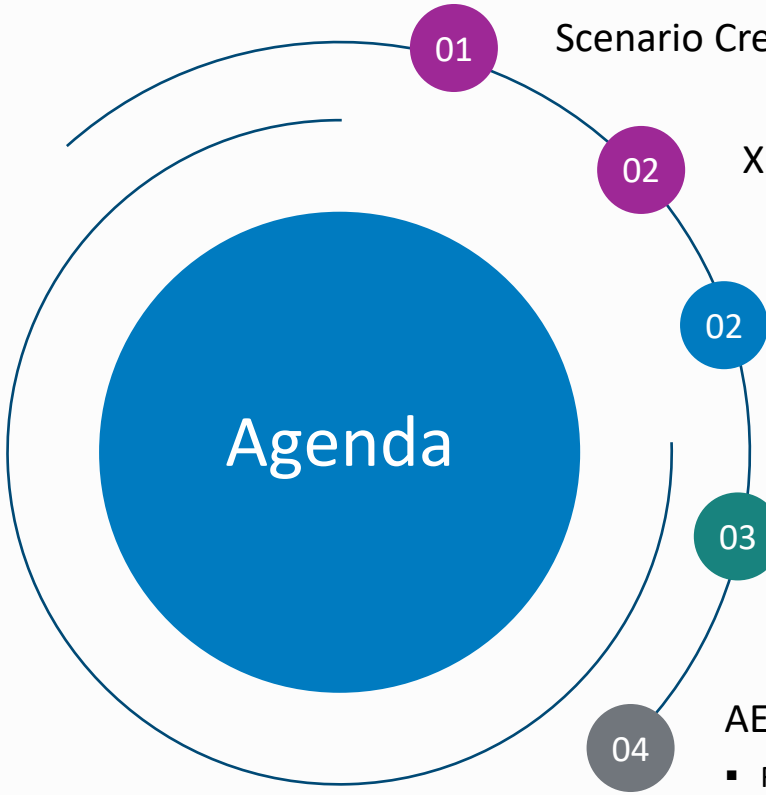


01 Scenario Creation with RoadRunner

02 XiL Integrated tool chain

02 Scenario Simulation

- Validation setup with co-simulation framework
- Data Exchange Mechanism

03 Scenario Synchronization

- Ego and Traffic Vehicles Position Update
- Time Synchronization

04 AEB Controller Validation

- Results Comparison

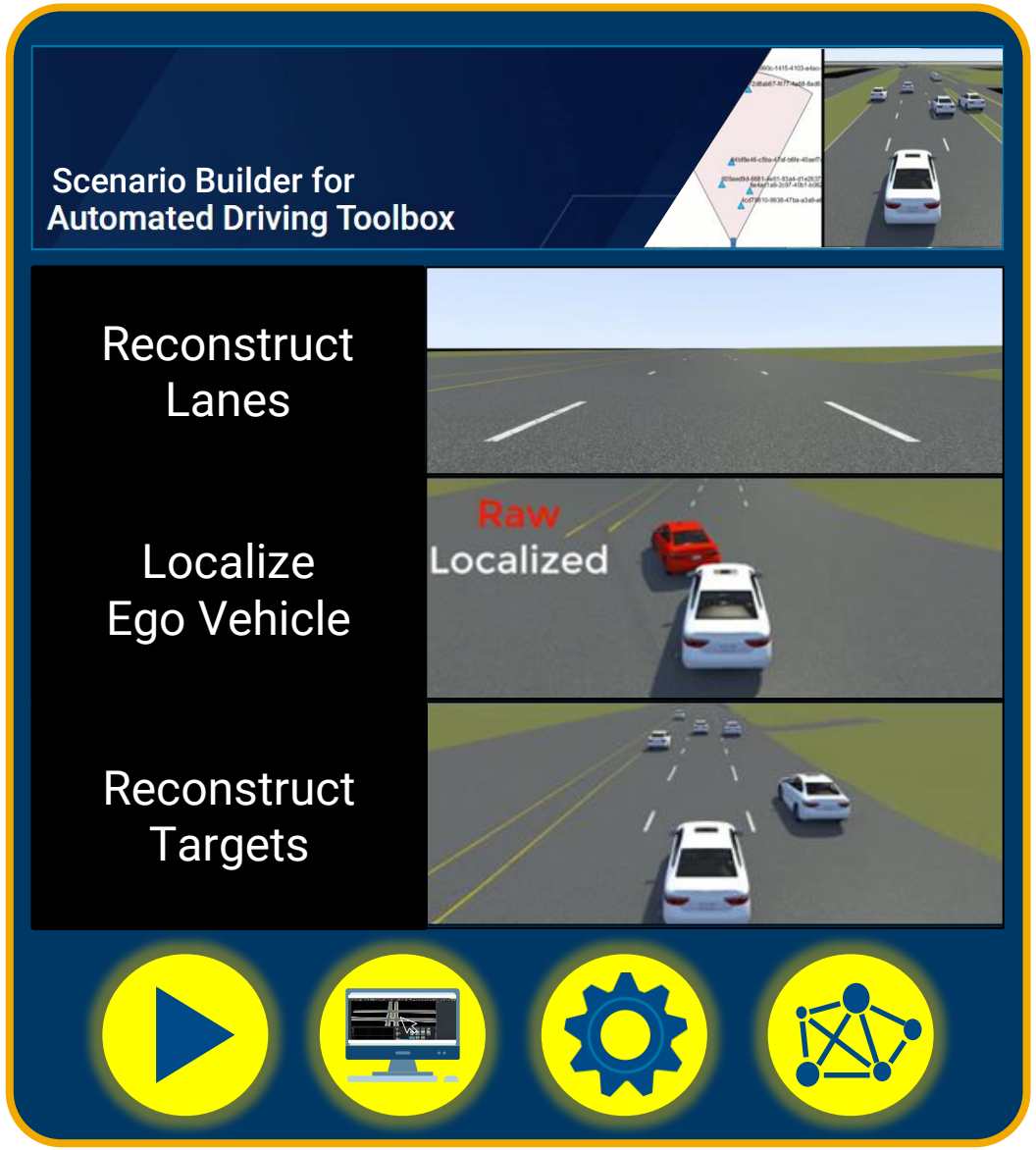
BOSCH

Design 3D scenes

Design scenarios

Simulate driving applications

Build scenarios from recorded data



Design 3D scenes

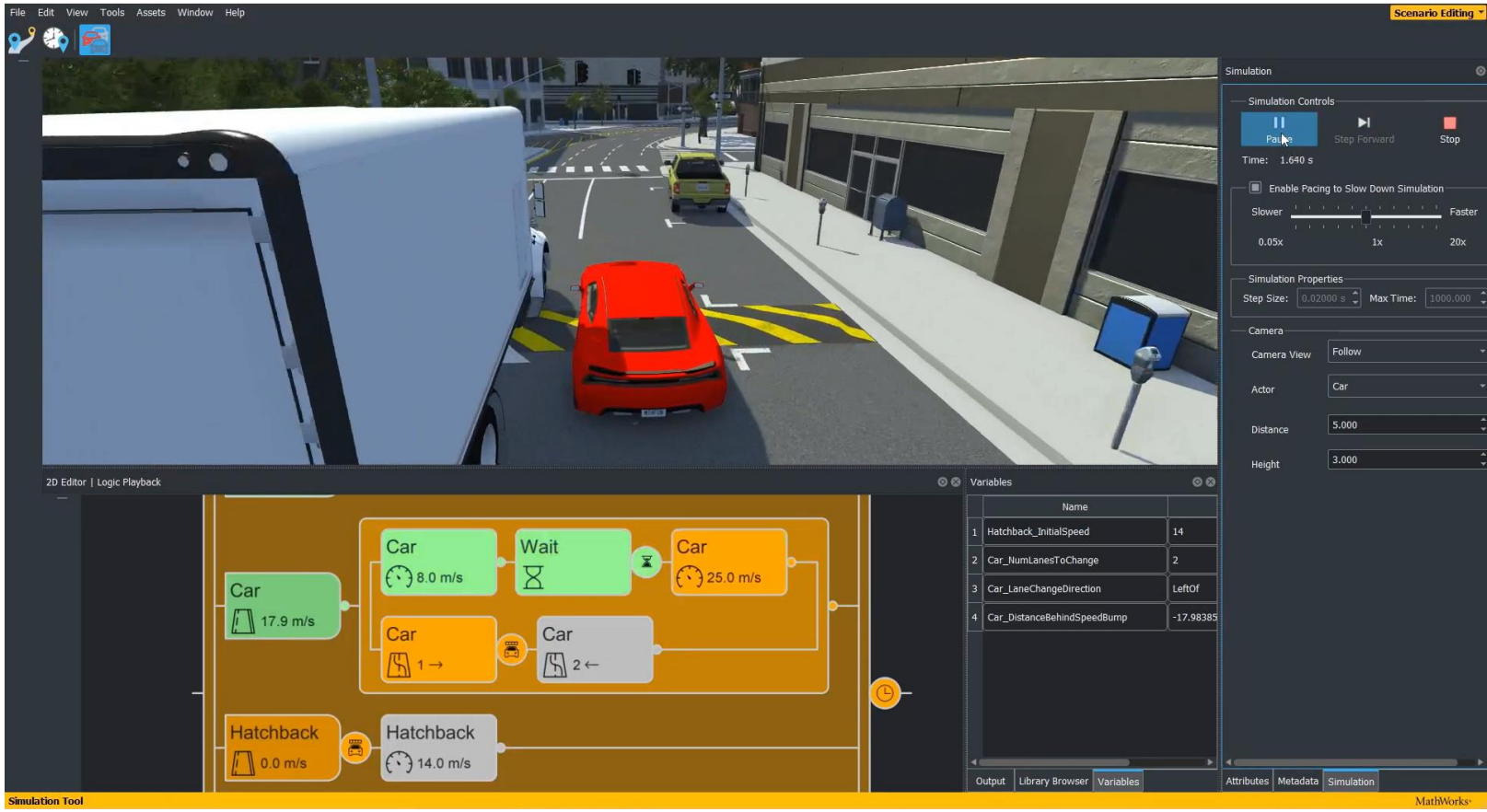
Design scenarios

Simulate driving applications

Build scenarios from recorded data

Interactively design scenarios with RoadRunner Scenario

- Add various vehicles and pedestrians
- Author trajectories
- Specify actions and logic
- Parameterize variations
- Spawn and Despawn vehicles as needed



