

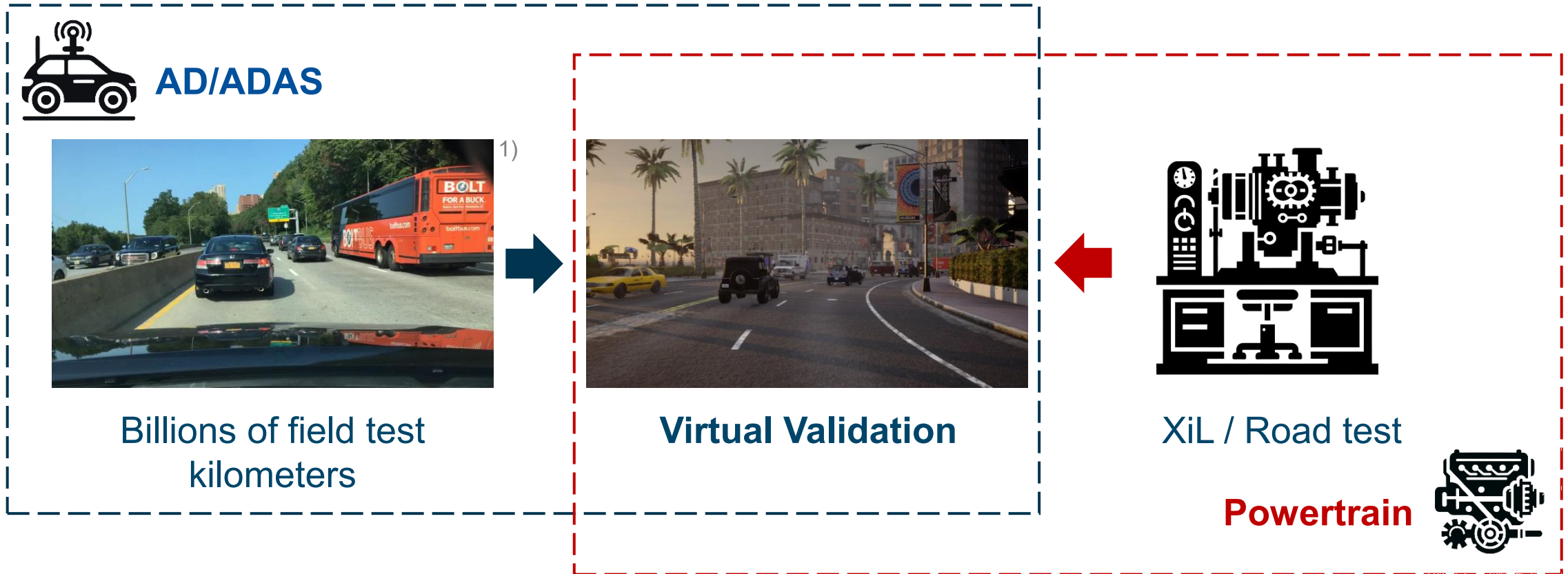
Transfer Virtual Validation from AD/ADAS to Powertrain

Aachen | 07 October 2026

Nick Schade, **Kazuo Takeuchi**, **Jürgen Pannek**

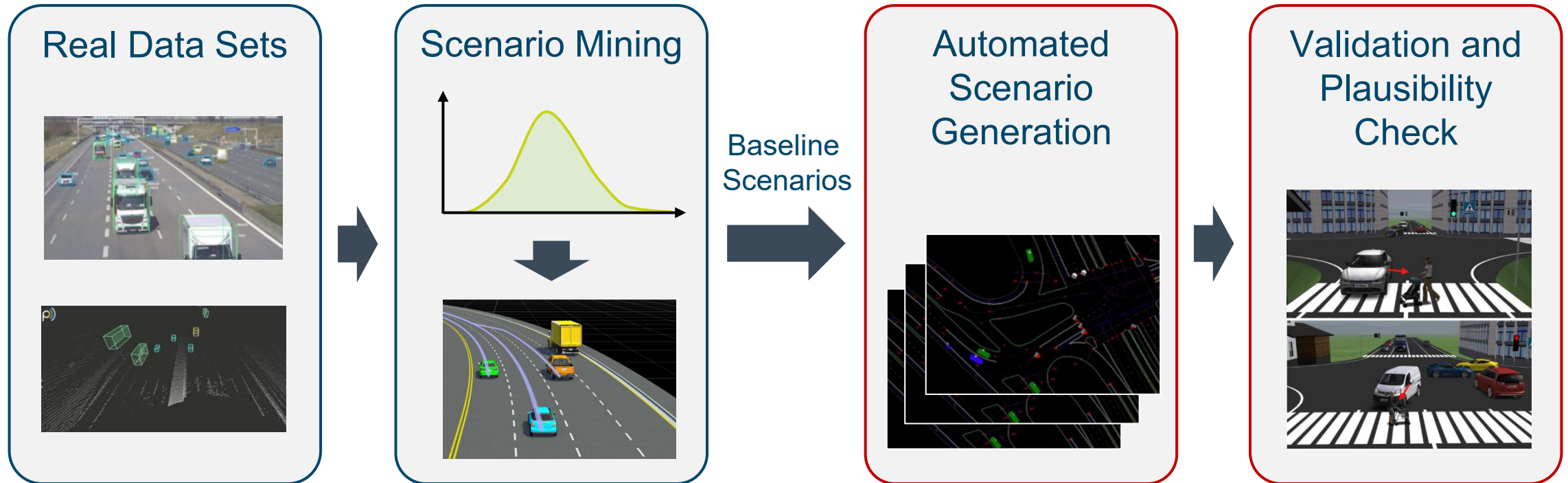
Virtual Validation

FROM AD/ADAS TO POWERTRAIN



Methodology and Work Packages

TRANSFORM DATA TO INFORMATION

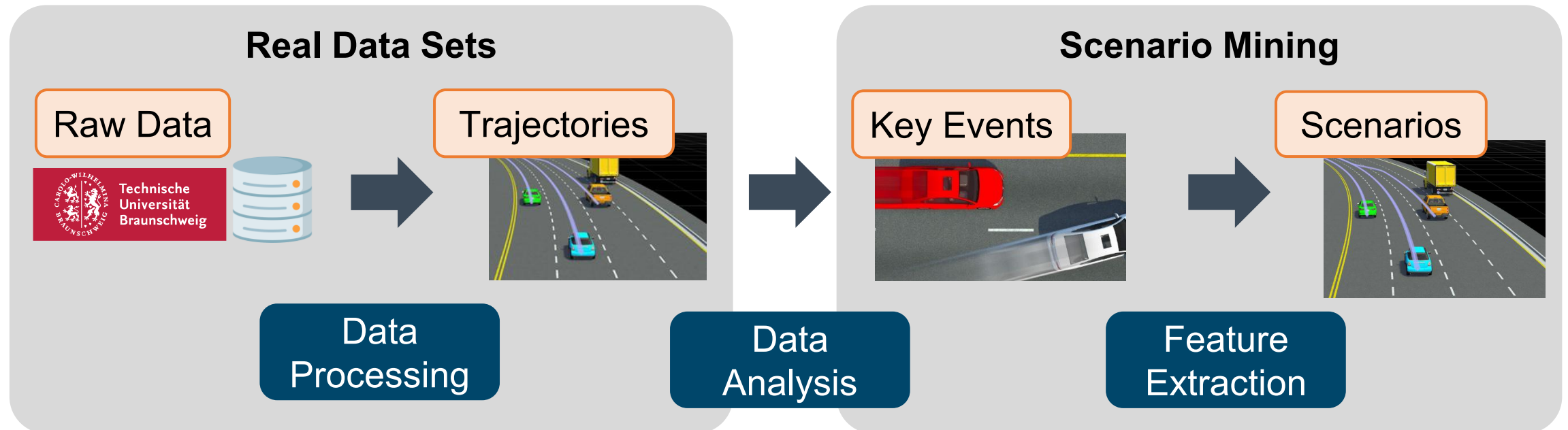


Data

Information

Data Aggregation and Processing

FROM DATA TO SCENARIOS



Data Aggregation and Processing

DATA PROCESSING



Raw Data

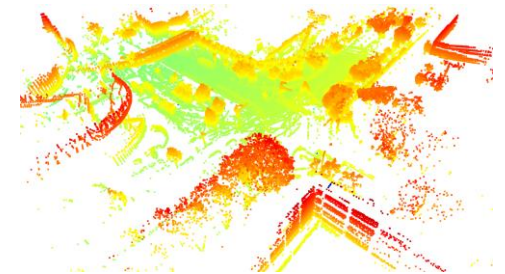


Relevant sensors

- GPS
- IMU
- Camera
- LIDAR

Digital reconstruction of Dataset

- Number of vehicles
- Position, velocity, etc.
- Number of lanes
- ...



