OPENPASS

THOMAS PLATZER, BMW
24.10.2022

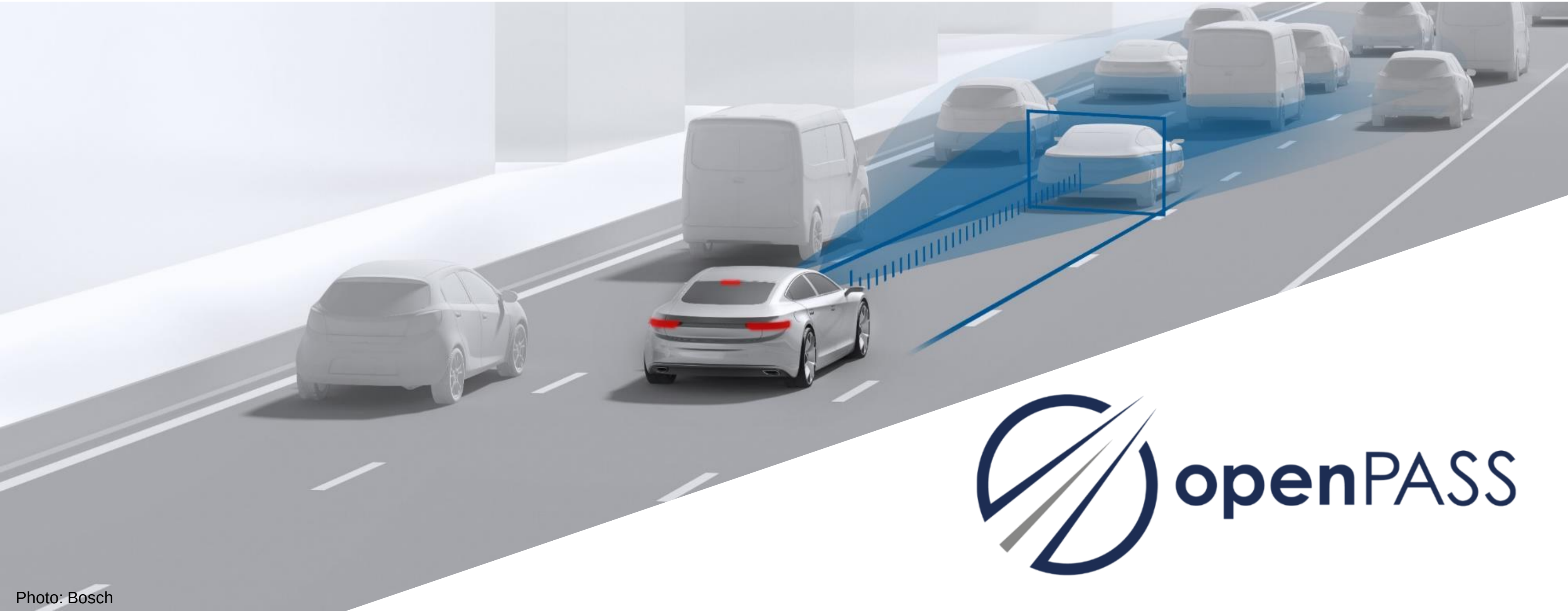

Photo: Bosch

SET Level

Simulation-based Engineering and Testing of Automated Driving

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

PROJECT of the PEGASUS FAMILY

Development and Usage of openPASS within SET Level

Simulation Use Case 1 – Closed-Loop Traffic Simulation for Criticality Analysis

24.10.2022

Simulation Use Case 1 – Traffic Simulation

History of the SET Level Project

The **PEGASUS Family** focuses on development / testing methods and tools for AD systems on highways and in urban environments

PEGASUS

https://www.pegasusprojekt.de/en/home

- Scope: **Basic methodological framework**
- Use-Case: L3/4 on highways
- Partners: 17

PEGASUS FAMILY

VV-Methods

VERIFICATION VALIDATION METHODS

- Scope: **Methods, toolchains, specifications for technical assurance**
- Use-Case: L3/4/5 in urban environments
- Partners: 23
- Timeline: 07/2019 – 06/2023

SET Level

- Scope: **Simulation platform, toolchains, definitions for simulation-based testing**
- Use-Case: L3/4/5 in urban environments
- Partners: 20
- Timeline: 03/2019 – 10/2022