[Scenario Edit Tool](#)

RoadRunner Scenario

Updated R2023a

Build scenarios from recorded sensor data with Scenario Builder

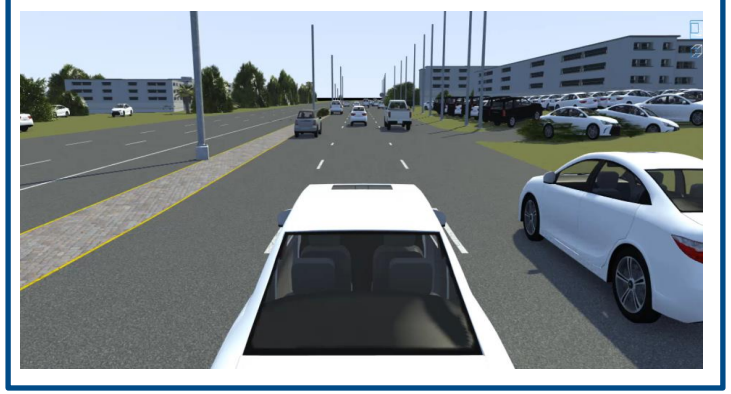
Recorded sensor data

Lidar
Camera
IMU
Radar
GPS
Lanes
Object List

Scenario Builder

Analysis, Extraction and Localization of static and dynamic objects

Reconstructed RoadRunner Scenario

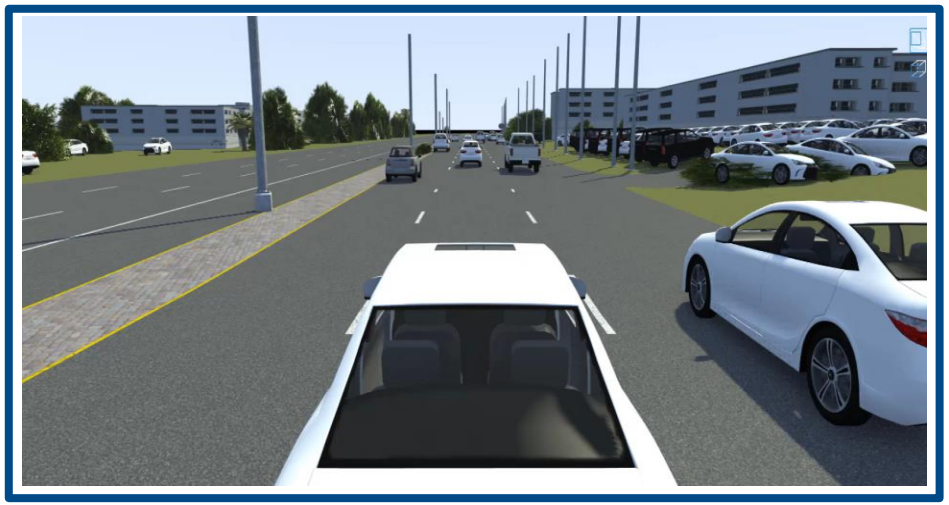


Virtual scenarios mimicking real-word sensor data

Scenario Builder for Automated Driving Toolbox

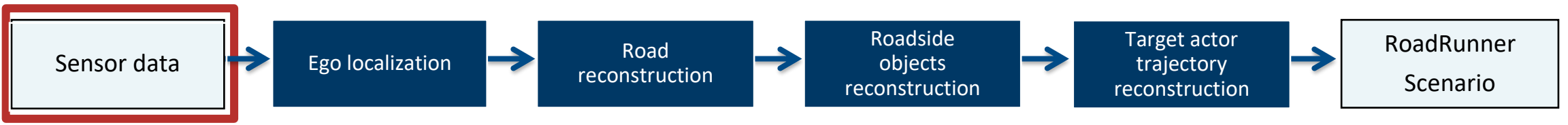
Support package shipping with Automated Driving Toolbox from **R2022b** release

Scenario Builder - workflow

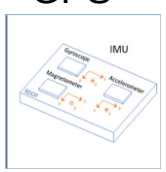


Sensor data → Ego localization → Road reconstruction → Roadside objects reconstruction → Target actor trajectory reconstruction → RoadRunner Scenario

Scenario Builder - workflow



GPS

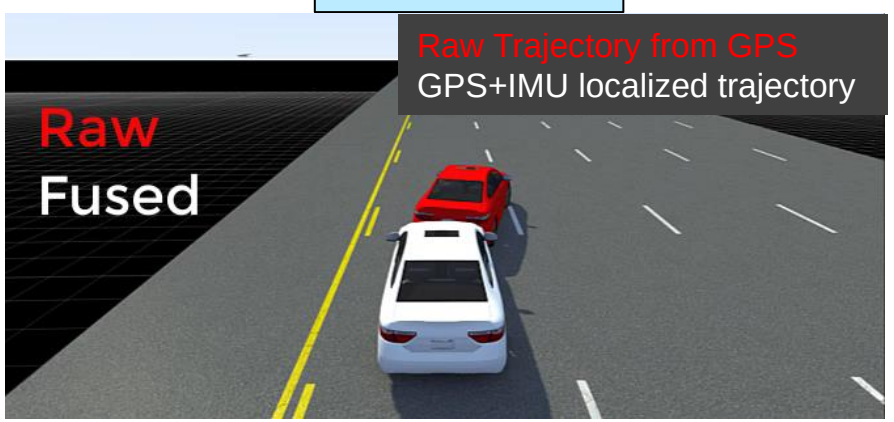


IMU

Lanes

HD Map

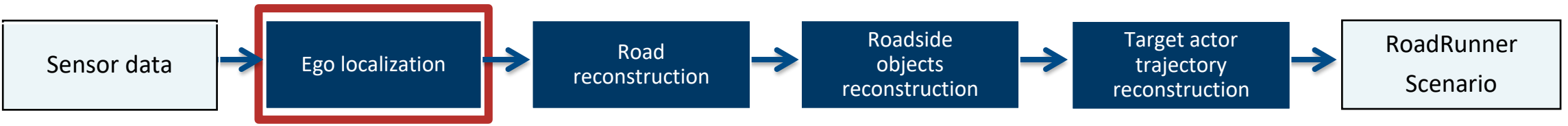
Pose correction



Offset correction

- Correct position and orientation of ego actor using GPS and IMU fusion
- Correct single/multi-lane level offsets using GPS, lane information and HD maps

Road reconstruction



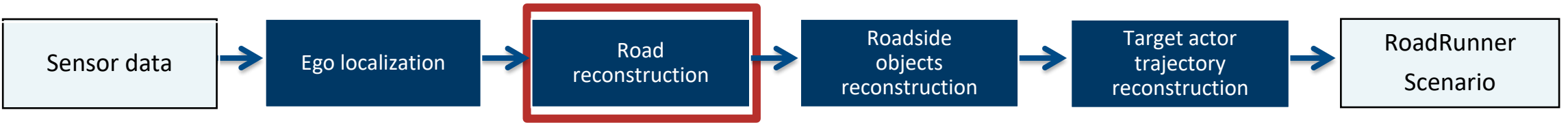

Lanes


Camera


Lidar

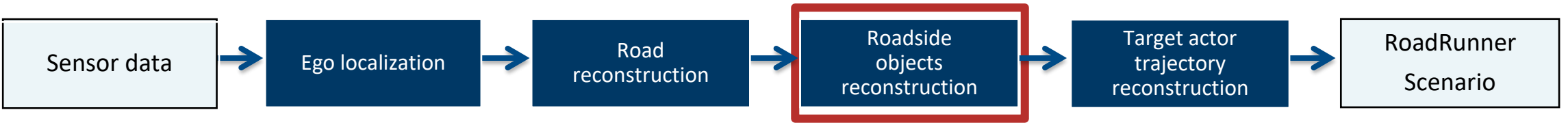
- Extract lanes, road boundaries from camera and lidar data
- Reconstruct road with lane add/drop, road curvature and junctions

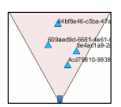
Roadside objects reconstruction



- Labelled Lidar data is used to reconstruct trees, buildings and other roadside objects.
  - Labels supported: buildings, trees, bushes, traffic cones, pylons, barricades, and electric poles
- Automate assets (trees and buildings) labelling using pre-trained models
- Alternatively use Camera + GPS to get approximate scene with roadside objects.

