

MATLAB EXPO

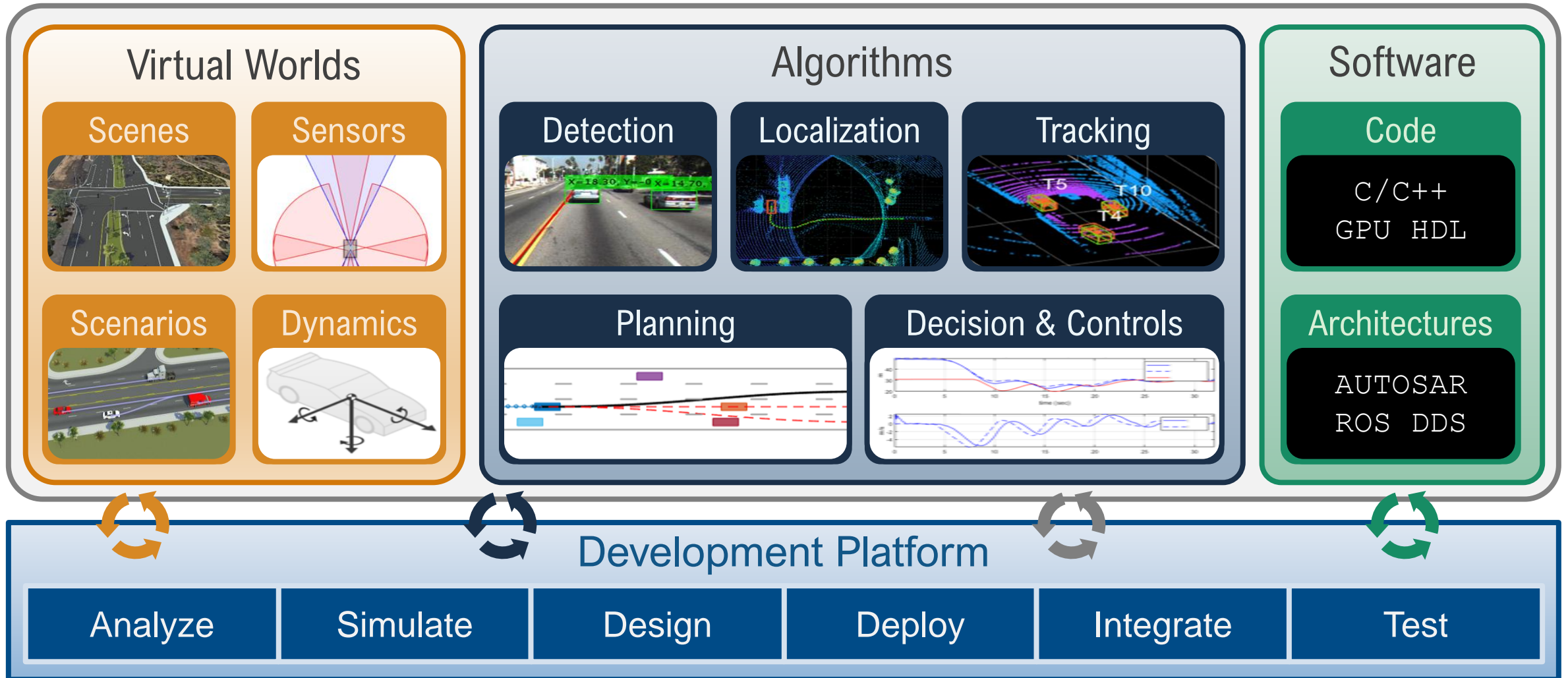
자율 주행 시스템을 위한 테스트 시나리오 개발

김종헌 부장, 매스웍스코리아

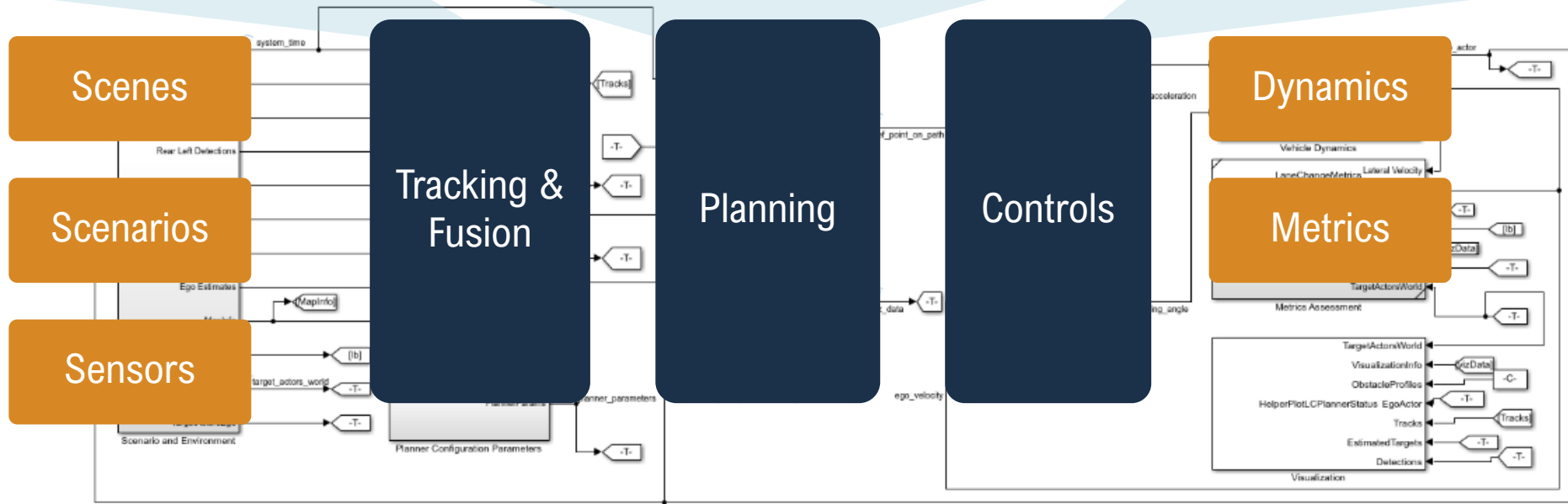