+ future projects of the PEGASUS Family

2016

2019

Time

Simulation Use Case 1 – Traffic Simulation

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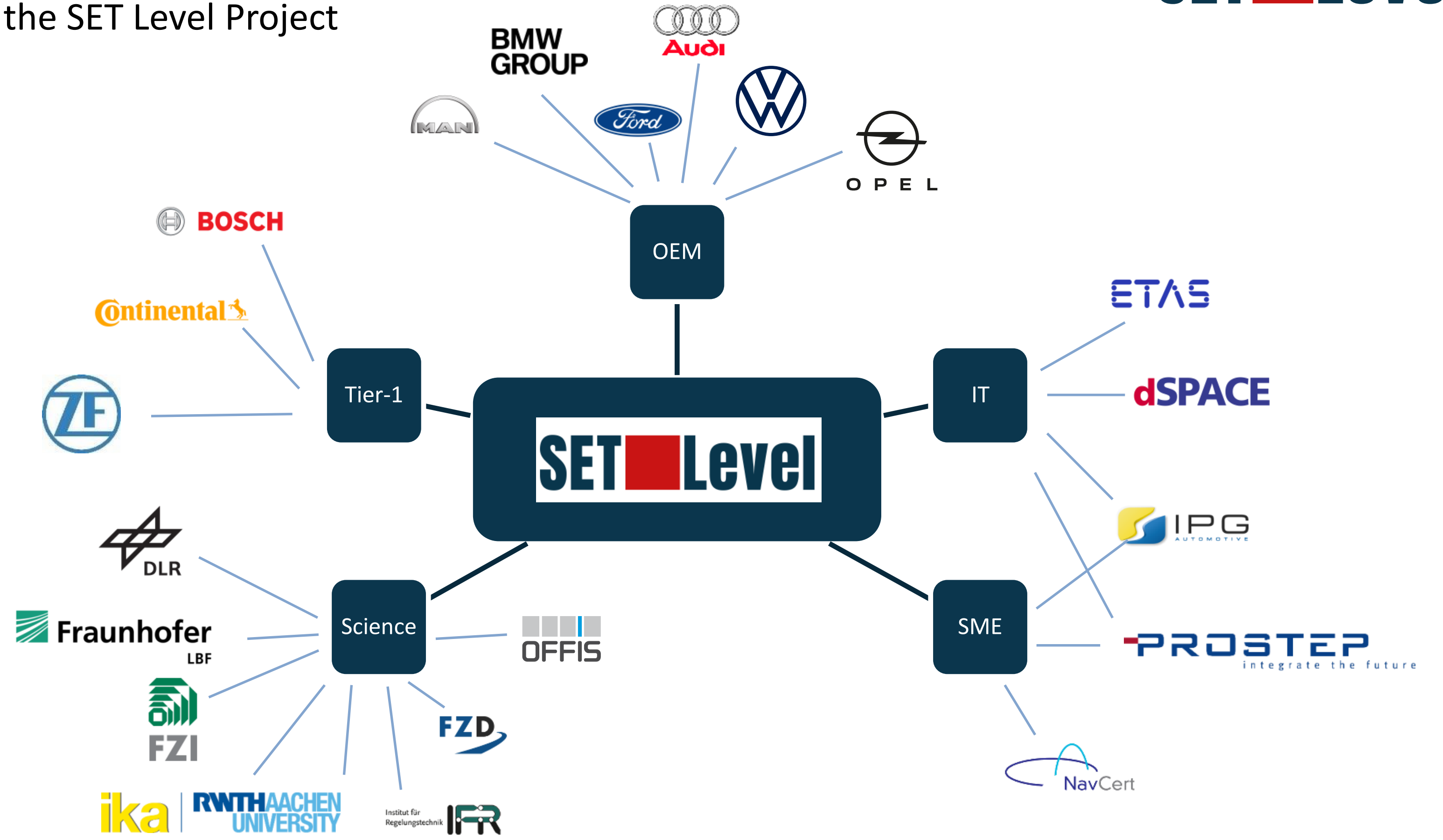
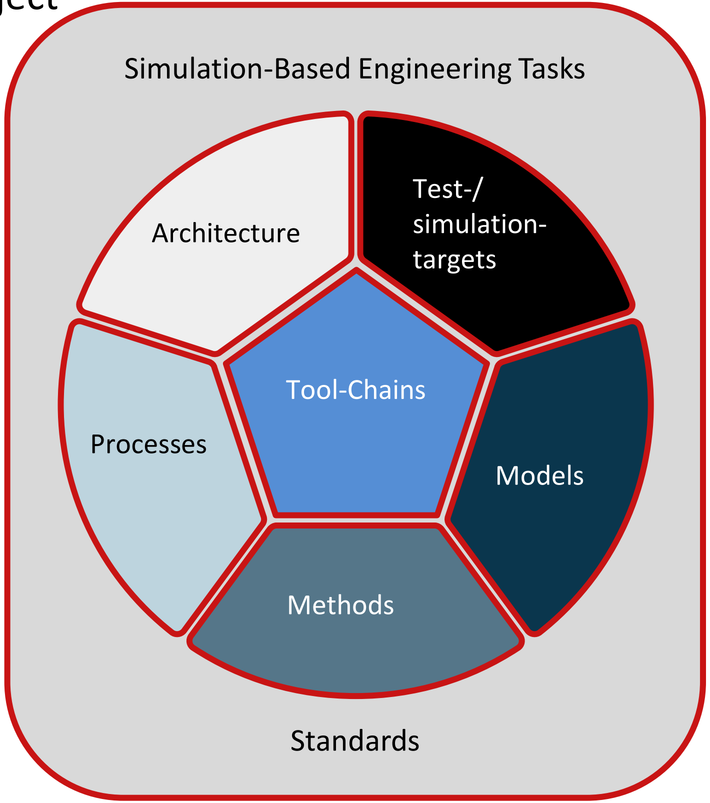
Partners of the SET Level Project