Trajectory reconstruction

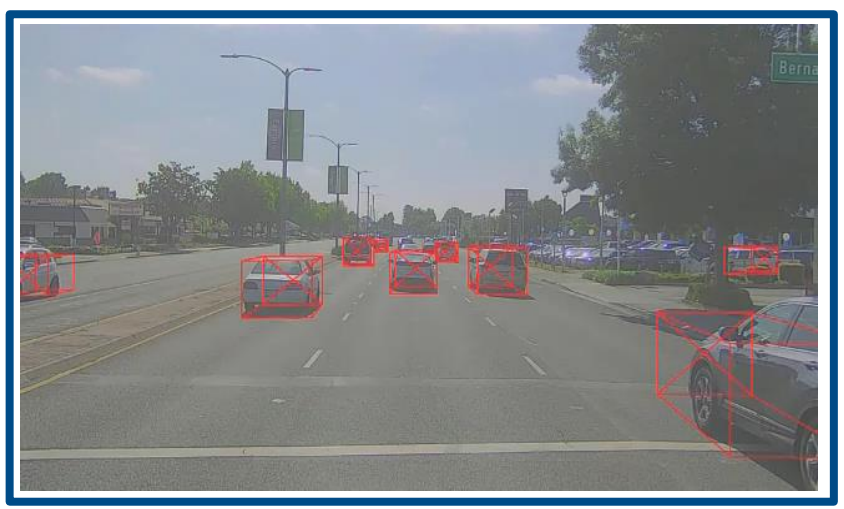


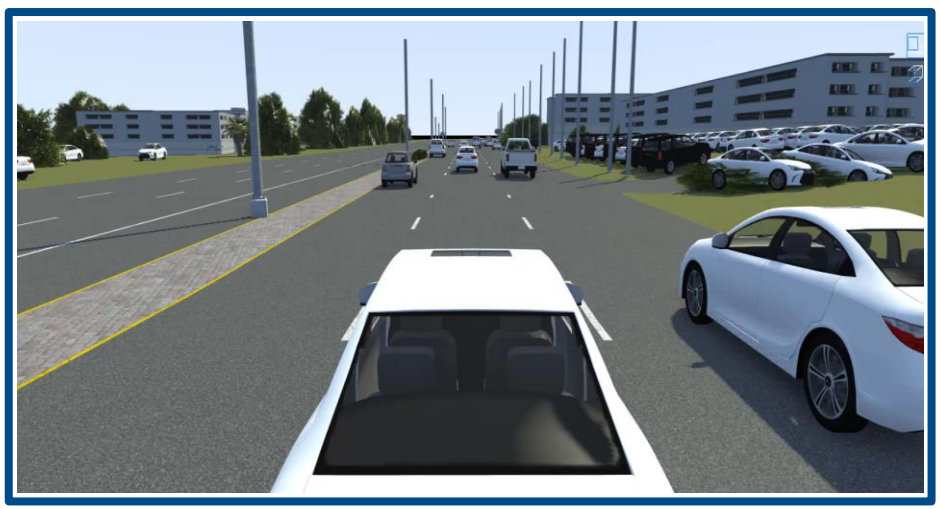

Object List


Camera


Lidar

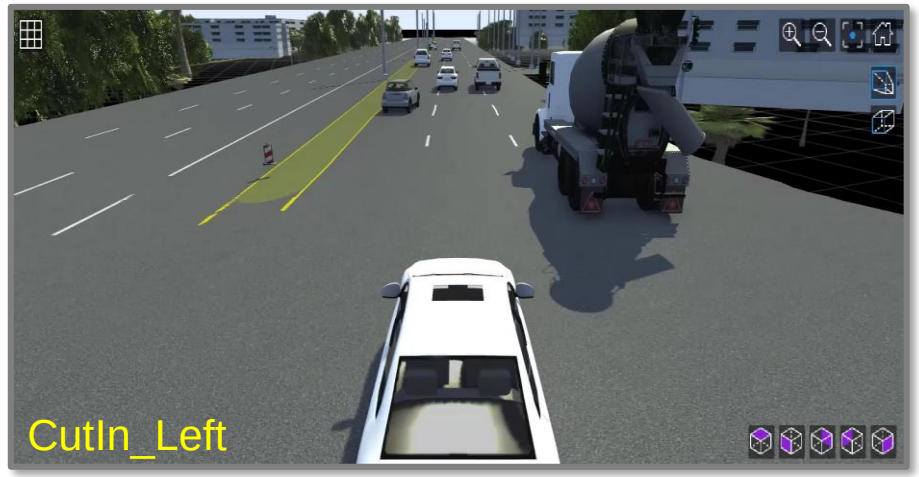

Radar

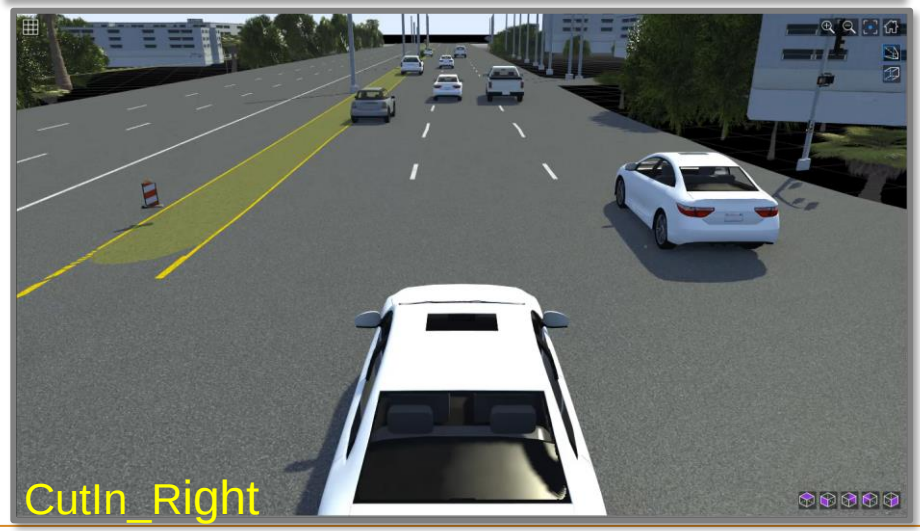


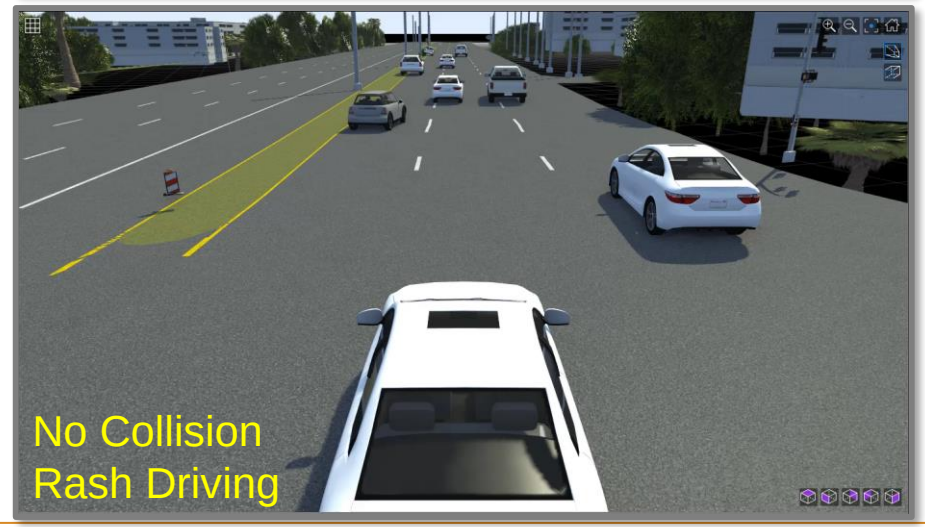


- Reconstruct dynamic actor tracklists, vehicles from camera or lidar or radar data and its combinations
- Lidar sensor data can enable extraction of objects from all the sides of the ego vehicle whereas Radar sensor data can enable farther objects.
- Camera sensor data can help identify object classes (car, truck etc.)

Variant scenarios







Develop scenarios for automated driving applications with RoadRunner Scenario

Trajectories
- CSV
- OpenSCENARIO 1.x

Automate Tasks
(import, export, set variables,…)

- MATLAB*
- C/C++
- Python
- Any gRPC supported language

RoadRunner Scenario

RoadRunner

Trajectories and logic
- OpenSCENARIO 1.x
- OpenSCENARIO 2.0

SSE

Simulate Actor Behaviors

- MATLAB*
- Simulink*
- CARLA

* = Enabled through Automated Driving Toolbox

Co-Simulation framework: RoadRunner and Carmaker

XiL integrated toolchain for ADAS V&V at BGSW:

Test Management & Automation

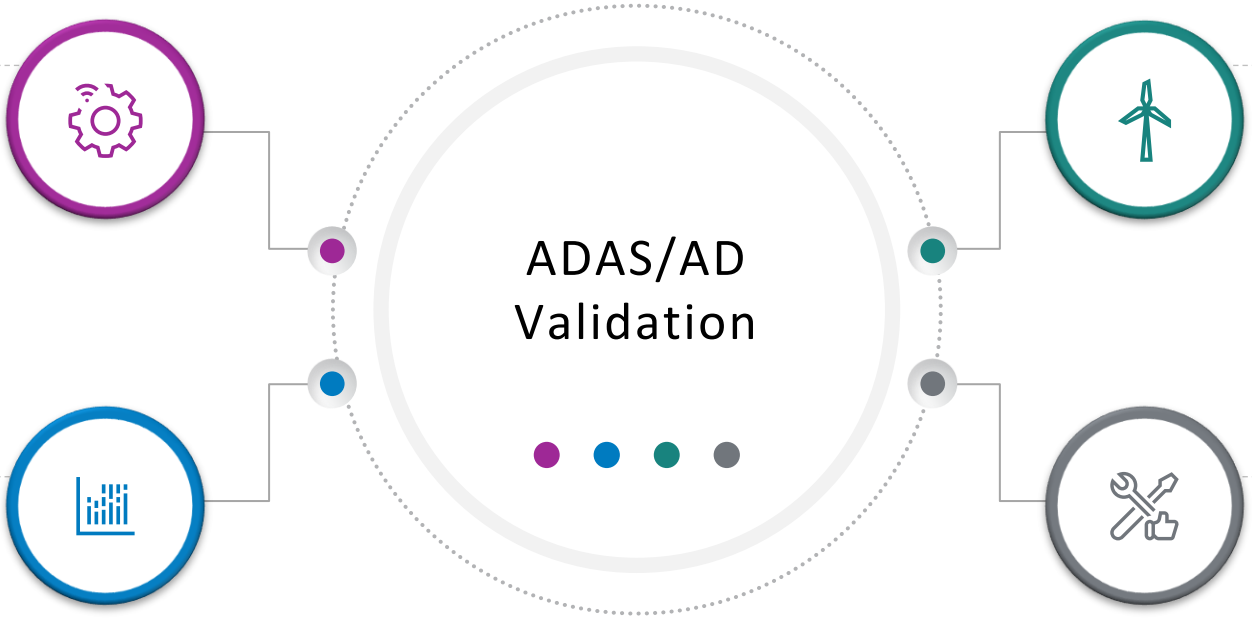
fasTest* and
ECU Test/RTF

Test Management and automation toolchain

Effective Test Scenarios

MathWorks
RoadRunner

Design of effective standard test scenarios for selected ADAS features



Environment Simulation

VTD/CARMAKER

High Fidelity Vehicle dynamics and simulation tool

XiL Integrated Middleware

ETAS COSYM

Integration of SUT and different simulators for XiL

* BGSW in-house developed tool

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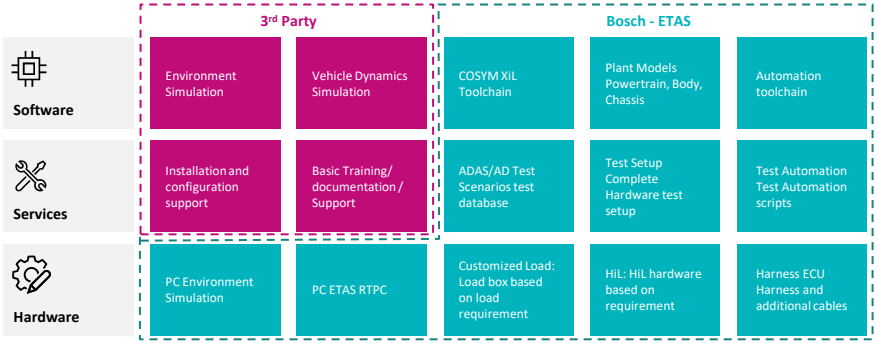
Co-Simulation framework: RoadRunner and Carmaker

ADAS reference implementation – XiL based

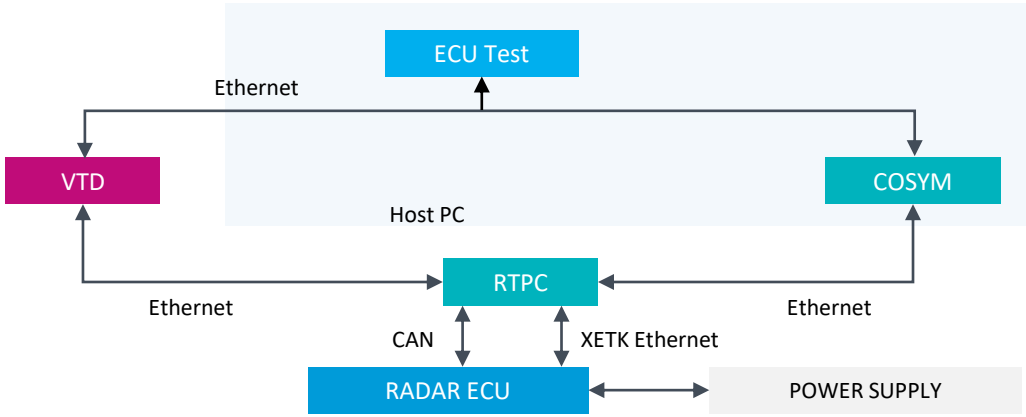
Development of XiL based hybrid ADAS validation environment with integration of

- Environment simulation tools (VTD, CarMaker, etc.)
- Co-simulation tools (like COSYM, Model connect, Silver, etc.)
- Test automation tools (like ECU test, Robot framework, etc.)
- MCD tools (like INCA, CANOE, CanAlyzer, etc.)

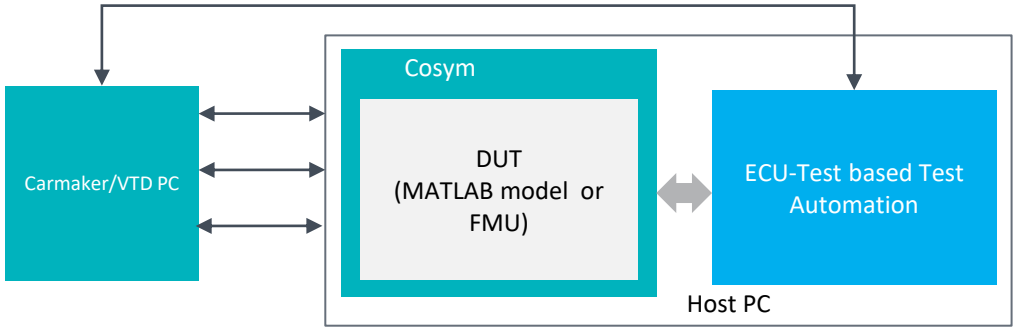
Development of database for scenario-based test cases for ADAS functions with scenarios



ADAS reference HiL based validation



ADAS reference SiL based validation



Stimuli and feedback signals

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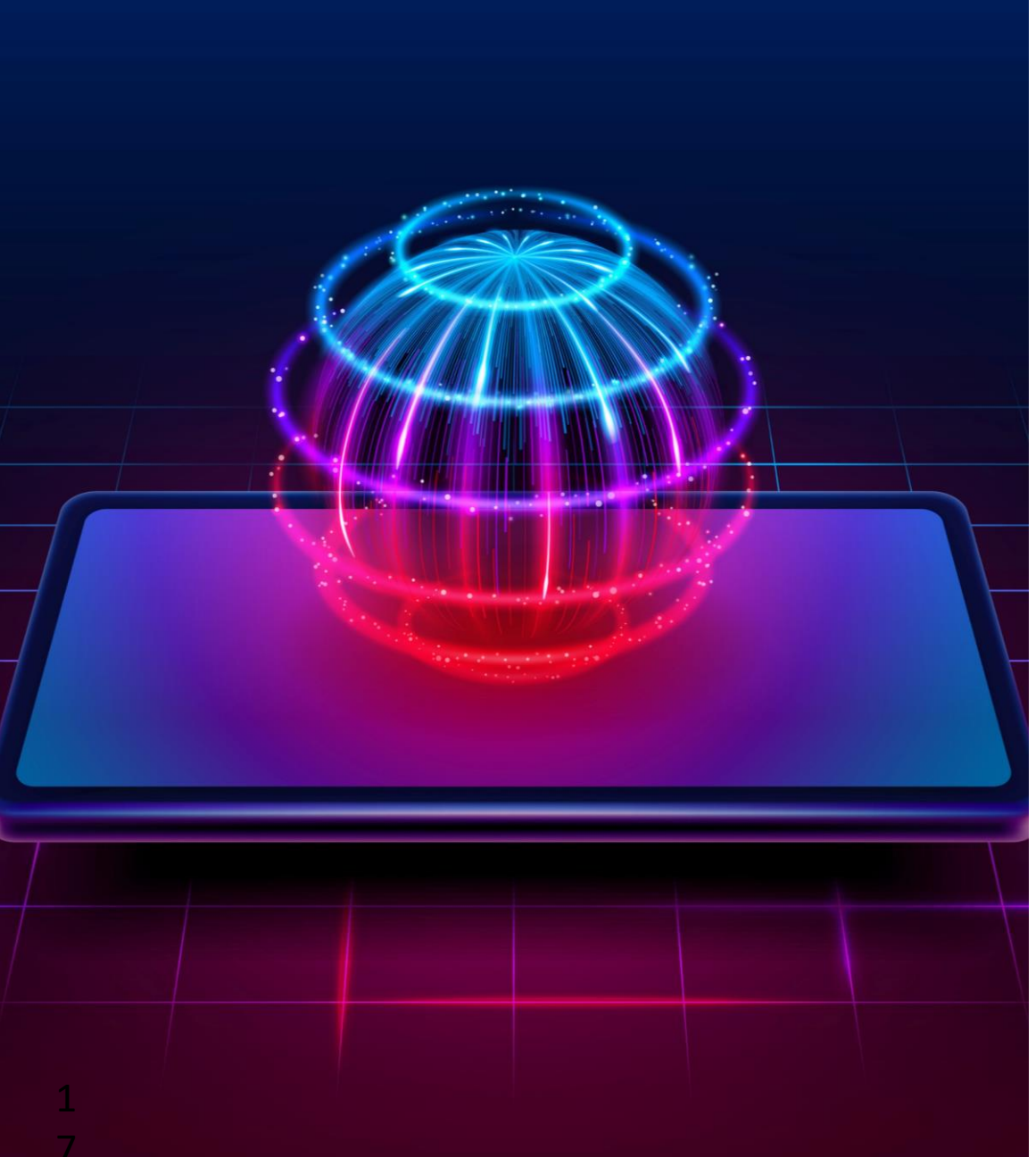
Co-Simulation framework: RoadRunner and Carmaker

Why Co-simulation?