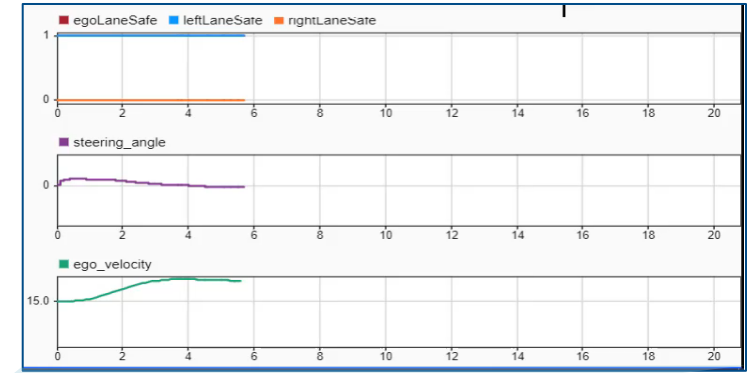
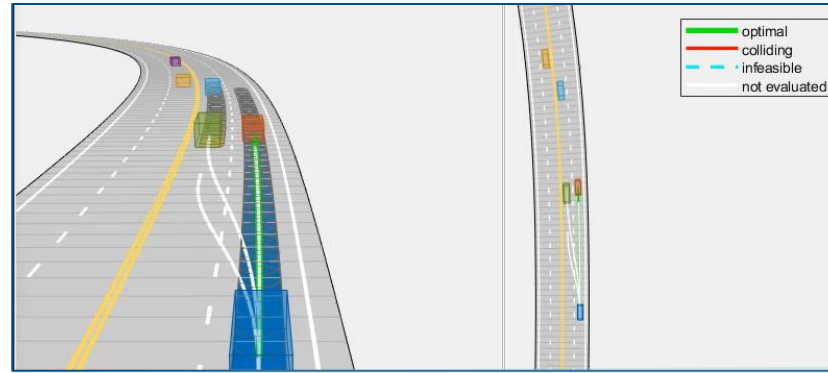
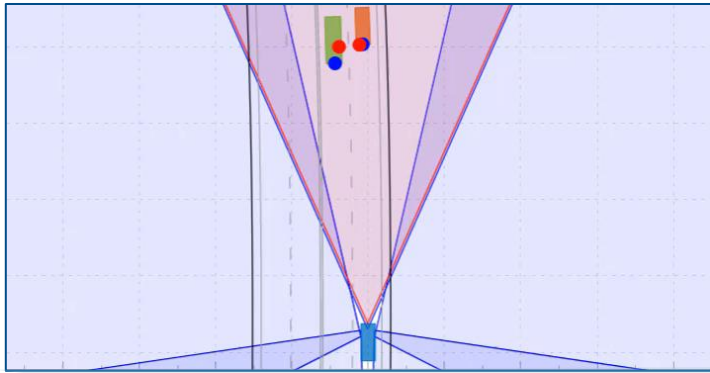