Data Processing

Scene
Extraction



Ego-
Localization



Non-Ego-Actor
Tracking



Trajectories



Scenario Reconstruction

Scenario Mining and Generation of Baseline Scenarios

FEATURE EXTRACTION

Data Analysis

Extract Key Events

Events

Position

Left

Right

Hold

Velocity

Accl

Brk

Hold

Ego
Vs.
Non-Ego

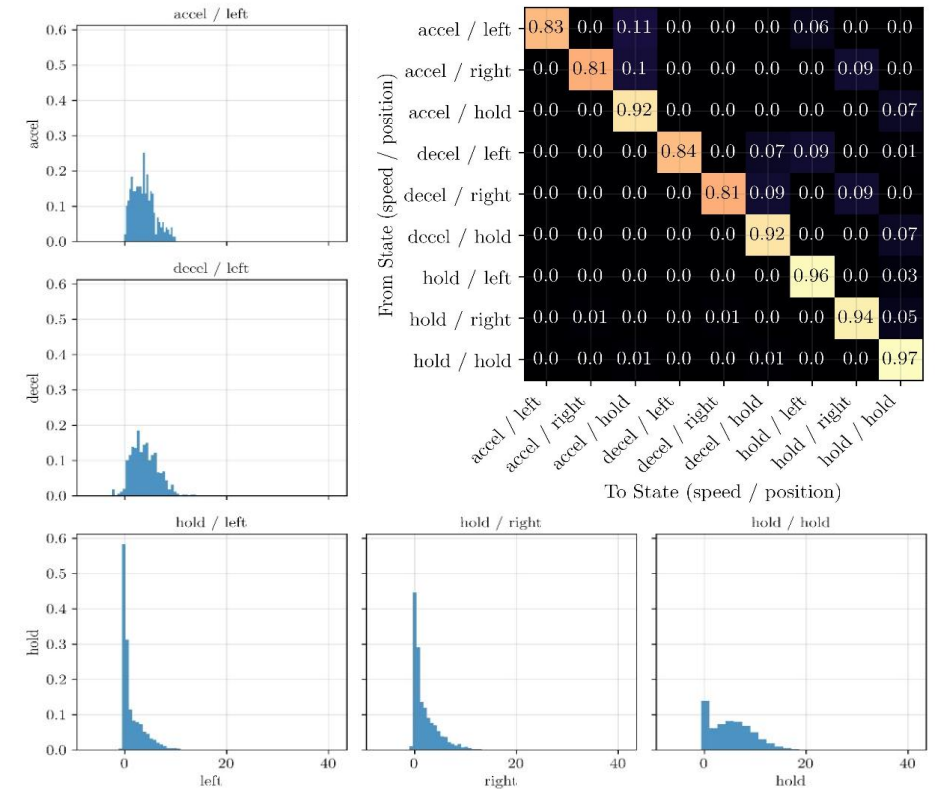
Feature Engineering

Number of Lanes

Number of Vehicles

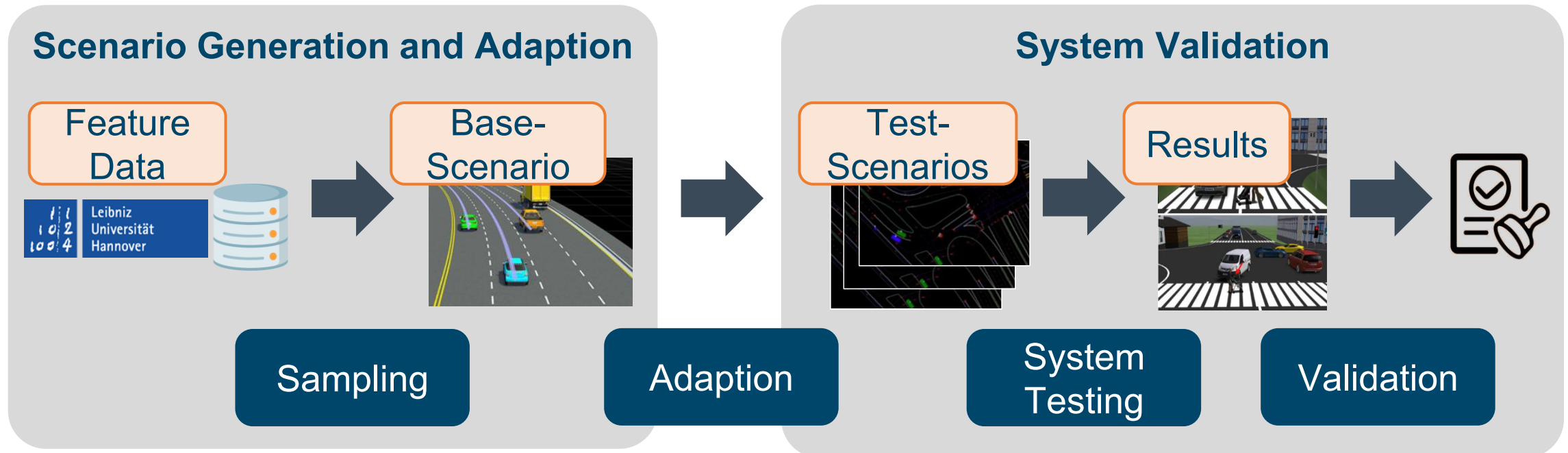
Vehicle Density

Vehicle Velocity



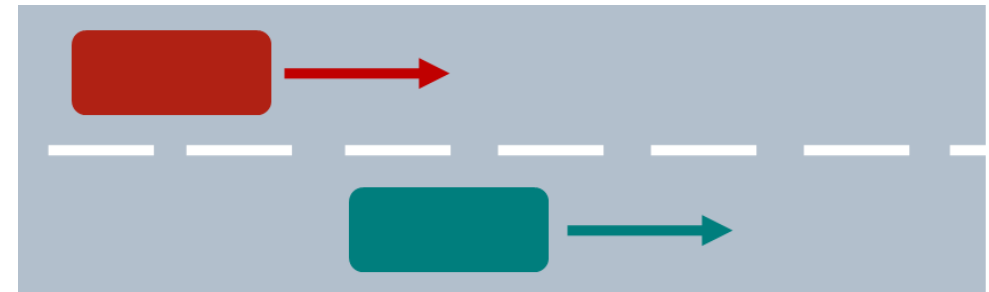
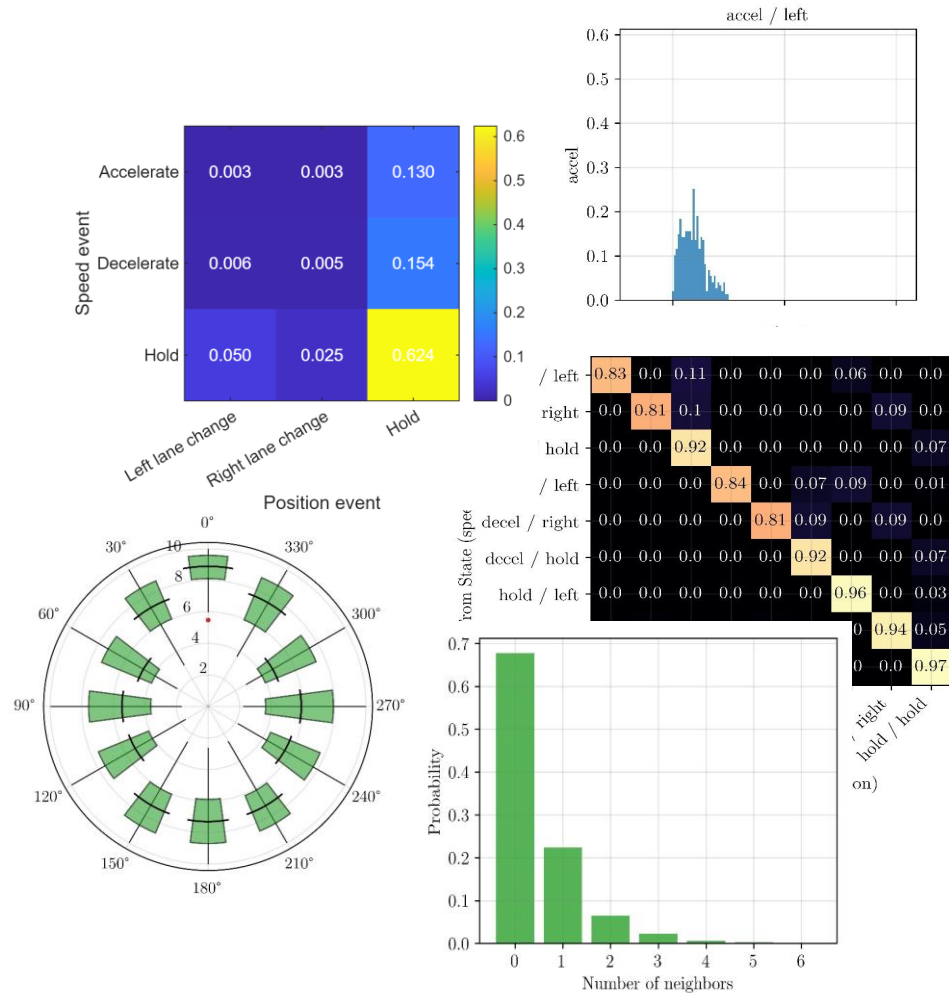
Scenario Generation and Validation