Challenges	Solutions
1. Inclusion of unexpected or non-connected objects	1. Running different scenarios taking into account intentions
2. Scenario completeness	2. Reproduce realistic traffic behavior
3. Self organization of vehicles	3. Integration of EGO vehicle driving through the traffic simulated by the external software
4. Unrealistic/Unachievable scenario	4. Export the same scenario to multiple simulators
5. openSceanrio is not compatible with all simulators	



Co-Simulation framework: RoadRunner and Carmaker

Scenario Simulation

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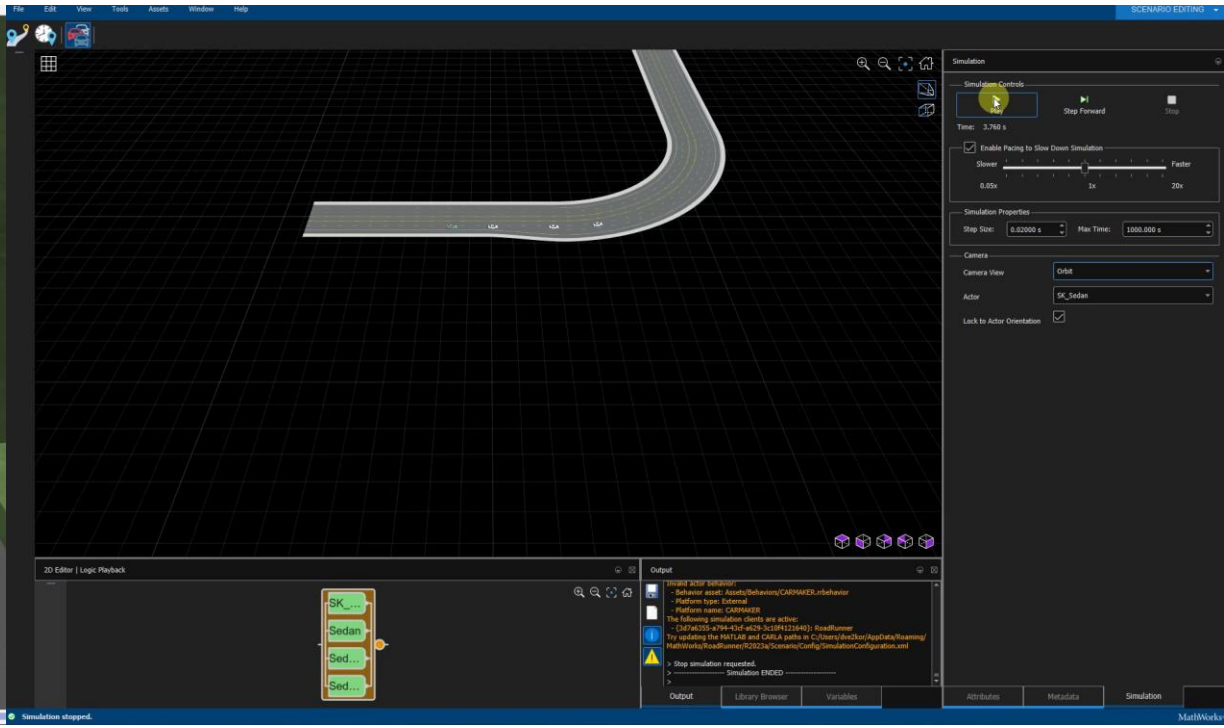
Co-Simulation framework: RoadRunner and Carmaker

Why Co-simulation?

Carmaker



RoadRunner

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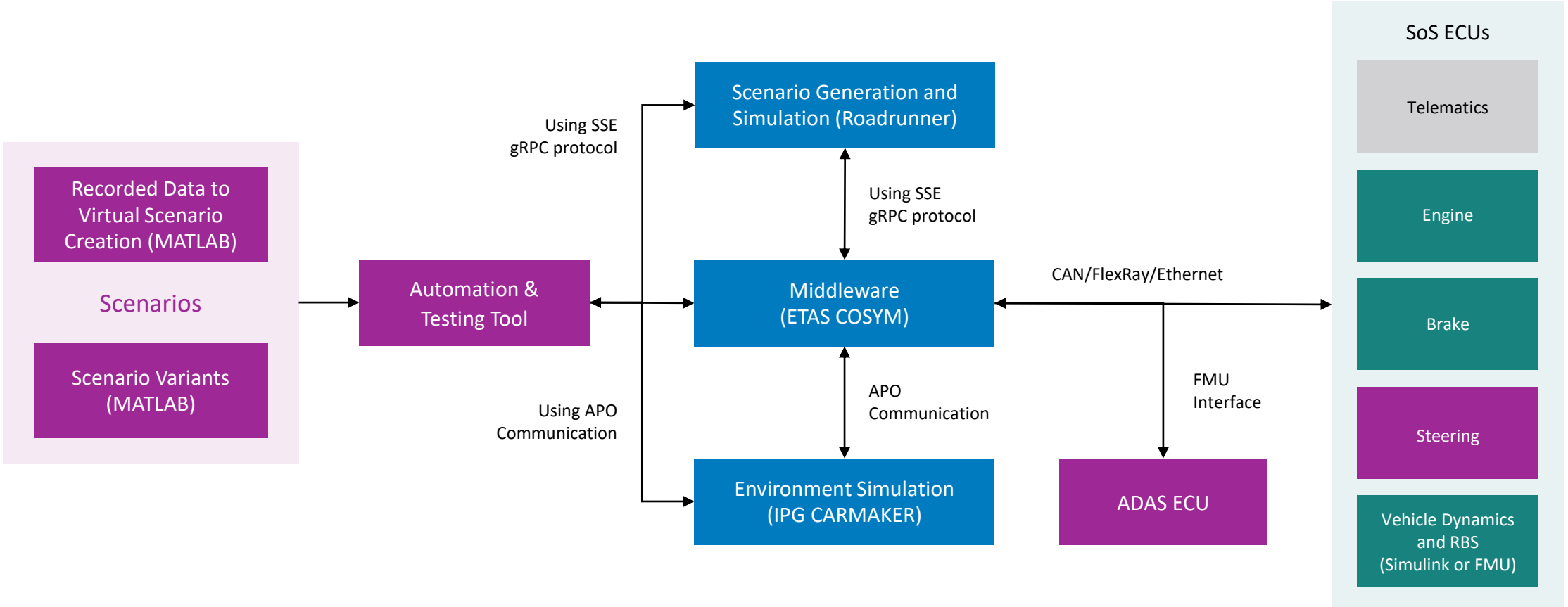
Co-Simulation framework: RoadRunner and Carmaker

Scenario Simulation: Validation Setup



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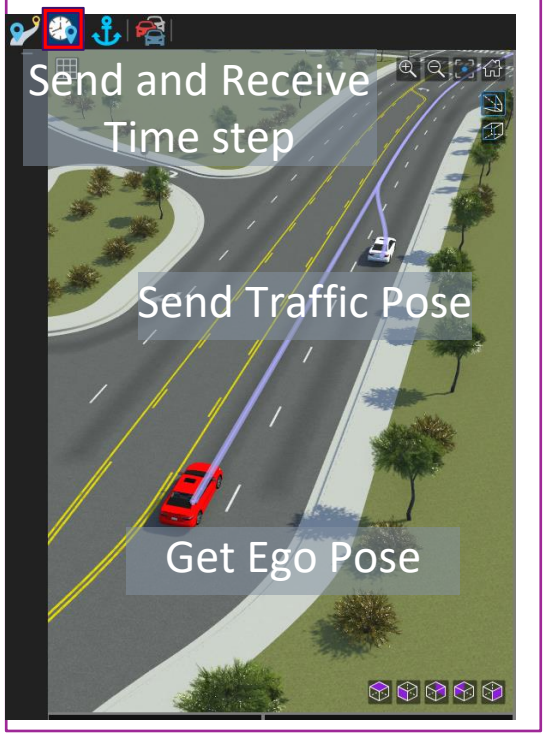
Co-Simulation framework: RoadRunner and Carmaker

Scenario Simulation: Data Exchange Mechanism

Scenario Generation and Simulation (Roadrunner)



Using SSE gRPC protocol

Client (ETAS COSYM/ Application Exe)

1. SSE Initialization
2. Download Scenario for traffic vehicles
3. Get Actor list from RoadRunner
4. Initialize Carmaker
5. Get Ego Vehicle initial position from Carmaker
6. Get Timestep from RoadRunner and send to Carmaker
7. Establish time step synchronization
8. Data exchange of Ego vehicle and Traffic Actors between RoadRunner and Carmaker
9. Sensor and Actuator data exchange between vECU and Carmaker

APO Communication

Environment Simulation (IPG CARMAKER)

1. Receive Traffic Actors Details
   - X,Y,Z Position of each actor
   - Rotation angles Roll, Pitch, Yaw
2. Send Ego Vehicle Data
   - Position X,Y,Z
   - Rotation angles at each simulation step
3. Time Step
   - Time step value at each simulation step
4. Send Object Sensor data
5. Receive Actuator Data

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Co-Simulation framework: RoadRunner and Carmaker