Simulation Use Case 1 – Traffic Simulation

Framework of the SET Level Project

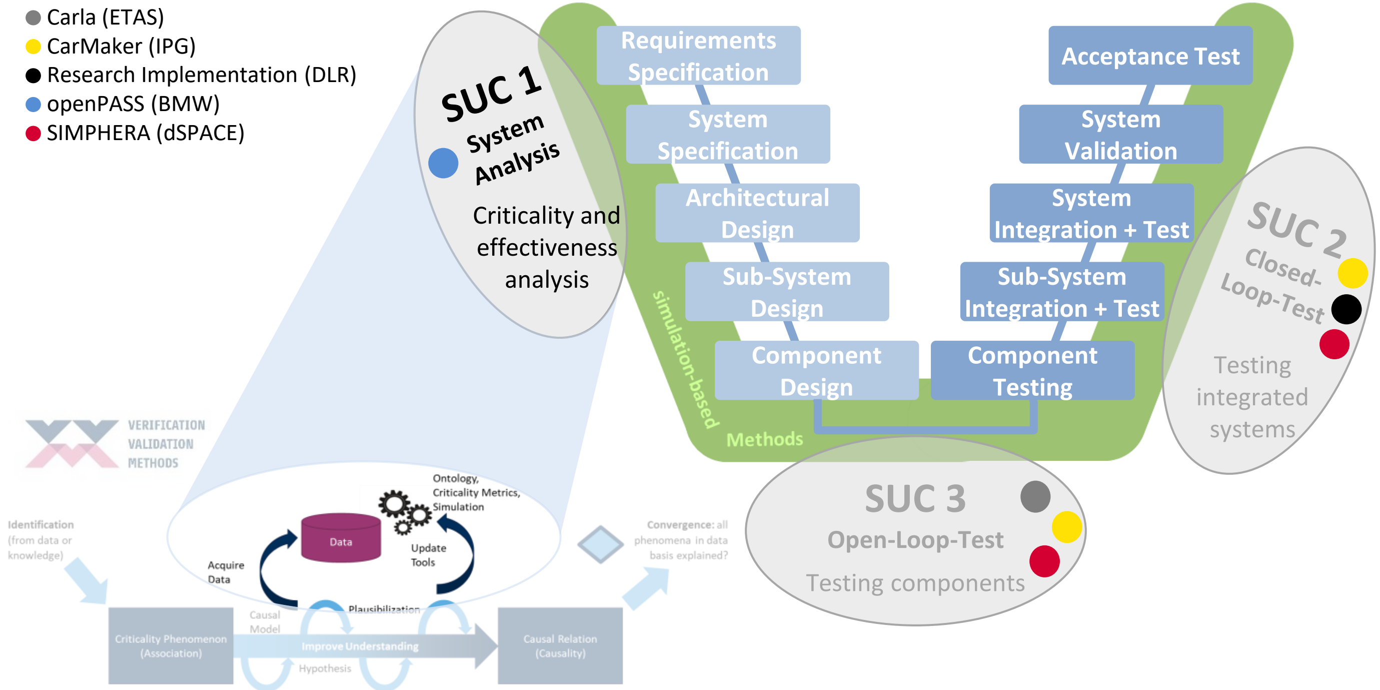


Simulation Use Case 1 – Traffic Simulation

Overview and Methodology

We focus on the simulation part of the **criticality analysis**, i.e. the data driven method (according to VV Methods).

Applied Tools:
- Carla (ETAS)
- CarMaker (IPG)
- Research Implementation (DLR)
- openPASS (BMW)
- SIMPHERA (dSPACE)



Criticality Analysis – Basic Concept (VV Methods, TP2)

Demonstration Goals of SUC 1:
- Specification and execution of analysis tasks
- Usage of the credible simulation process and assurance of traceability
- Implementation of appropriate architectures and interfaces
- Demonstration of applicability and usability of standards (OSI, FMI, SSP, …)
- Variation of traffic scenarios for exploration of scenario spaces
- Evaluation of criticality using corresponding metrics and KPIs
- Provide project internal feedback and identify needs for further work

Simulation Use Case 1 – Traffic Simulation

Map and Scenario

Simulation Goal:

- **„Identify critical scenarios during a left turn on a multi-lane urban crossing through simulation."**
- Left turn is chosen as it may contain several risks that can lead to a critical coincidence (oncoming traffic and crossing pedestrians).

Map Setup (Research Crossing in Brunswick):

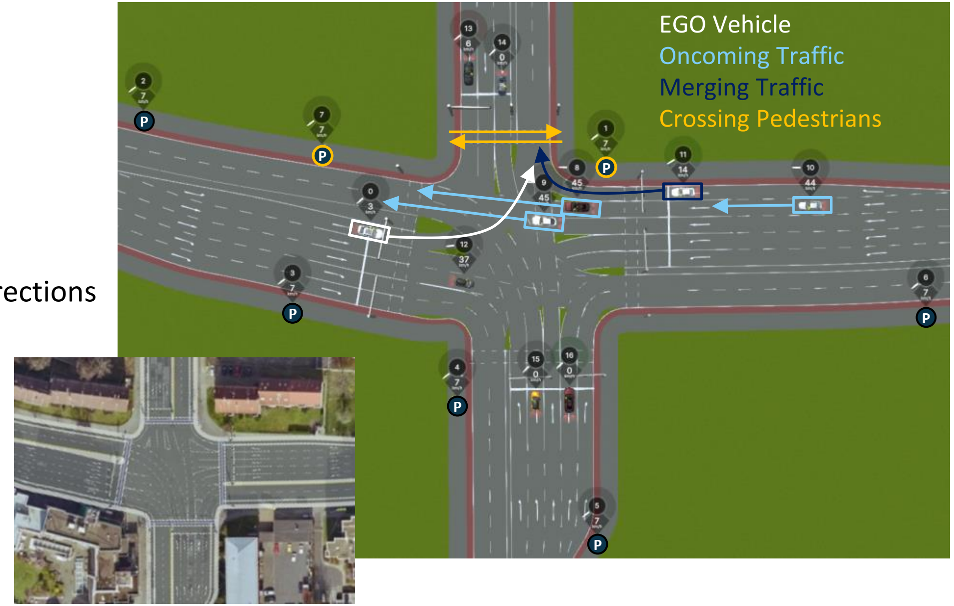
- Complex crossing, controlled via traffic lights
- Several lanes per driving direction
- Further traffic infrastructure (e. g. parking lots)

Scenario Setup (Left Turn at Research Crossing):

- EGO vehicle with automated driving function
- **9 surrounding vehicles** with predefined destinations from all directions
  4 of these surrounding vehicles are **oncoming**
- **7 pedestrians** with predefined destinations
  2 of these pedestrians have to **cross the street**

Evaluation (Two Criticality Metrics):

- Time-To-Collision (**TTC**)
- Post-Encroachment-Time (**PET**)



Outlook: The specified setup for this criticality analysis can also be used for evaluating the performance of ADAS or AD.