FROM REAL-WORLD FEATURES TO RESULTS

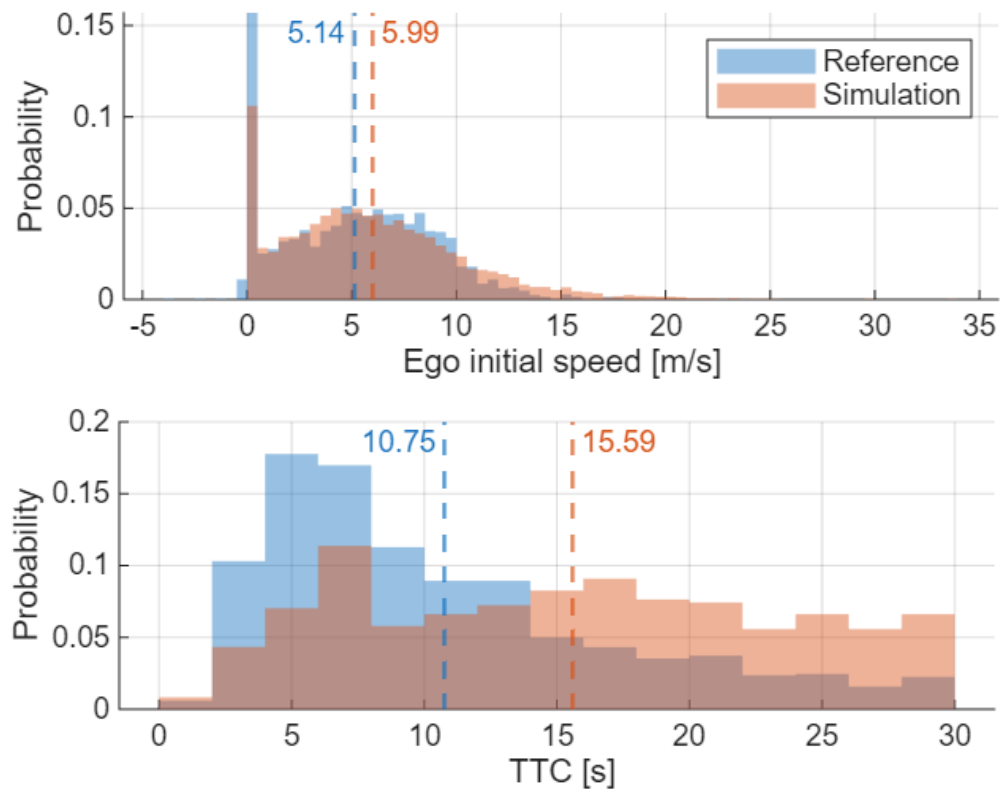


Scenario Mining and Generation of Baseline Scenarios

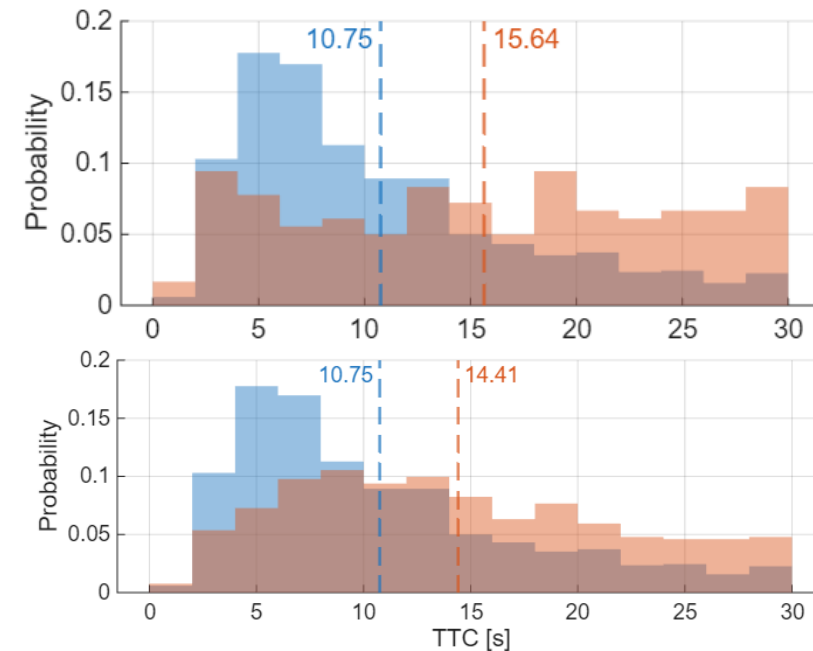
SCENARIO DEFINITION



Monte-Carlo Sampling



Importance Sampling



3000
samples

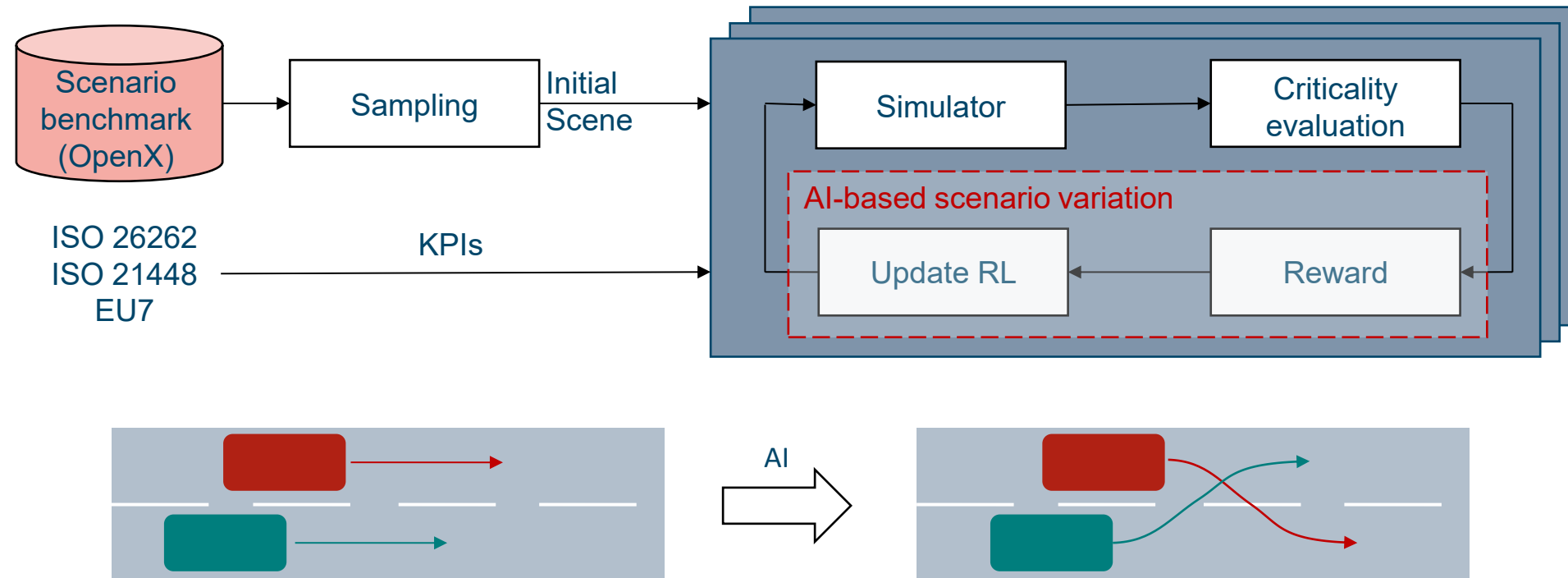
6000
samples

- Reduced number of samples
- Increased number of critical scenes

Scenario Generation and Validation

SCENARIO ADAPTION

- Implementation of (Multi-agent) reinforcement learning to provoke critical scenarios