Actors Position Update

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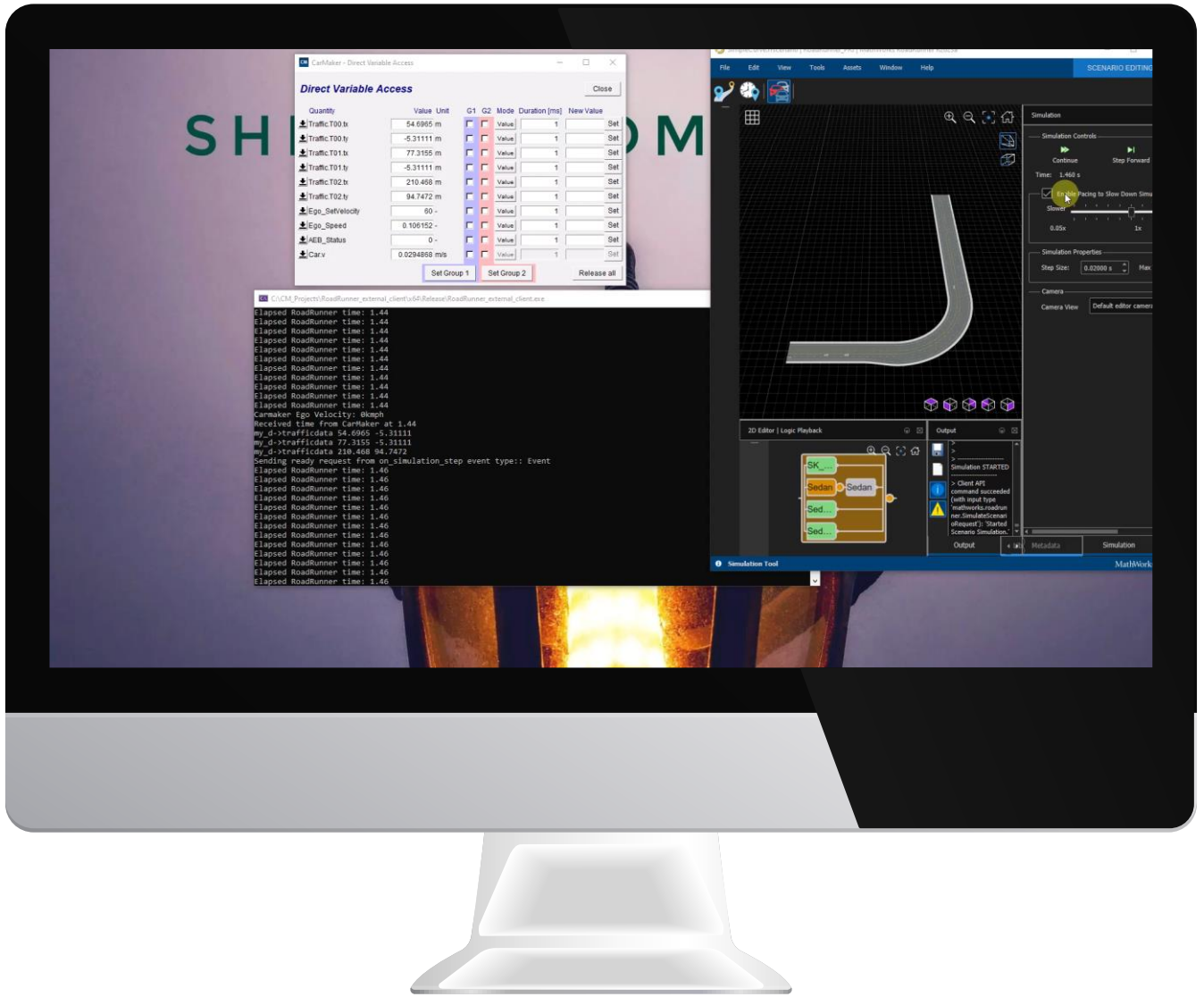

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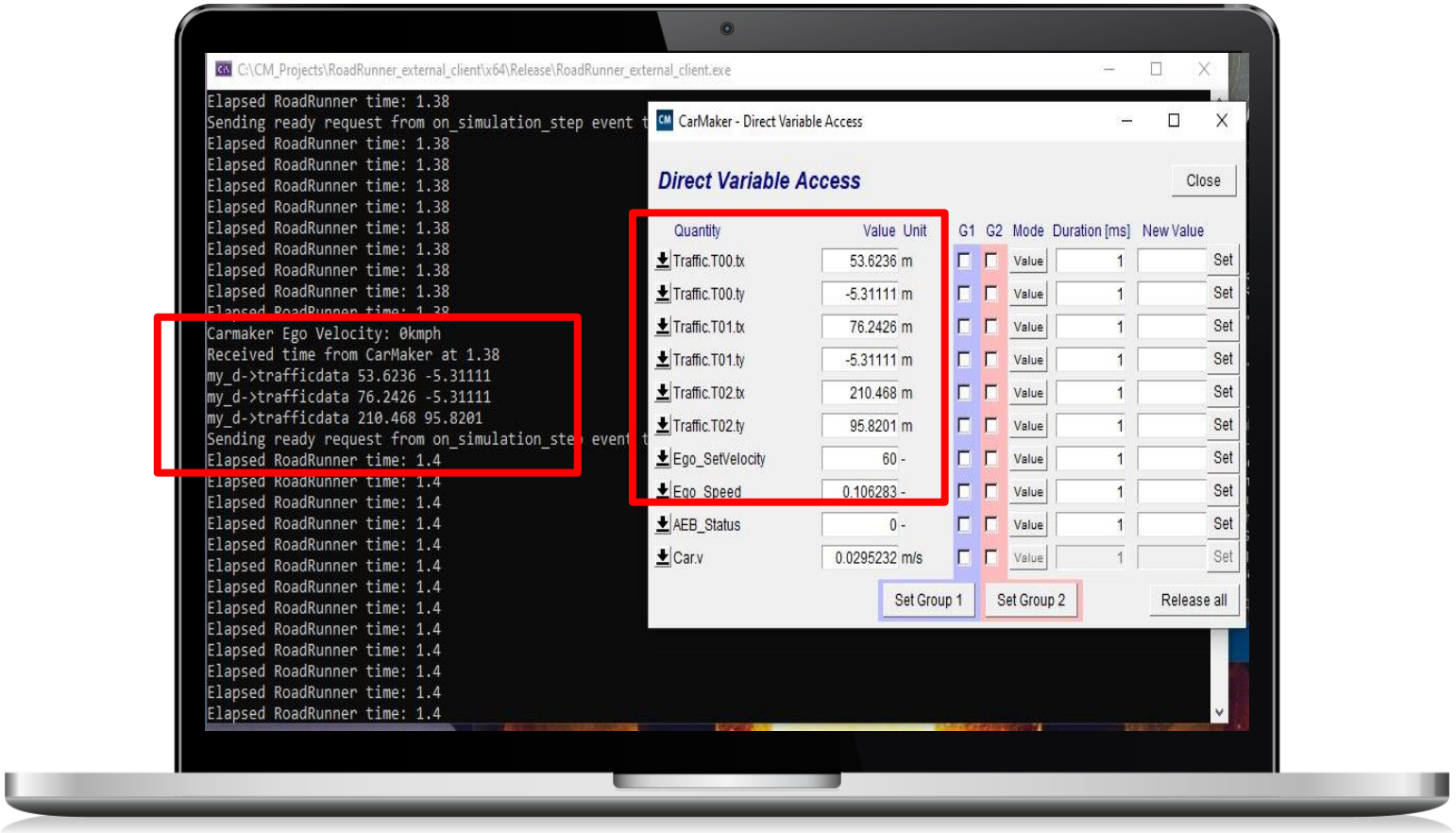
Co-Simulation framework: RoadRunner and Carmaker