Develop Automated Driving Applications

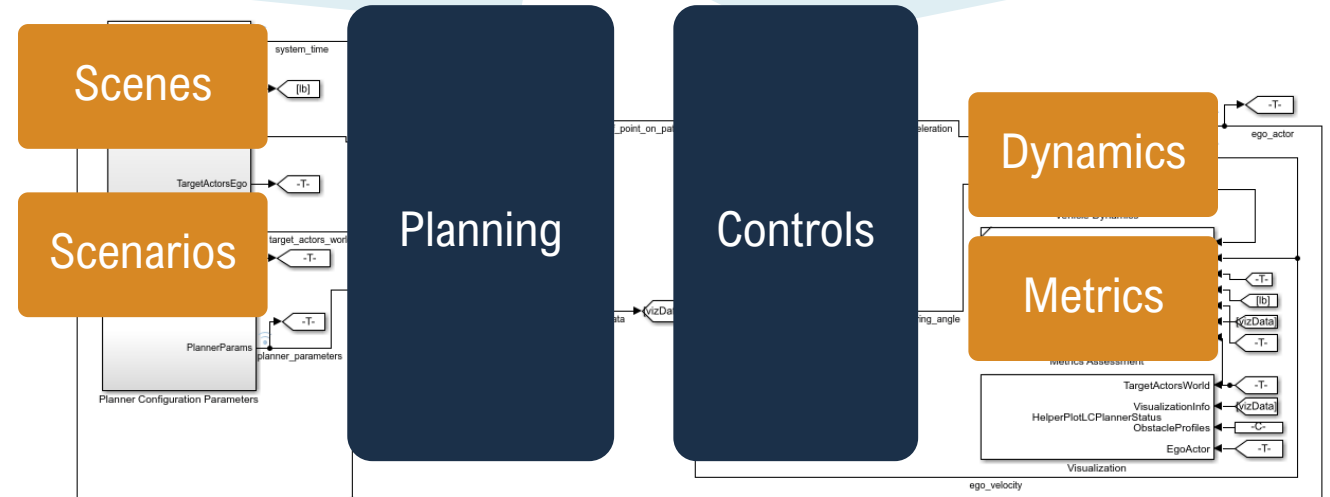
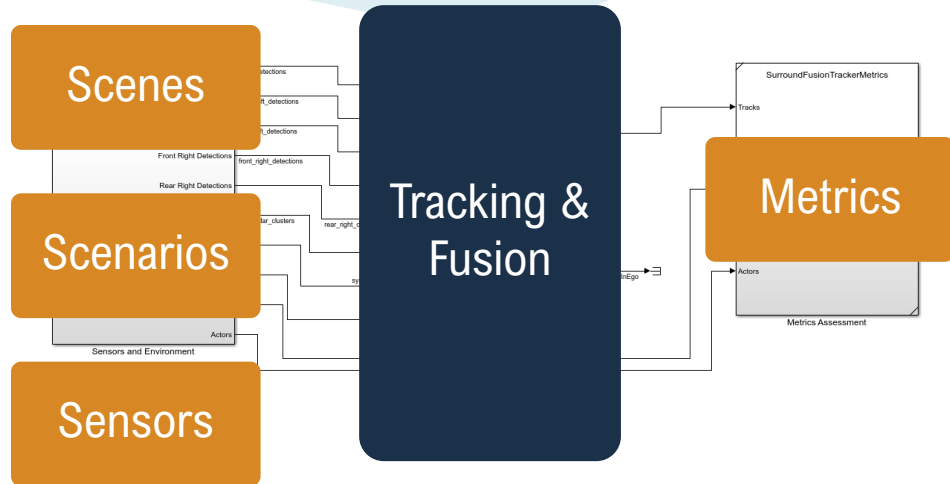
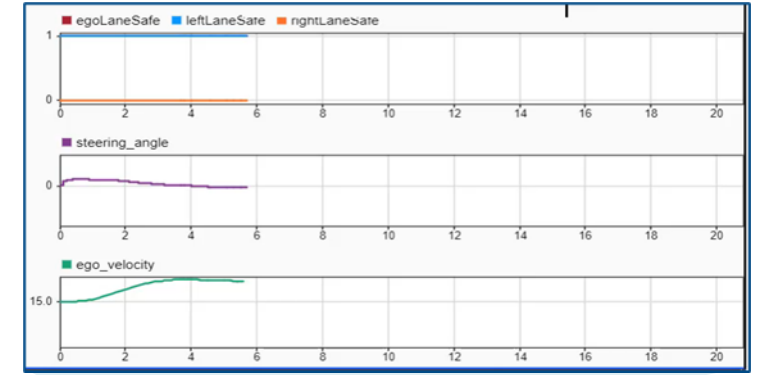
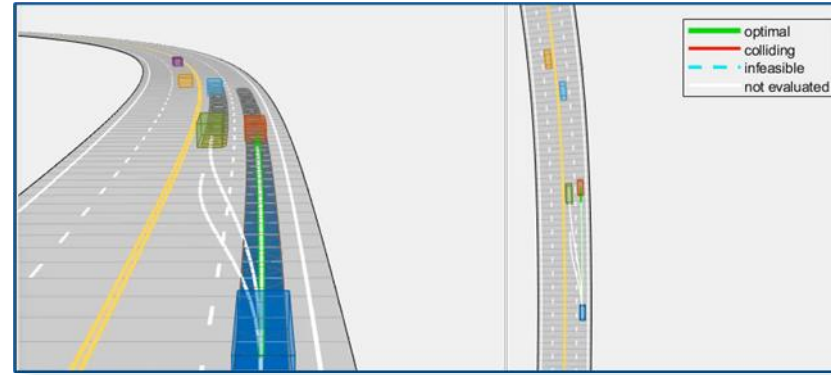
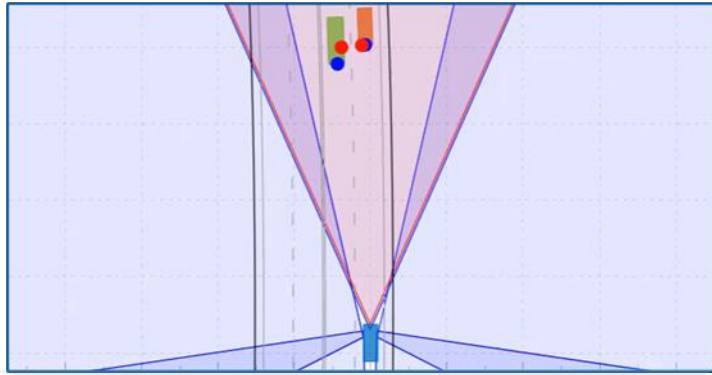
with MATLAB, Simulink, & RoadRunner