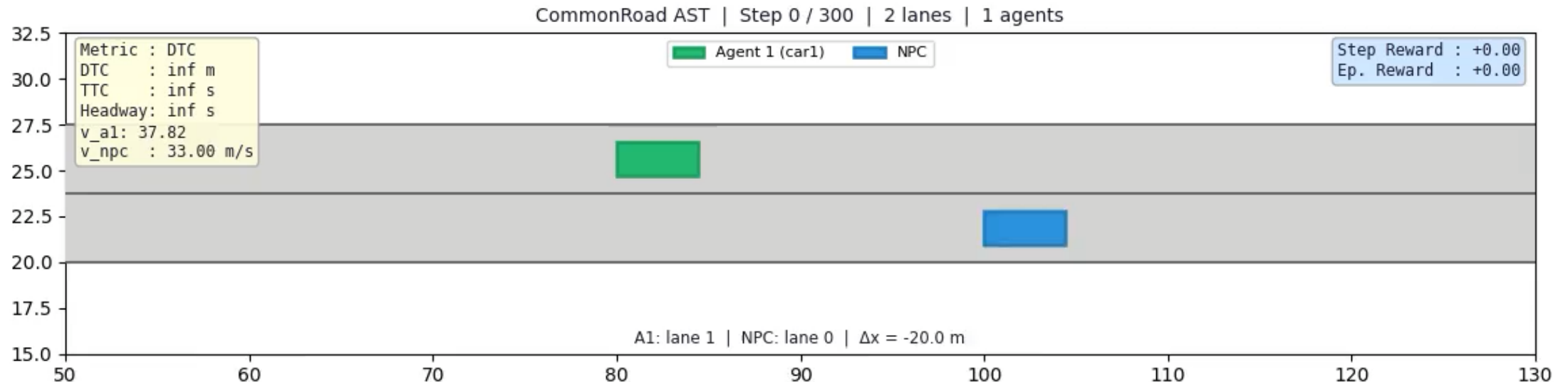


Scenario Generation and Validation



SCENARIO ADAPTION

- Application of Multi-Agent CTDE Stabilized Discrete SAC

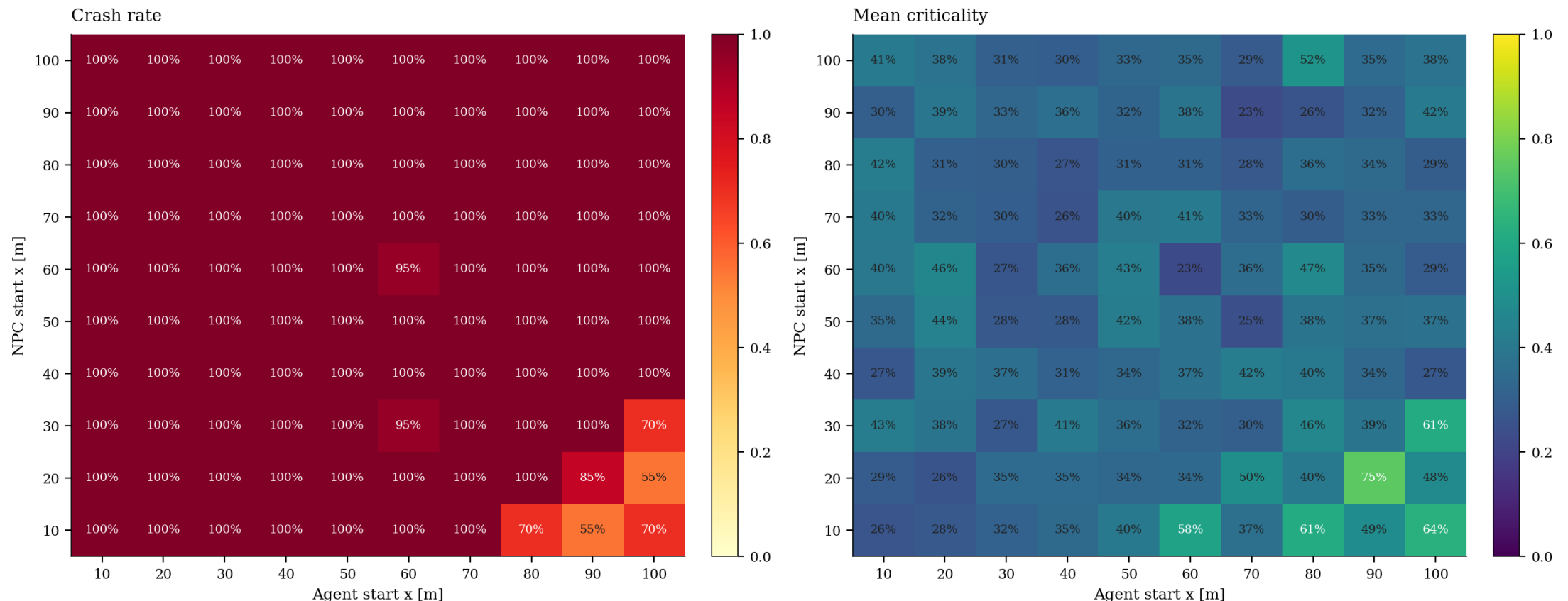


Scenario Generation and Validation

SCENARIO ADAPTION



- Evaluation on 20 iterations in 100 combinations

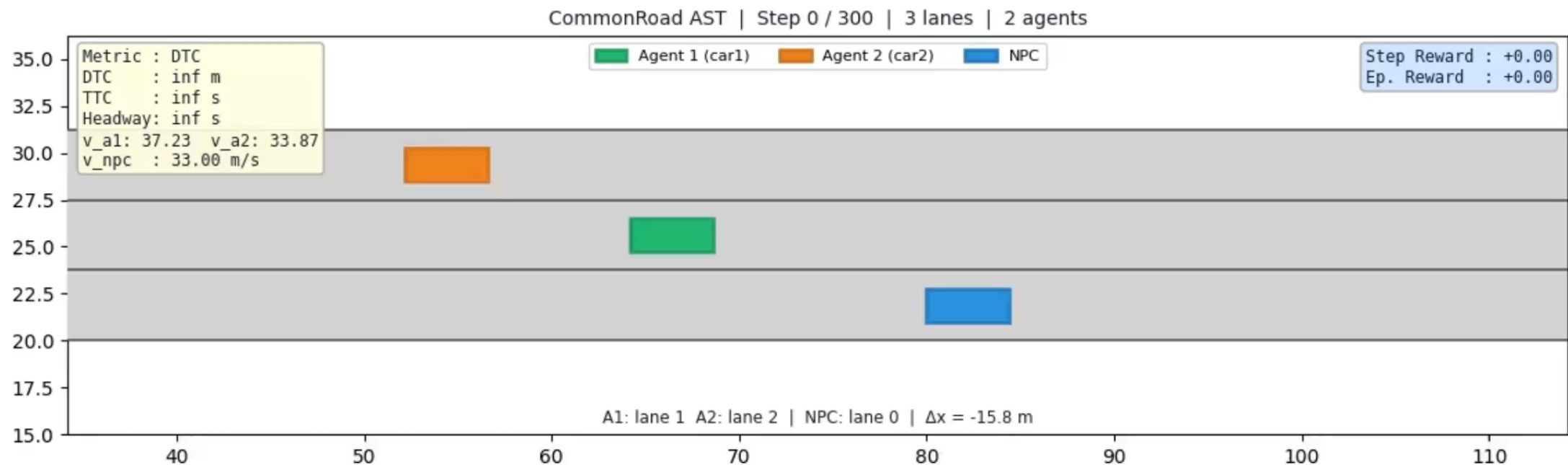


Scenario Generation and Validation



SCENARIO ADAPTION

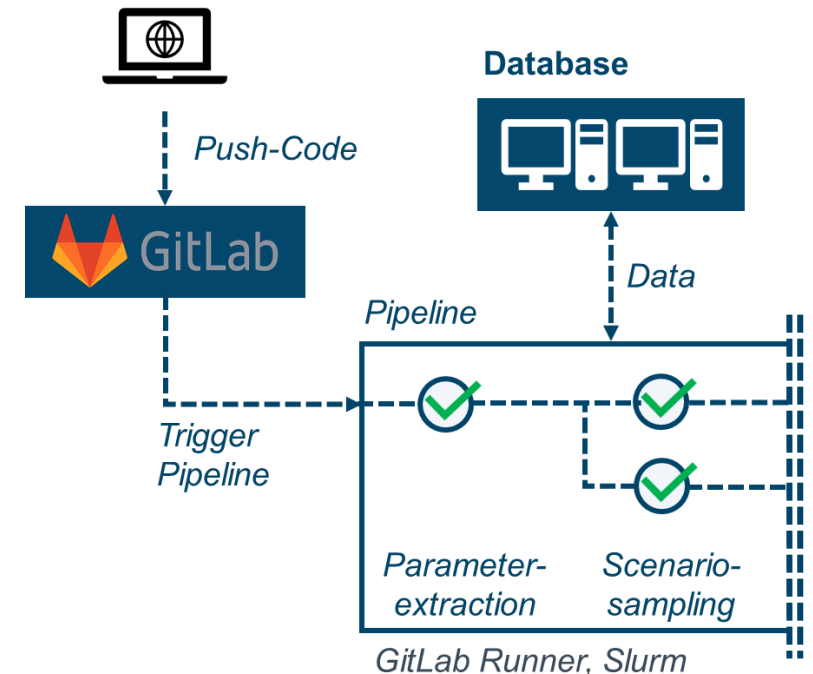