Simulation Use Case 1 – Traffic Simulation

Tool Requirements

SET Level

Technical Challenges:

- Description of the whole scenario space by using a logical scenario with several parameter distributions
- Implementation of this logical scenario by using stochastics to build up concrete scenarios
- Simulation on a complex urban crossing
- Programming of a comprehensive traffic light controller
- Integration and execution of many extensive models
- Simulation of numerous concrete scenarios with multiple real time
- Evaluation of all successful simulations

SET Level Simulation Models

- Camera Sensor
- HAD Function
- Motion Control
- Vehicle Dynamics
- Driver Model
- Pedestrian Model

visit → B1-7

Stochastic Variation

Functional Scenario → **Logical Scenario** → (Parameter sampling) → **Concrete Scenario** → (Simulation input) → **SUC 1 Simulation**

Functional Scenario: Abstract description of the scenario

„Left turning ego agent on a multi-lane urban crossing. Surrounding traffic and pedestrians…“

Logical Scenario: Formal scenario description with specification of parameter distributions

```
<parameter name="$Ego_Spawn_Position_X" unit="m" type="continuous">
    <distribution>
        <normalDistribution mean="60.0"
                            standardDev="7.0"
                            lowerLimit="35.0"
                            upperLimit="82.0"/>
    </distribution>
</parameter>
```

Concrete Scenario: Formal scenario description with fixed parameter values

```
<ParameterDeclaration name="$Ego_Spawn_Position_X"
<ParameterDeclaration name="$Ego_Spawn_Position_X"
<ParameterDeclaration name="$Ego_Spawn_Position_X"
                      parameterType="double"
                      value="63.7"/>
```

SUC 1 Simulation

- Specification of stochastic and deterministic variations
- Definition of limits (truncated distributions)

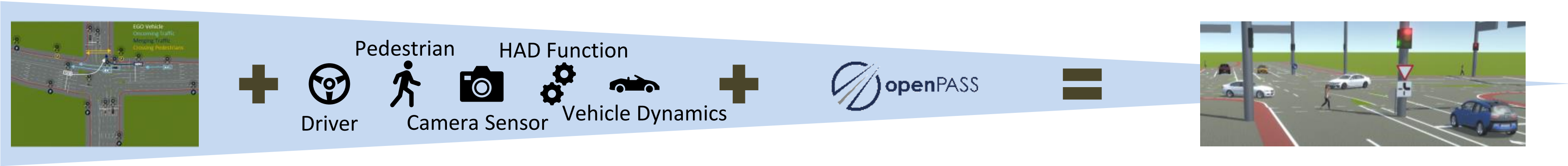
→ Input for OpenSCENARIO 1.1

Stochastic variation of initial position

Simulation Use Case 1 – Traffic Simulation

Architecture, Standards and Model Integration

Challenge: Set up and execute a traffic scenario with a bunch of delivered simulation models



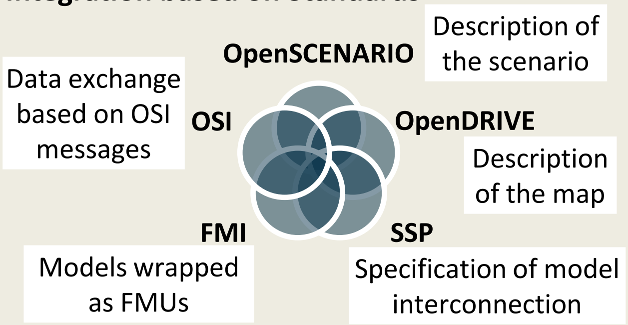
Map and Scenario
- Complex crossing
- Traffic lights
- Surrounding traffic

Simulation Models
- Delivered from different partners
- Data exchange based on OSI
- Models wrapped as FMUs

Simulation Tool
- Open source available
- Wide support for standards
- Suited for stochastic simulation

Traffic Simulation

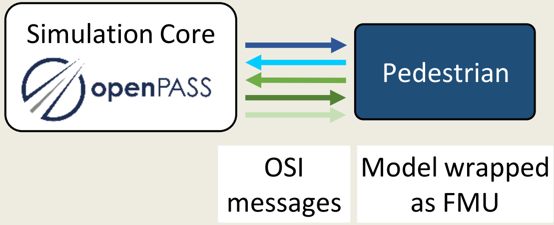
Integration based on Standards



Core fields of application for standards
- Simulation configuration (map, scenario)
- Specification of parameter variation
- Programming interfaces
- Data exchange

Contribution to standardization projects
- Utilization of existing standards
- Development of further extensions
- Contribution to standardization projects

Example: Coupling with Pedestrian Model



OSI = Open Simulation Interface; FMI = Functional Mockup Interface; SSP = System Structure and Parameterization

