for DNN
- Current key activities
  - Fault tree analysis based on the system architecture
  - Identifying possible Insufficiencies in the ML-Based Systems
  - Selecting & implementing metrics for argumentation on compensating these insufficiencies

Fault Tree Analysis



Identify ML-Insufficiencies

- Lack of performance
- Lack of robustness
- Lack of scenario coverage
- Etc. …

Compensating Insufficiencies

- Performance metric
- Robustness metric
- Scenario coverage metric
- Transparency metric
- Etc. …

Work package 3: Overview/Preliminary Results

WP 3: Safety architecture for AI based functions of driverless regional train operation

Goal:

Development of integrated requirements and architecture incl. safety case for an AI based obstacle detection system of a driverless regional train

Requirements

- Definition of requirements for a driverless train operation (incl. safety requirements)
- Definition of an AI based obstacle detection system of a driverless train (incl. safety requirements)
- Definition of ODD

First draft of requirements

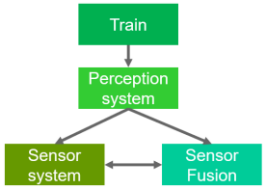
Challenge: Transfer qualitative requirements (derived from the performance of a driver) to measurable requirements for a system (What is hazardous?)

Architecture

Development of an architecture for an AI based obstacle detection system of a driverless train

- Architecture for:
- Vehicle
- Obstacle detection system
- Sensor fusion
- Sensor system

First draft of architecture with definition of interfaces between the building blocks



Implementation

- Development of a hardware prototype for the sensor system

and

- Implementation of a safe obstacle detection system incl. safe sensor fusion and ML-functions

- Definition of camera criteria
- Testing of the impact of external conditions on the camera calibration

Safety

Definition of a safety case for the architecture of a driverless regional train

First draft of safety case concept

Challenge: Converge safety argumentation and safety architecture

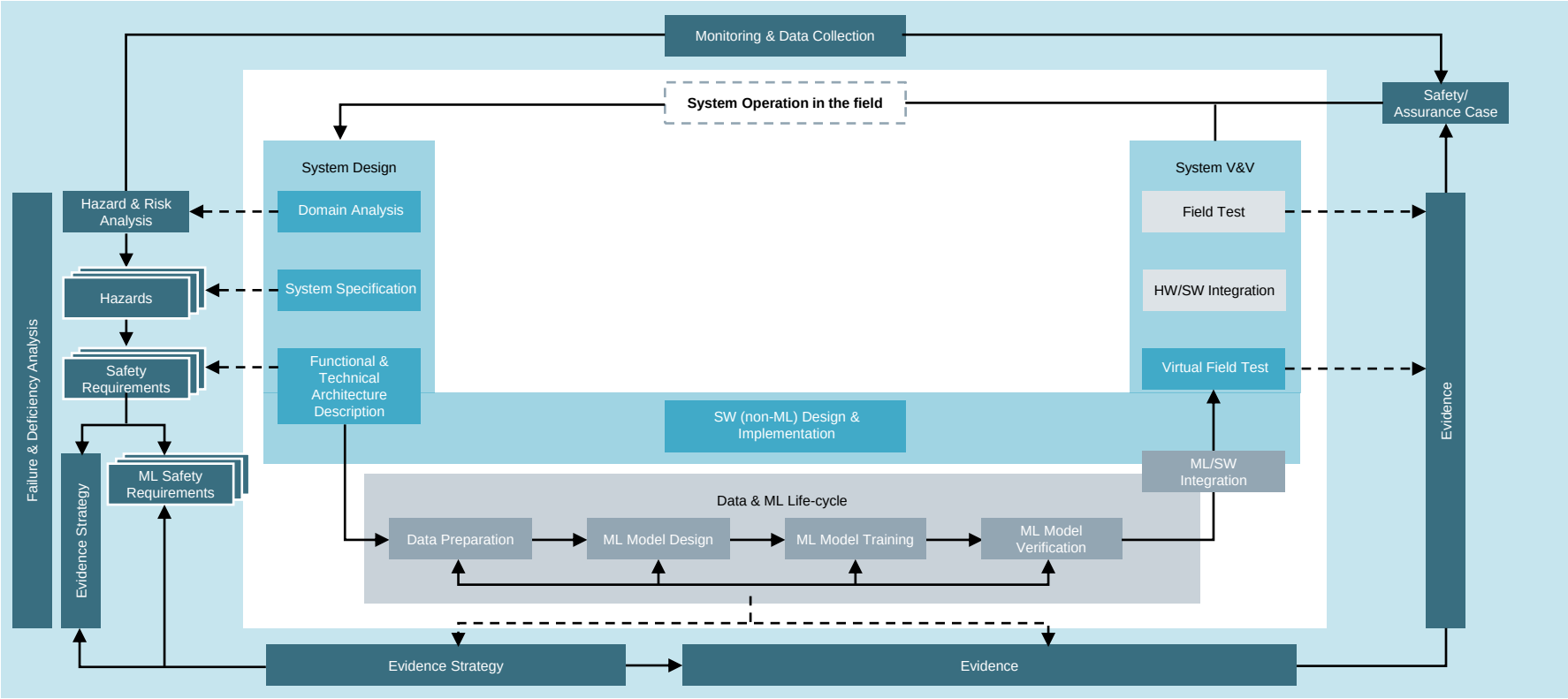
Work package 4: Overview/Preliminary Results

WP 4: Virtual V&V Platform, Safety Assessment

Goal: Development of a virtual V&V platform ("virtual test field") to evaluate the project results and to create and assess a safety case using the object detection of a driverless regional train as a case study

First Results

- Definition of a SafeMLOps process for autonomous regional trains
- Specification of a simulation-based "virtual test field" to create evidences for the safety case
- Creation of first test scenarios und setup of a tool-chain to create synthetic test data as input for the virtual test field



System engineering | ML Life-Cycle | Safety engineering | Out of scope in safe.trAIn

Questions?

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