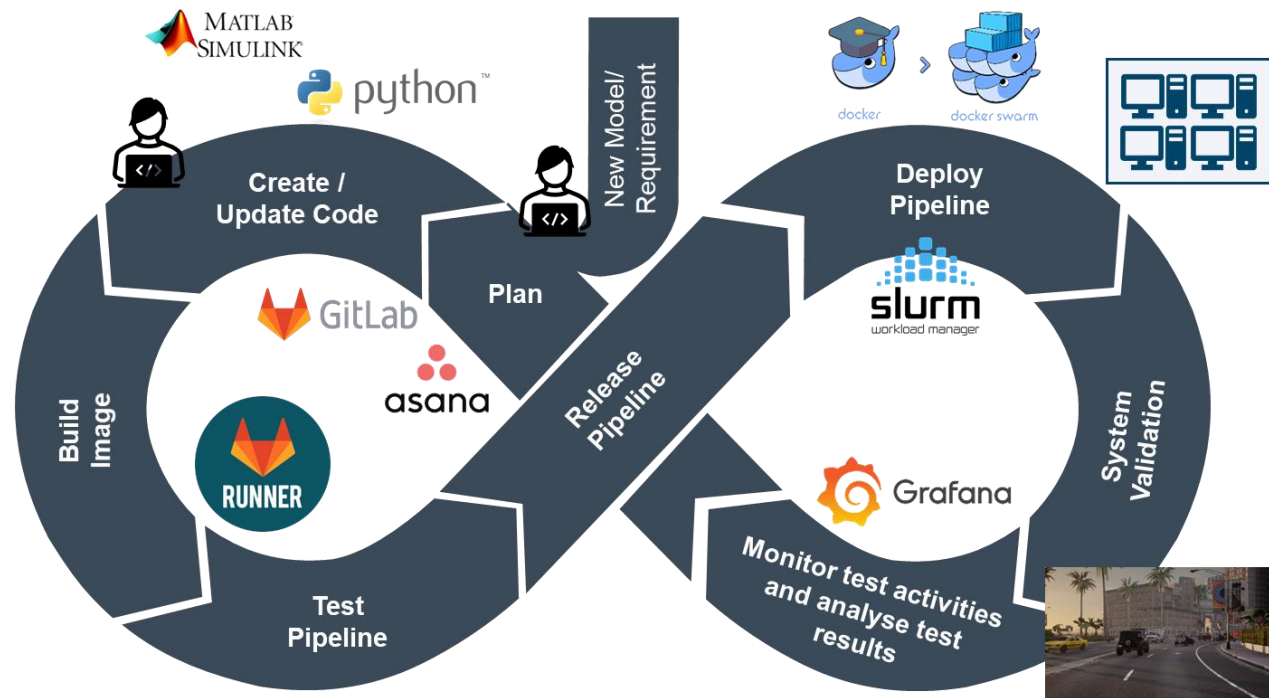
- Extension to Multi-Agent Setting



Scenario Generation and Validation

SIMULATION SETUP

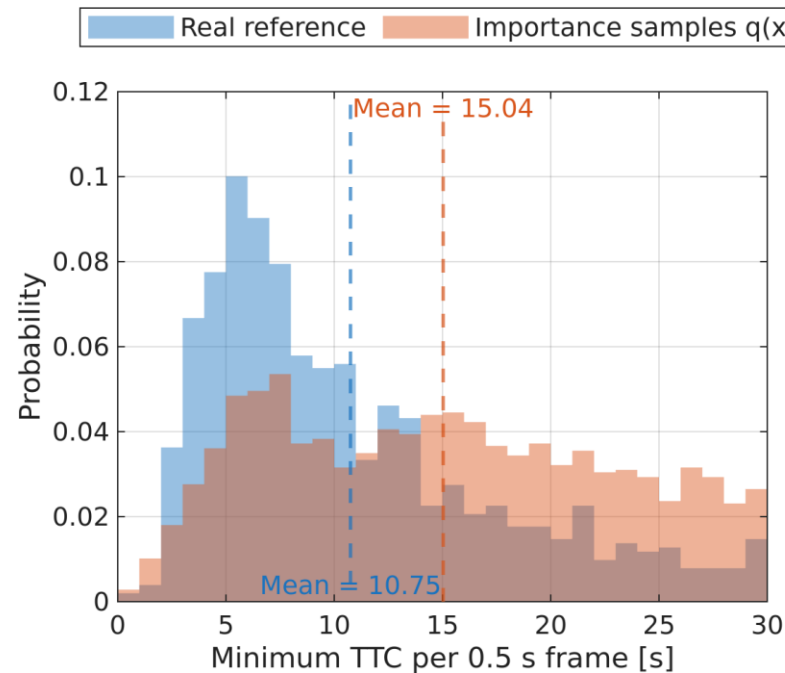
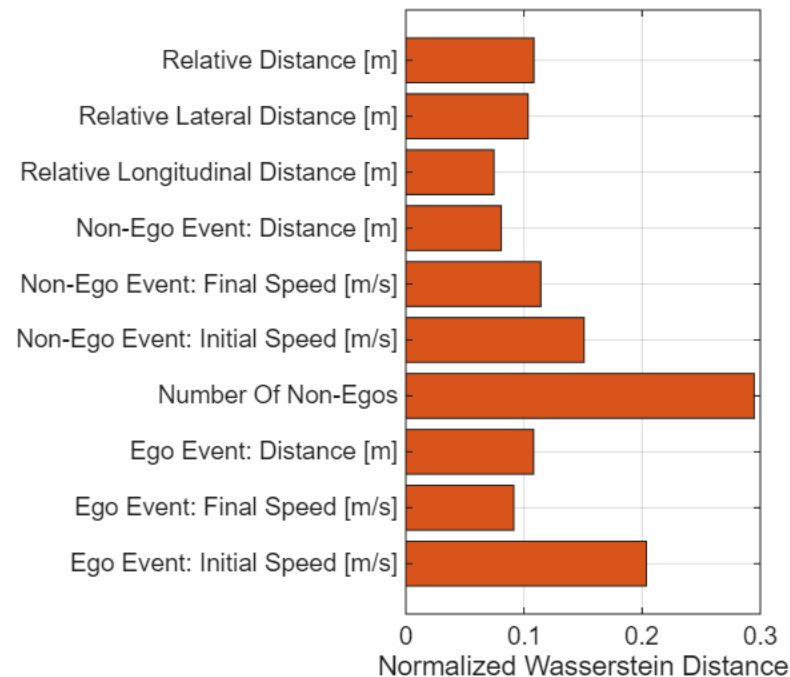
- Assesed 19 simulators in a ABC-analysis → Mathworks Product Family
- Developed and Implemented DevOps-Driven Framework based on Git
- Implemented Parallel Computing (up to 1000 simulations in parallel)