Simulation Use Case 1 – Traffic Simulation

Architecture, Standards and Model Integration

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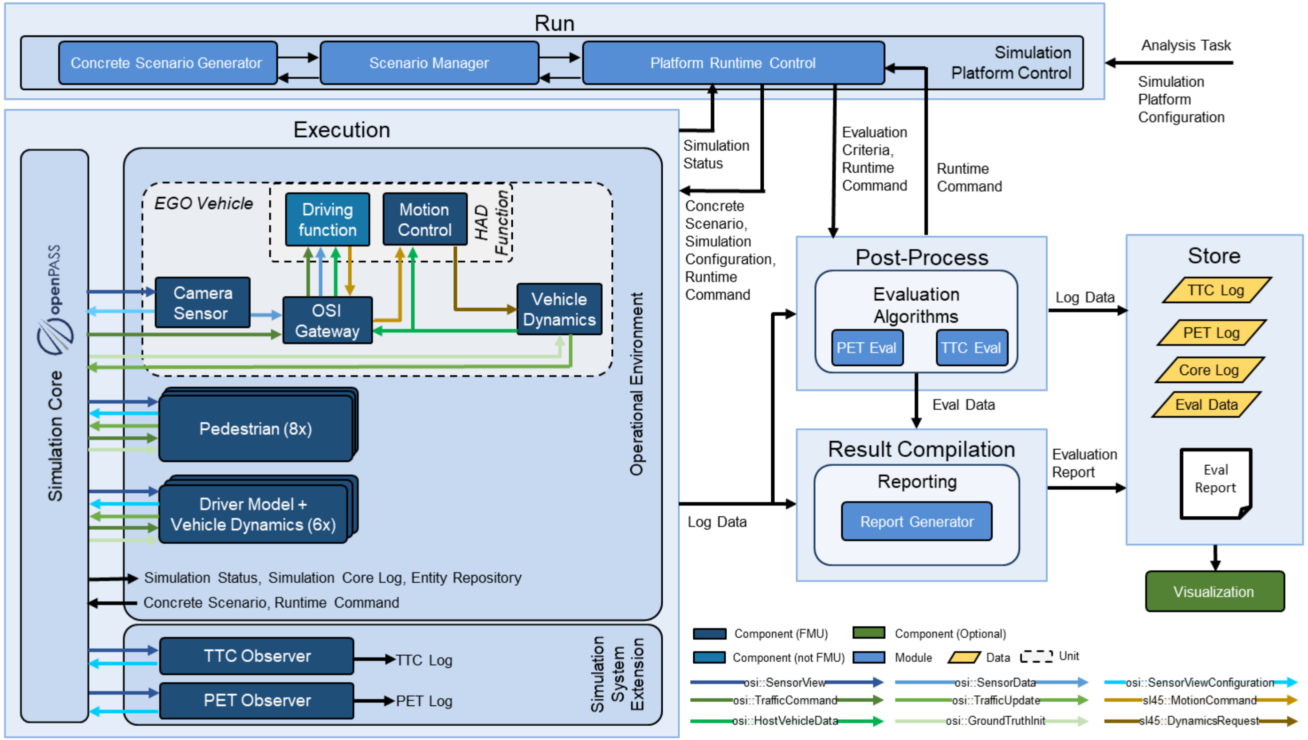
Challenge: Enable the execution of multiple concrete scenarios generated from one logical scenario



- Orchestration of simulations through Simulation Platform Control implemented in Python
- Open source tool openPASS serves as simulation core
- Modular approach utilizing standards to achieve high level of decoupling and exchangeability
- Simulation models are wrapped as FMUs and communicate through OSI messages
- Driving function runs as a ROS node in a Docker container

Simulation Use Case 1 – Traffic Simulation

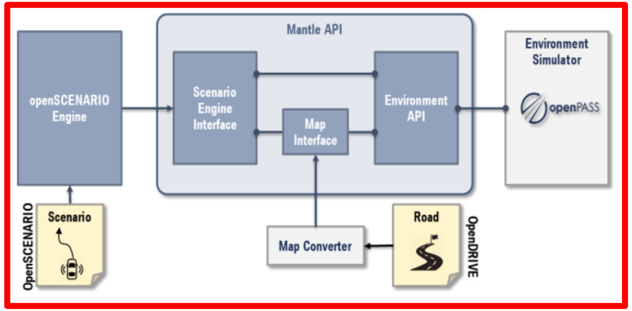
YASE – Yet Another / Agnostic Scenario Engine

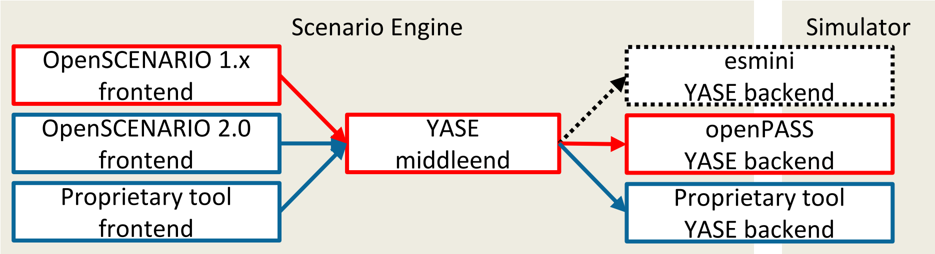
Challenge: Enable the execution of different scenario formats on different simulator backends

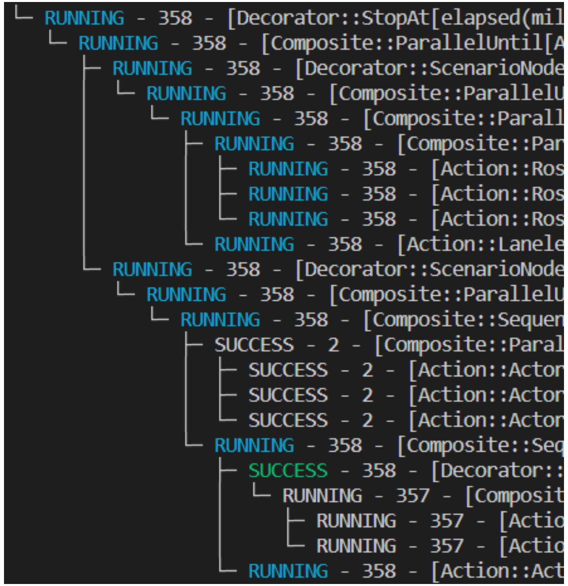
Solution: Open source agnostic C++ framework (YASE) connecting different scenario language formats with different simulators

Outlook: Connect more simulator backends with scenario frontends

- **SUC 1 Example:**
  Execution of OSC1.x in openPASS via Mantle API
- **Second Example Use Case:**
  Execution of OSC2.0 and proprietary scenario language in a proprietary tool