Scenario Simulation: Vehicles Position Synchronization



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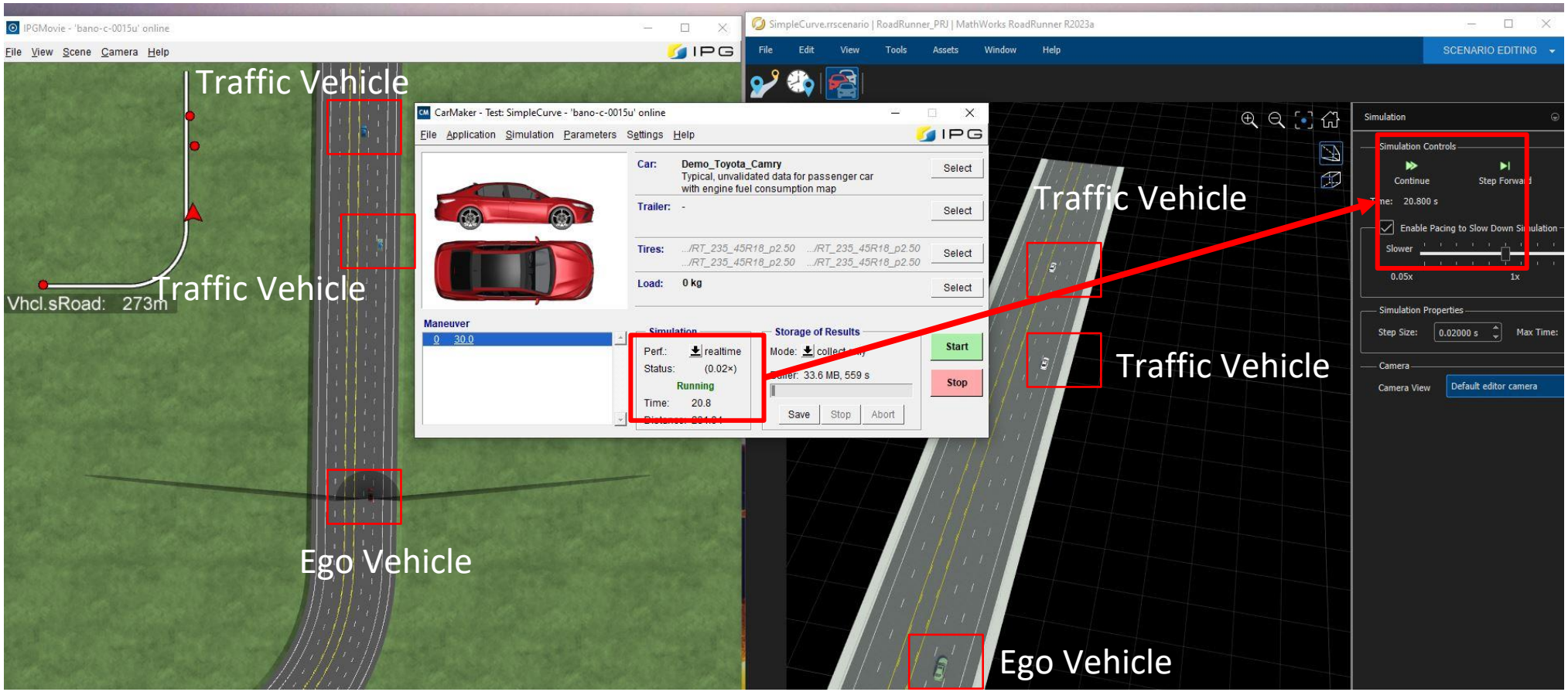
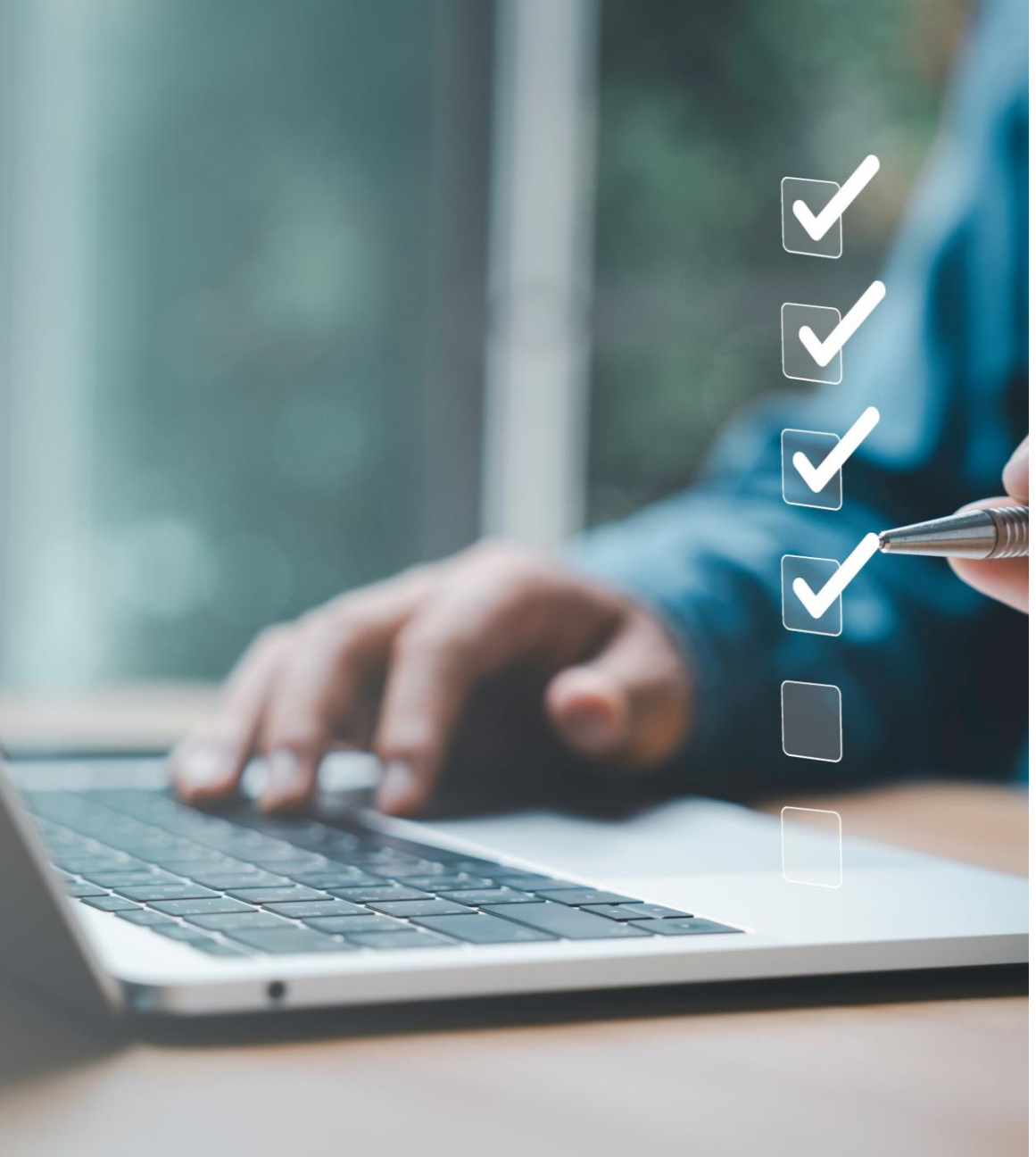
Co-Simulation framework: RoadRunner and Carmaker

Scenario Simulation: Time Synchronization



BOSCH



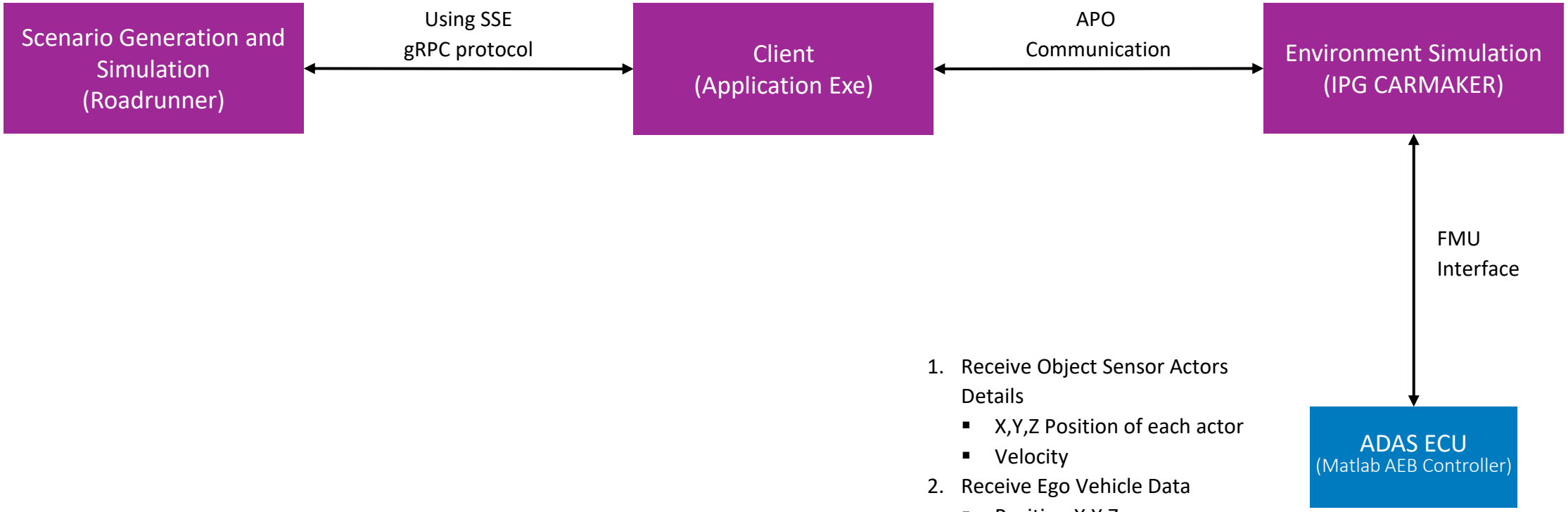
Co-Simulation framework: RoadRunner and Carmaker

AEB Controller Validation

BOSCH

Co-Simulation framework: RoadRunner and Carmaker

AEB Controller Validation: Approach 1 using Visual Studio



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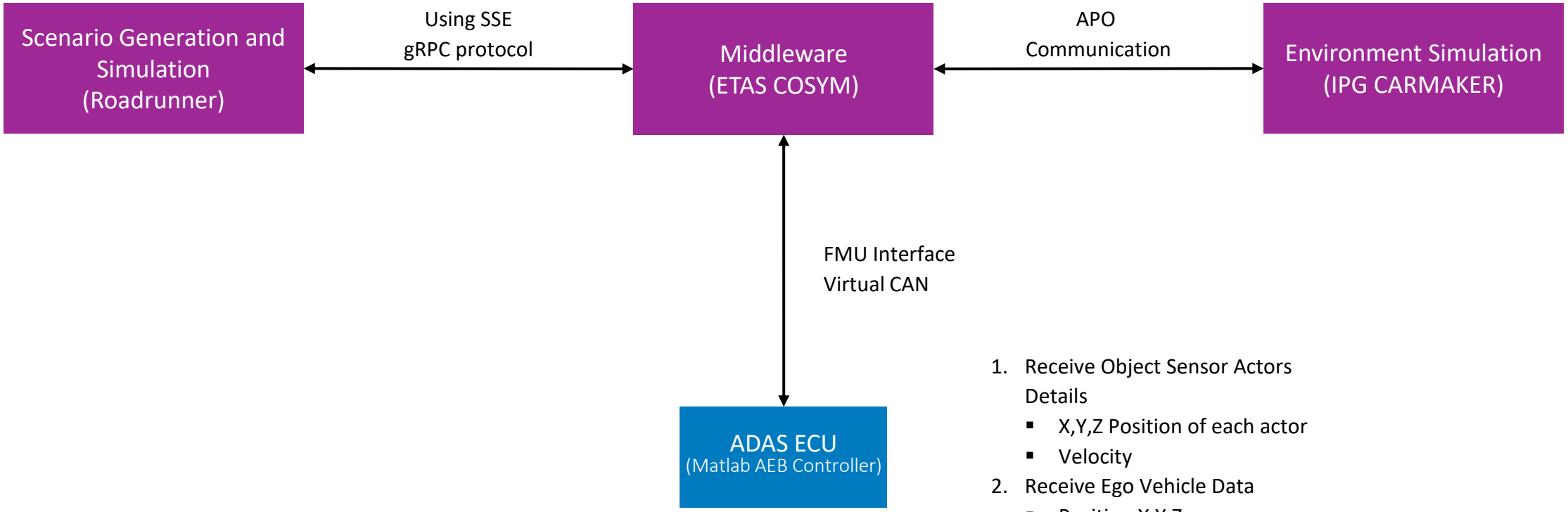
Co-Simulation framework: RoadRunner and Carmaker