Scenario Generation and Validation

RELIABILITY ASSESSMENT

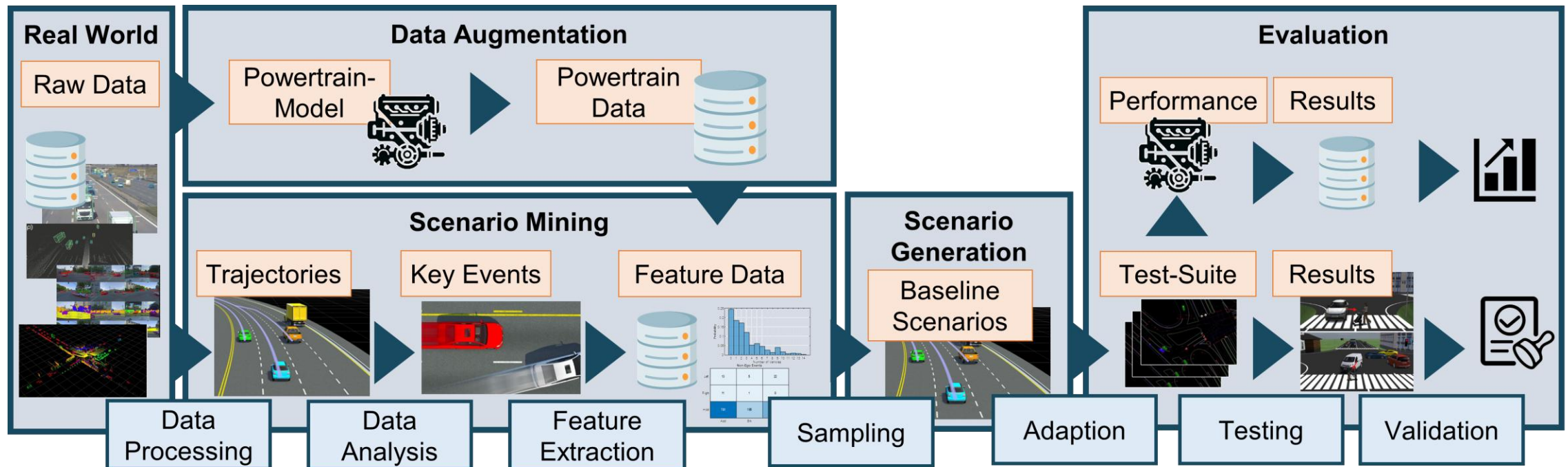
- Implementation of exemplary System-Under-Test
- Assessment based on 25,000 simulations
- Quantification based on Wasserstein-Distance



Transfer to Powertrain

DATA IS NOT DATA

- (Suitable) Powertrain-Data is missing
- Data Augmentation based on simulation model conducted

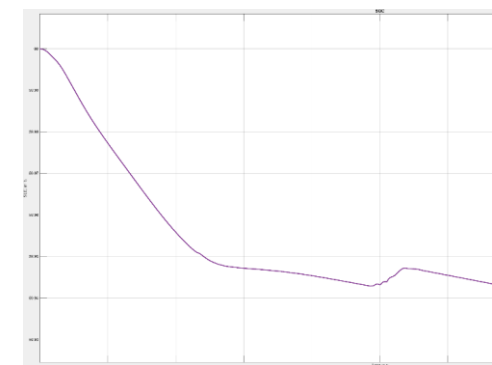
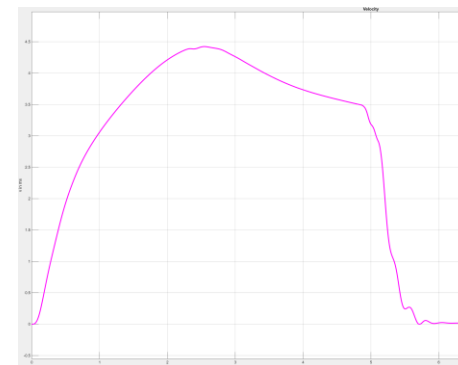
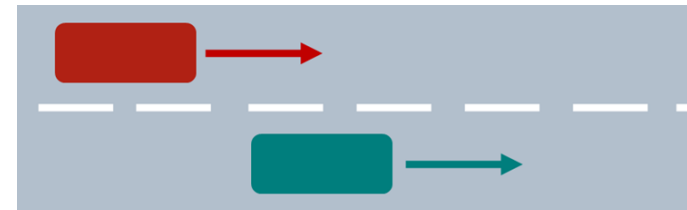


FUNDAMENTAL DIFFERENT QUESTIONS

„Identify agent actions that force the SUT to consume a large amount of fuel, without a collision.“

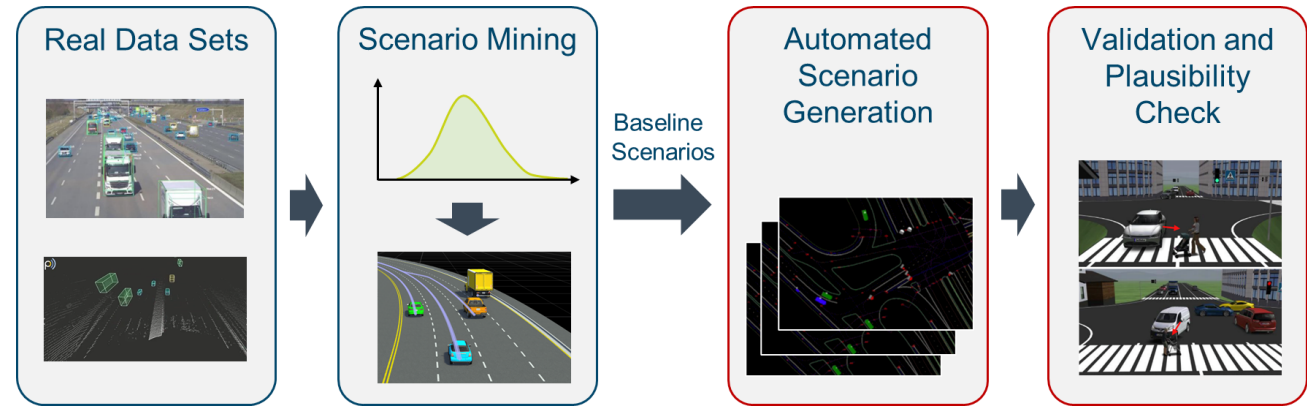
High Fuel Consumption due to:

- Rapid Acceleration
- Frequent Braking and Acceleration
- Driving at an Inefficient Speed
- Stop-and-Go Traffic
- Unnecessary Delays
- Longer Travel Times



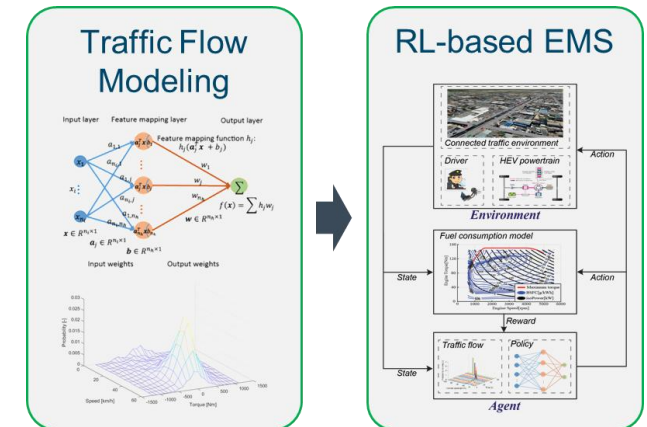
Summary and Conclusion

- Developed and demonstrated a generic methodology for virtual validation
- Analyzed potential of transfer to powertrain domain



Next Steps:

- Demonstrate the extension AD/ADAS data and validation into the powertrain domain



Outlook

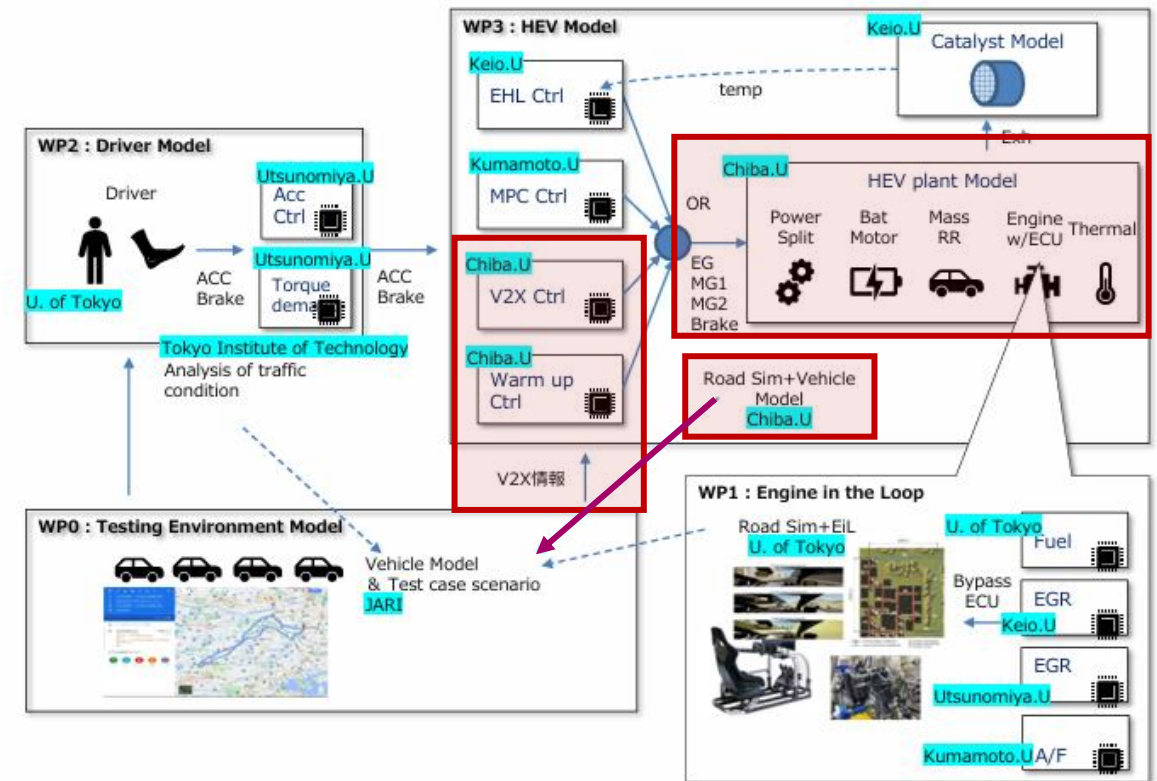
BACKGROUND AND OBJECTIVES

Background:

- Vehicles and traffic flow interact with and influence each other.
- Information on vehicle states and traffic flow is essential for optimizing fuel economy.
- Collecting and validating data of vehicle and traffic-flow in real-world is challenging.
- Simulation environments capable for V2X traffic scenarios is required.

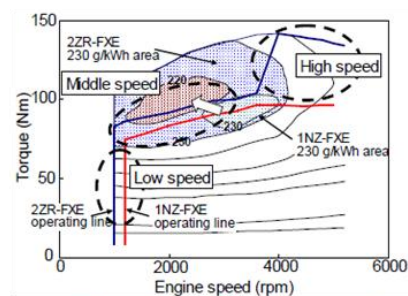
Objectives:

- Development of a reinforcement learning-based energy management strategy for HEV
- Development of a simulation environment including V2X function

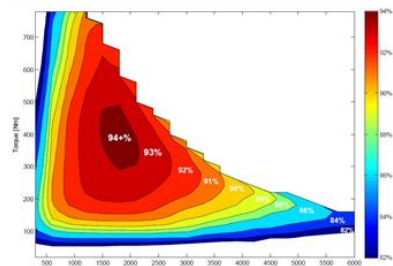


BACKGROUND AND OBJECTIVES

- Considering the fuel economy improvement of HEV powertrain
- Reinforcement learning-based energy management strategy using V2X information
- Large-scale traffic scenario data is necessary for learning the policy
- Verification of the proposed approach in Rapid Prototyping Systems (dSPACE)

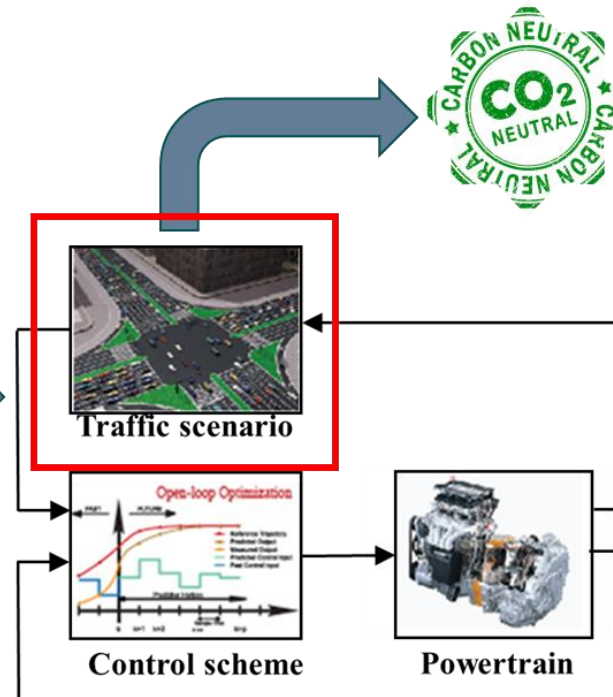
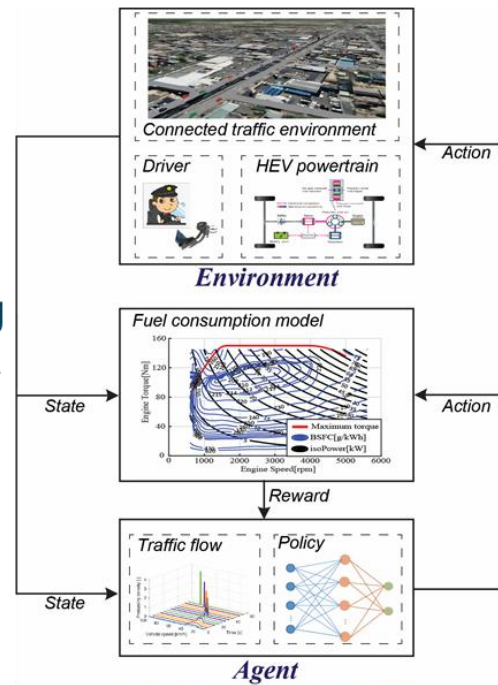


Engine fuel cost



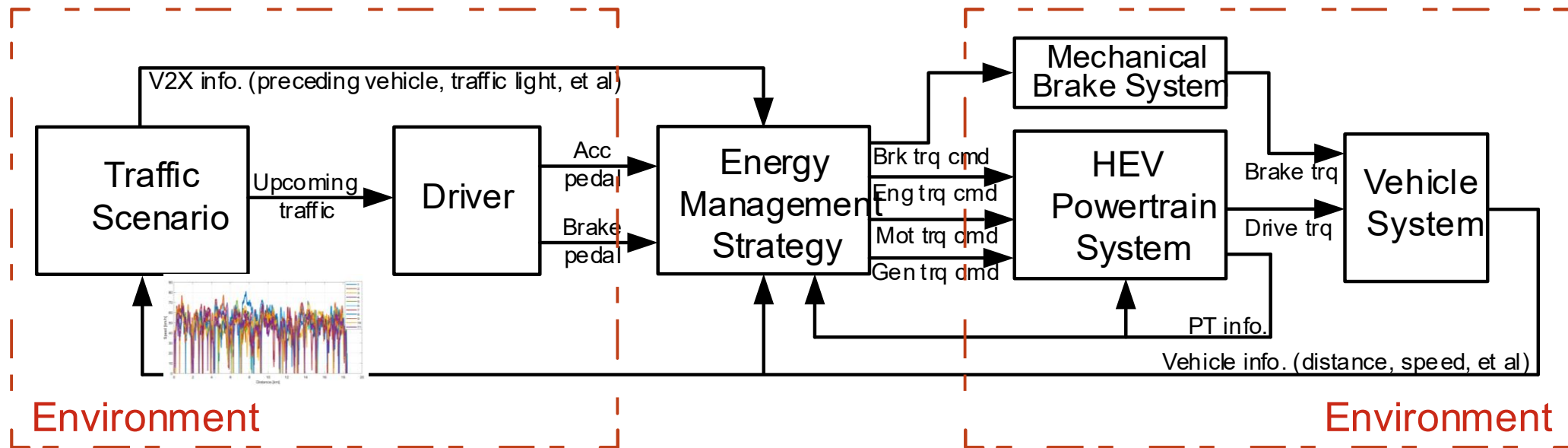
Motor efficiency

Minimizing



CURRENT STATE

- Traffic, driver, powertrain and vehicle are seen as the environment
- Fuel and electricity consumption are seen as the cost



CURRENT STATE

- Investigation of benchmark environment development using traffic scenarios
- V2X Information required for EMS and vehicle speed optimization
- Acquisition of route-wide traffic and infrastructure information through V2X
- CarMaker simulation using traffic information surrounding the ego vehicle

Conventional method used in former research (series-parallel HEV):

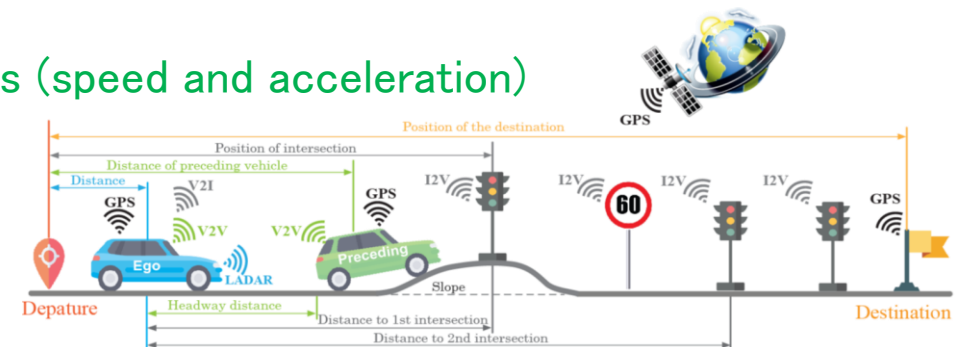
- GPS: Distance traveled by the ego vehicle from start line
- I2V: Road grade (slope)
- I2V: Positions and signal states of the first and second upcoming traffic lights
- I2V: Speed limit
- V2V: Distance to the preceding vehicle and its driving states (speed and acceleration)