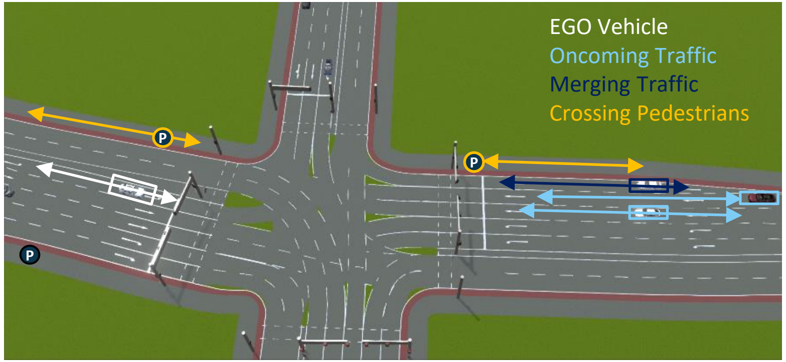


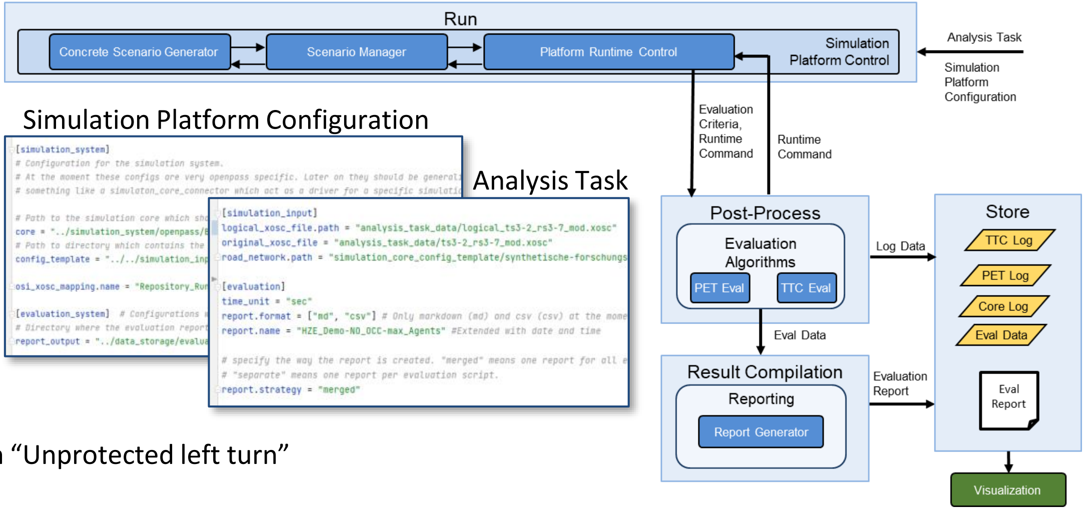




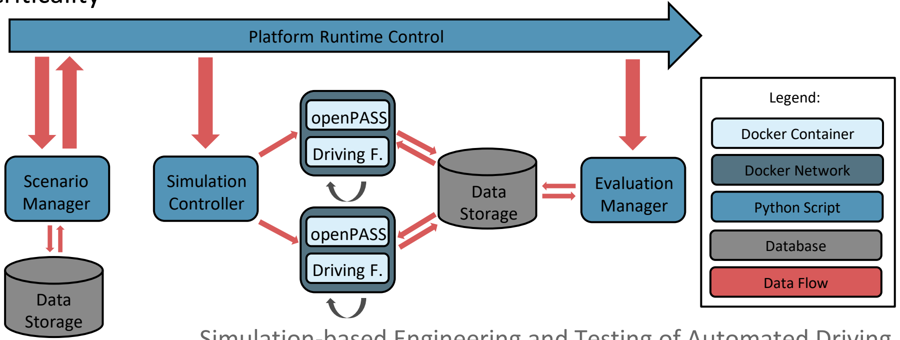
Simulation Design

Preparation and Design of the Analysis



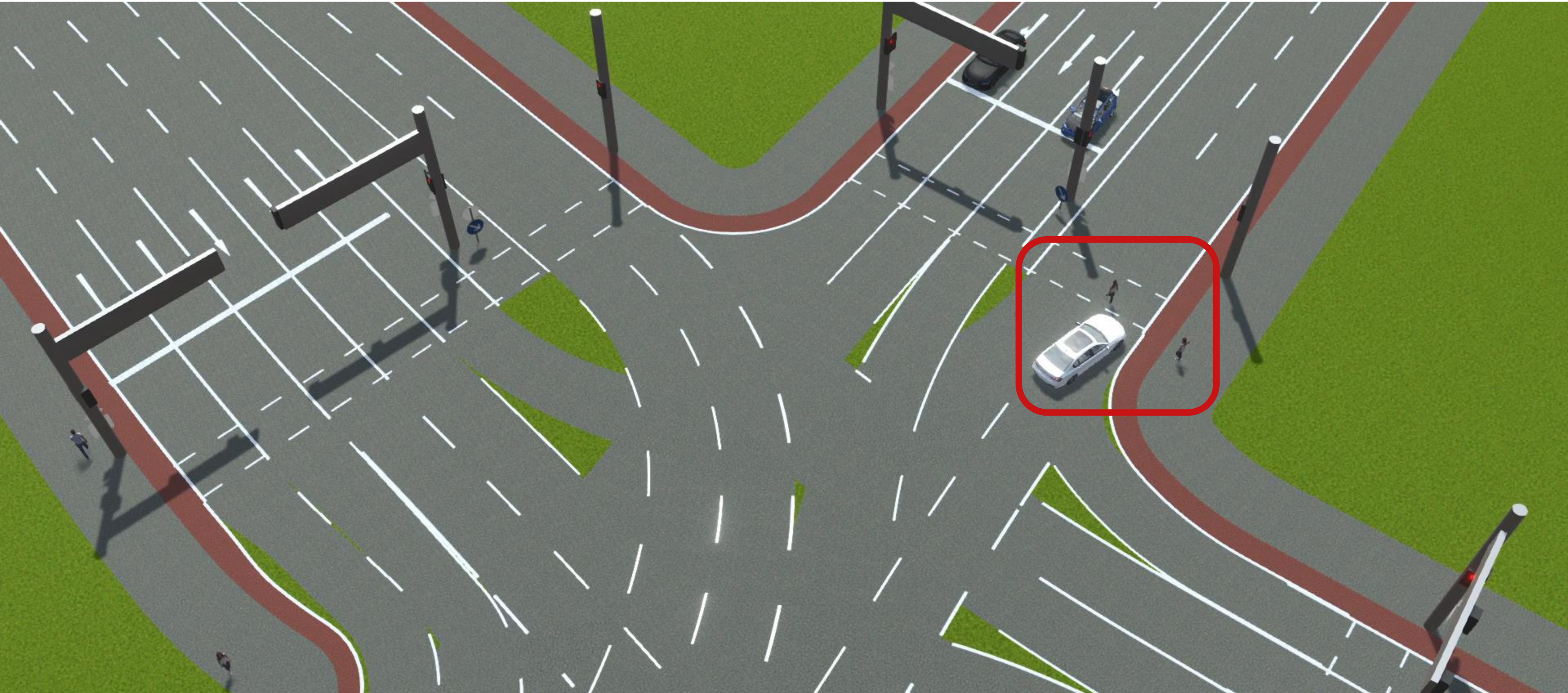


- **Explorative Analysis Task:**
  - Find critical scenarios regarding the criticality phenomenon “Unprotected left turn”
- **Phenomenological Analysis Task:**
  - Evaluate whether a lane merge during an unprotected left turn increases criticality
    - Concretized phenomenon “Unprotected left turn with merging traffic”
- **Variation of:**
  - Start positions of EGO vehicle and surrounding traffic
  - Start and end position of pedestrians
  - Presence of merging traffic in the scenario
    - Only during phenomenological analysis
- Parallelization of simulation runs due to size of parameter space



Simulation Execution

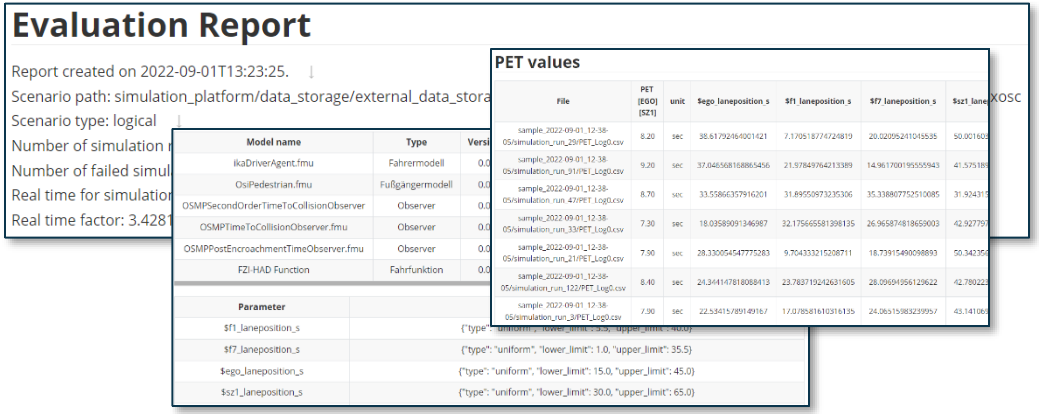
Packed Situation between EGO and the Pedestrians



Simulation Evaluation

Explorative and Phenomenological Analysis