AEB Controller Validation: FMU inside Carmaker

BOSCH

Co-Simulation framework: RoadRunner and Carmaker

AEB Controller Validation: Approach 2 using ETAS COSYM



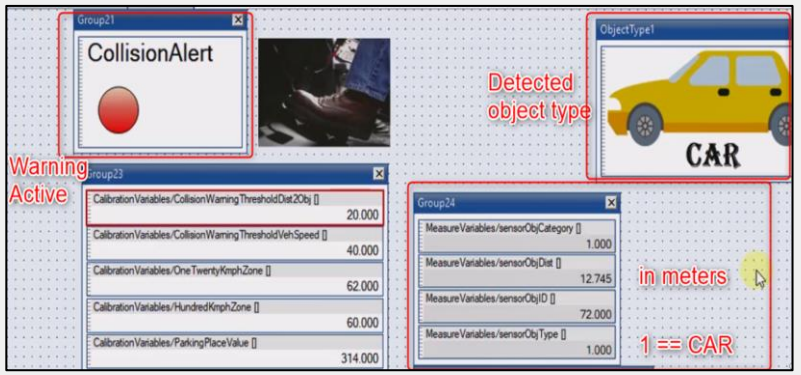
1. Receive Object Sensor Actors Details
   - X,Y,Z Position of each actor
   - Velocity
2. Receive Ego Vehicle Data
   - Position X,Y,Z
   - Velocity
3. Send Acceleration, Brake values

Co-Simulation framework: RoadRunner and Carmaker

AEB Controller Validation: ETAS COSYM Labcar Experiement

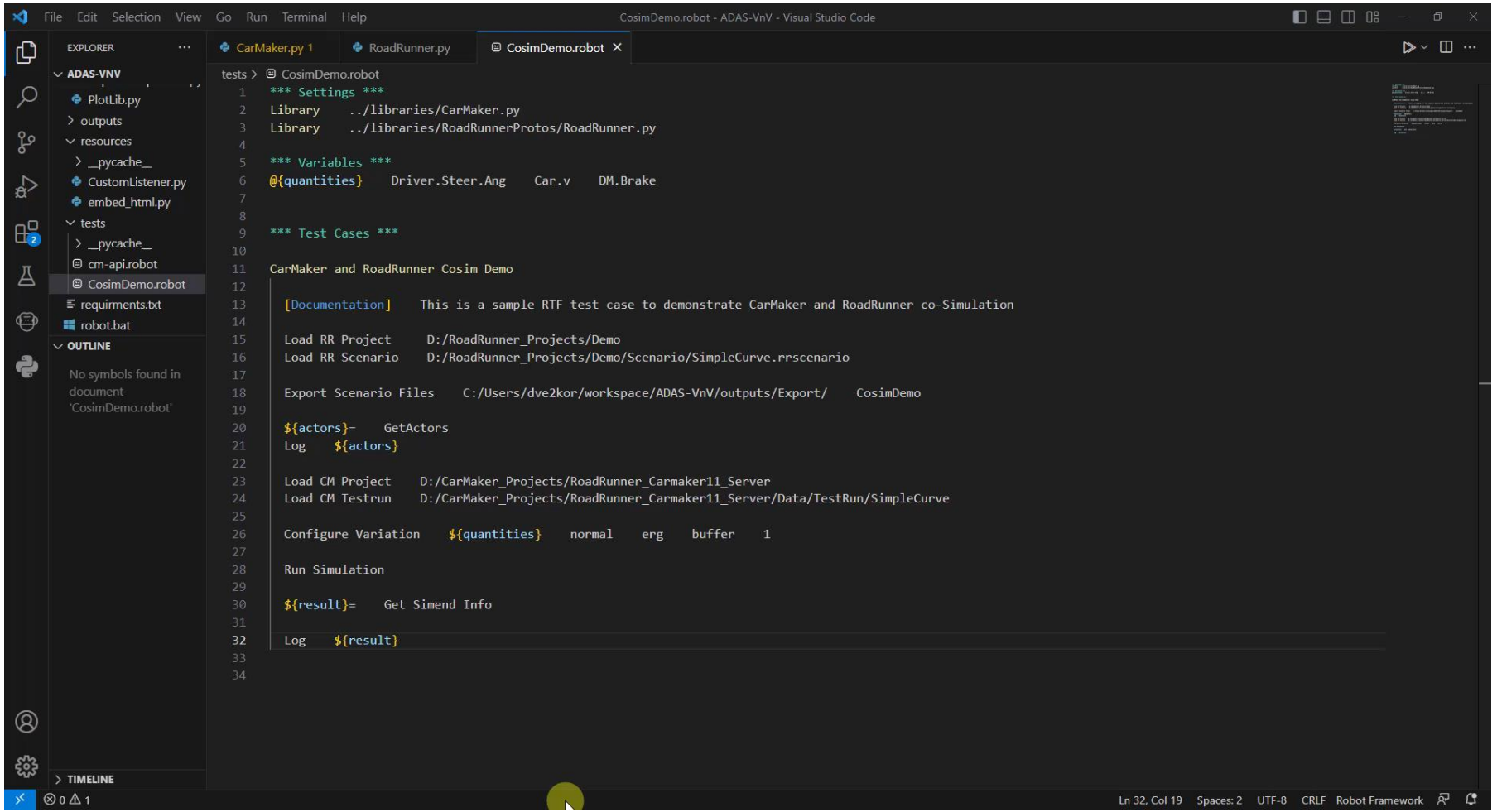
	A	B	C	D	E	F	G
1	Test Scenario #	Test Description					
	AEB_Scenario1	Ego/Host Vehicle is approaching target vehicle when multiple Obstacles are around the scenario.					
2							

UUT→ Front object detection and warning



Co-Simulation framework: RoadRunner and Carmaker

Test Automation: Robot Framework



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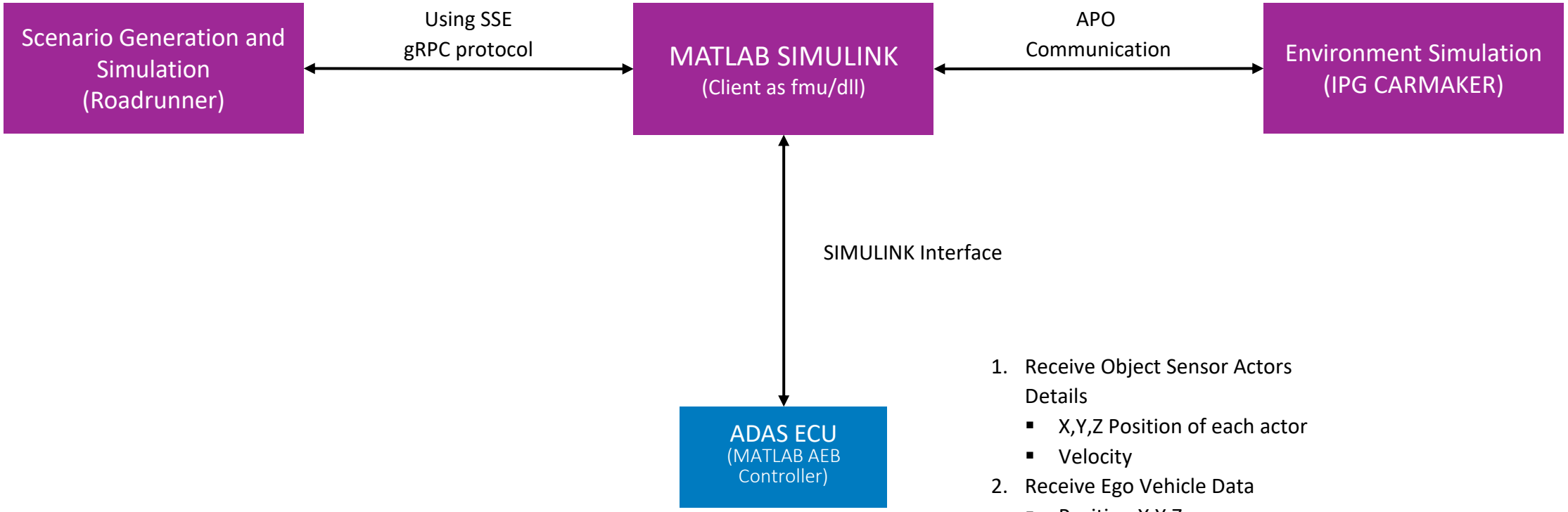
Co-Simulation framework: RoadRunner and Carmaker

AEB Controller Validation: Approach 3 (Future Focus)



1. Receive Object Sensor Actors Details
   - X,Y,Z Position of each actor
   - Velocity
2. Receive Ego Vehicle Data
   - Position X,Y,Z
   - Velocity
3. Send Acceleration, Brake values

Co-Simulation framework: RoadRunner and Carmaker

Benefits:

- Interactive traffic simulation ensuring a realistic traffic environment
- Accurate traffic conditions for testing different traffic scenarios

Questions?

Thank you!

BOSCH