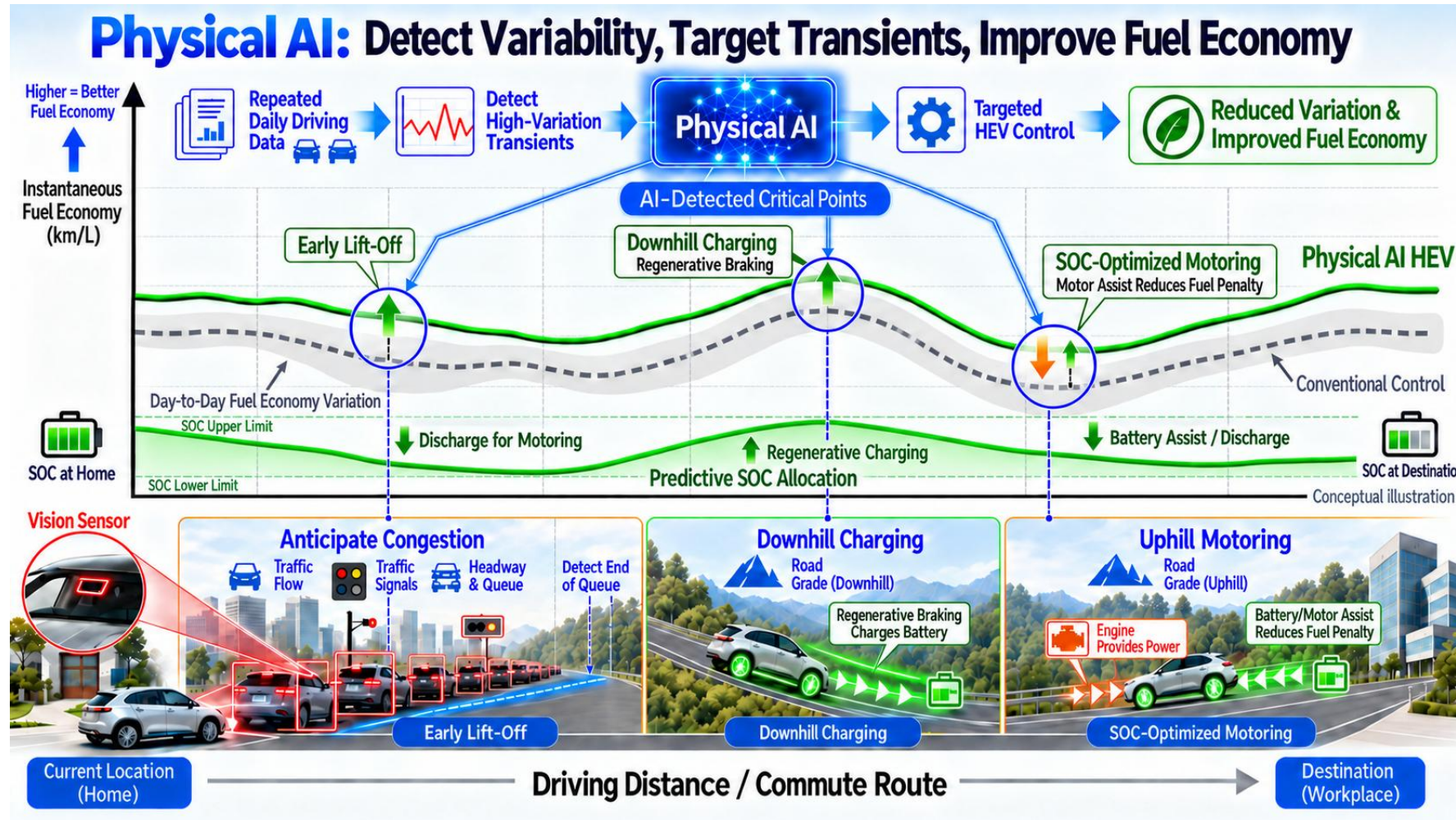
Control variables:

Vehicle speed, Torque output, Energy management (ON/OFF)

Target:

Fuel consumption, Travel time

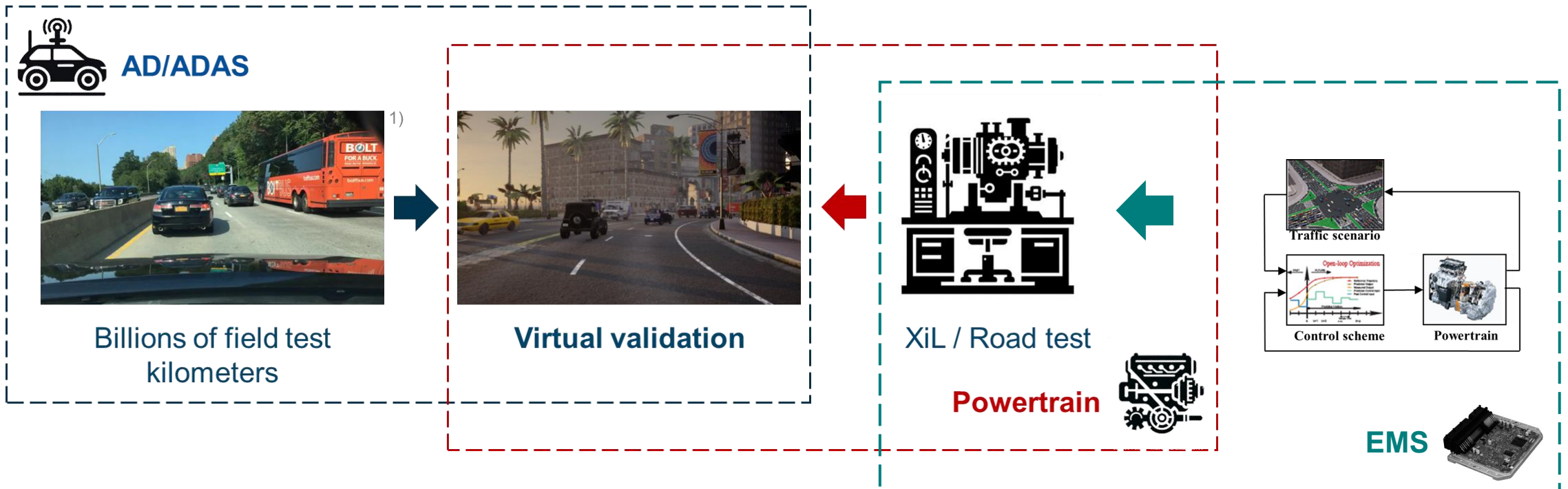




Outlook

PLANNED EXTENSION

- Integrate traffic scenarios into a V2X simulation environment
- Identify traffic scenarios that are critical to key performance parameters
- Upgrade the EMS control strategy through optimization based on the scenarios



Acknowledgement



TRANSFER VIRTUAL VALIDATION FROM AD/ADAS TO POWERTRAIN (FVV PROJECT NUMBER 1527)

This report is the scientific result of a research project undertaken by the FVV eV and performed by Institute for Intermodal Transport and Logistic Systems (ITL) at Technische Universität Braunschweig under the direction of Prof. Dr. Jürgen Pannek and by Institute of Mechatronic Systems (IMES) at Leibniz University Hannover under the direction of Prof. Dr.-Ing. Thomas Seel.

The FVV would like to thank the professors Prof. Dr. Jürgen Pannek and Prof. Dr.-Ing. Thomas Seel and their scientific research assistants – Nick Schade, M.Sc. (ITL) and Björn Volkmann, M.Sc. (IMES) – for the implementation of the project. The project was conducted by a working group led by Prof. Dr.-Ing. habil. Reza Rezaei (IAV GmbH). We gratefully acknowledge the support received from the project coordination and from all members of the project user committee.

In addition, we would like to thank all Japanese Partners, in particular AICE and METI, for the support, discussions and provision of models and expertise in the field of powertrain control.

The research project was self-financed (funding no. 6015271, 6015272) by the FVV eV.

Thank you very much!

Aachen | 07 October 2026

Nick Schade, **Kazuo Takeuchi**, **Jürgen Pannek**