- **Explorative analysis** identifies critical realizations of the logical scenario
- Detection of critical subspaces using criticality metrics TTC and PET
- Optimization of parallelization of simulation runs using a heuristic



Evaluation Report

Report created on 2022-09-01T13:23:25.
Scenario path: simulation_platform/data_storage/external_data_stora … xosc
Scenario type: logical
Number of simulation r…
Number of failed simul…
Real time for simulatio…
Real time factor: 3.4281…

Model name	Type	Versi…
ikaDriverAgent.fmu	Fahrermodell	0.0
OsiPedestrian.fmu	Fußgängermodell	0.0
OSMPSecondOrderTimeToCollisionObserver	Observer	0.0
OSMPTimeToCollisionObserver.fmu	Observer	0.0
OSMPPostEncroachmentTimeObserver.fmu	Observer	0.0
FZI-HAD Function	Fahrfunktion	0.0

Parameter	
$f1_laneposition_s	{"type": … }
$f7_laneposition_s	{"type": "uniform", "lower_limit": 1.0, "upper_limit": 35.5}
$ego_laneposition_s	{"type": "uniform", "lower_limit": 15.0, "upper_limit": 45.0}
$sz1_laneposition_s	{"type": "uniform", "lower_limit": 30.0, "upper_limit": 65.0}

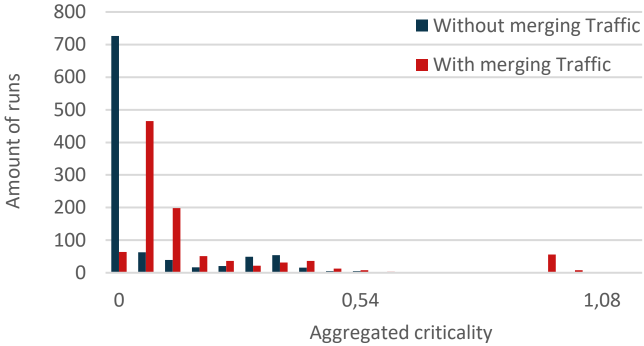
PET values

File	PET [EGO] [SZ1]	unit	$ego_laneposition_s	$f1_laneposition_s	$f7_laneposition_s	$sz1_lane…
sample_2022-09-01_12-38-05/simulation_run_29/PET_Log0.csv	8.20	sec	38.61792464001421	7.170518774724819	20.02095241045535	50.001603…
sample_2022-09-01_12-38-05/simulation_run_91/PET_Log0.csv	9.20	sec	37.046568168865456	21.97849764213389	14.961700195555943	41.575189…
sample_2022-09-01_12-38-05/simulation_run_47/PET_Log0.csv	8.70	sec	33.55866357916201	31.89550973235306	35.338807752510085	31.924315…
sample_2022-09-01_12-38-05/simulation_run_33/PET_Log0.csv	7.30	sec	18.03589091346987	32.175665581398135	26.965874818659003	42.927797…
sample_2022-09-01_12-38-05/simulation_run_21/PET_Log0.csv	7.90	sec	28.330054547775283	9.704333215208711	18.73915490098893	50.342356…
sample_2022-09-01_12-38-05/simulation_run_122/PET_Log0.csv	8.40	sec	24.344147818088413	23.783719242631605	28.09694956129622	42.780223…
sample_2022-09-01_12-38-05/simulation_run_3/PET_Log0.csv	7.90	sec	22.53415789149167	17.078581610316135	24.06515983239957	43.141069…

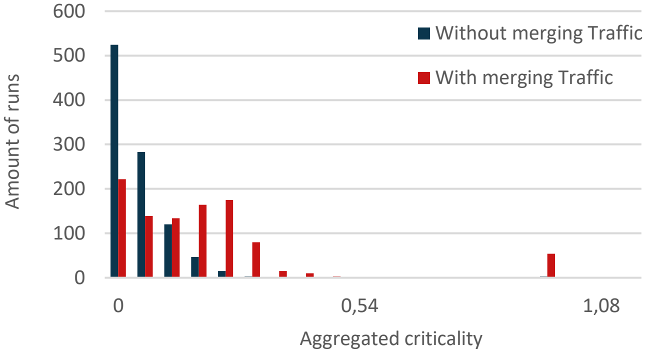
- **Phenomenological analysis** of criticality provides insight into the relevance of criticality phenomena
- Criticality is defined as the combined risk of the involved actors if the traffic situation is continued
- Criticality is exemplarily aggregated over all relevant actors using (CM = PET, TTC)

$$C_{CM} = \sum_{A,B \in Actors} e^{-CM(A,B)}$$

Comparison regarding criticality phenomenon using TTC



Comparison regarding criticality phenomenon using PET

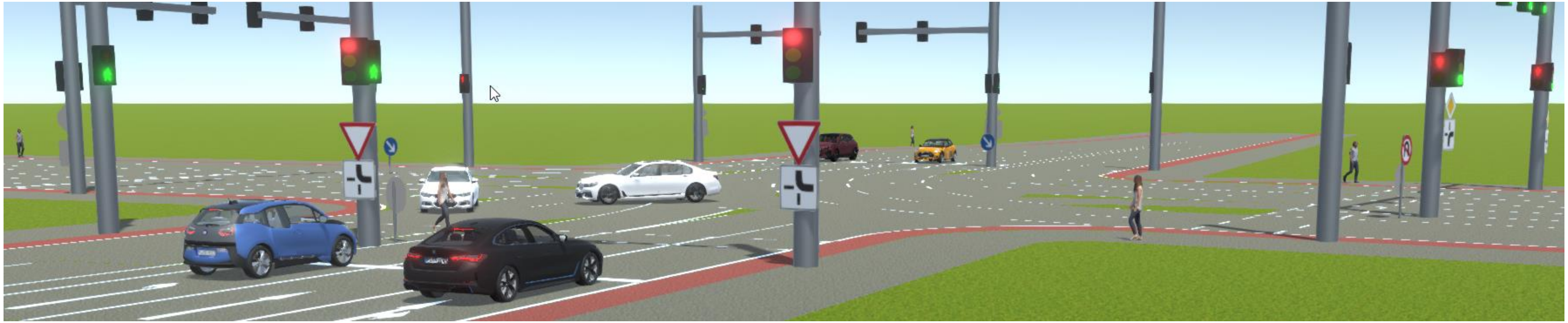


Summary

Closed-Loop Traffic Simulation for Criticality Analysis

SET Level

- Simulation of complex intersection scenario with multiple agents
- Stochastic variation of the scenario implemented on simulation platform level
- Coupling of tools and models through standardized interfaces following the generic platform architecture
- Realistic traffic behavior due to interactions between traffic participants
- Evaluation of criticality through TTC and PET



PARTICIPATION IN THE WORKING GROUP

ECLIPSE FOUNDATION

The company should be at least an Eclipse Solution Member

- Networking and learning
- The annual membership fee for Solutions Members is tiered based on revenue

openPASS

Working Group participation agreement

- Contribution in development of openPASS
- Discussion of the roadmap
- Active collaboration with the working group

Membership Privileges

Privilege	Driver Member	User Member	Service Provider Member	Project Manager
Steering Committee	X	Elected	Elected	-
Architecture Committee	X	-	-	X
Quality Committee	X	Elected	Elected	X
GeneralAssembly	X	X	X	-

For more information, look at the openPASS charter:
https://www.eclipse.org/org/workinggroups/openpasswg_charter.php

COMMUNICATION WITH THE WORKING GROUP

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