Develop virtual worlds for automated driving applications

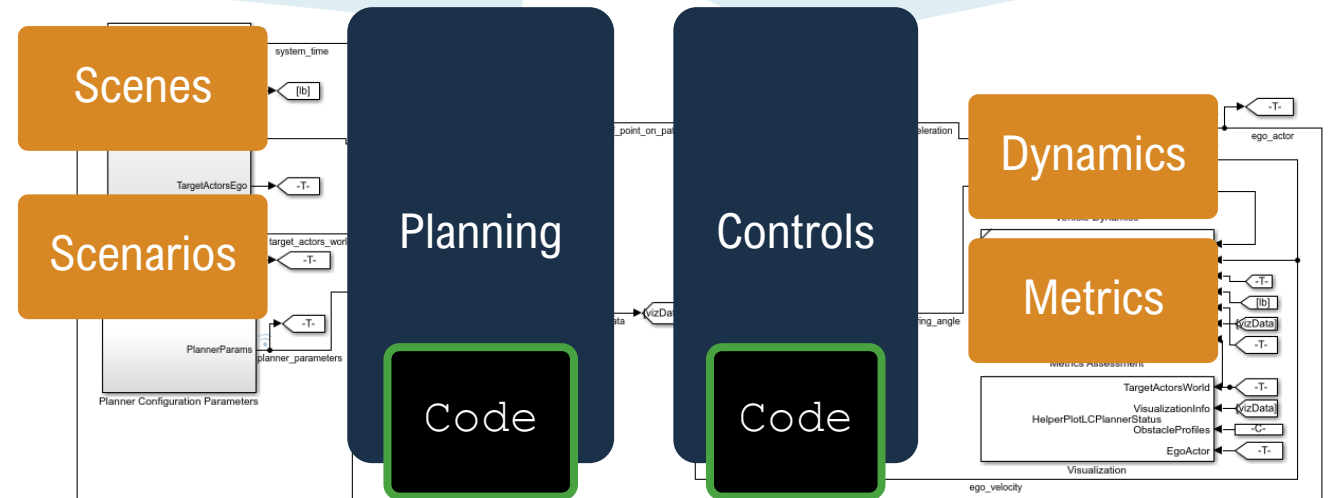
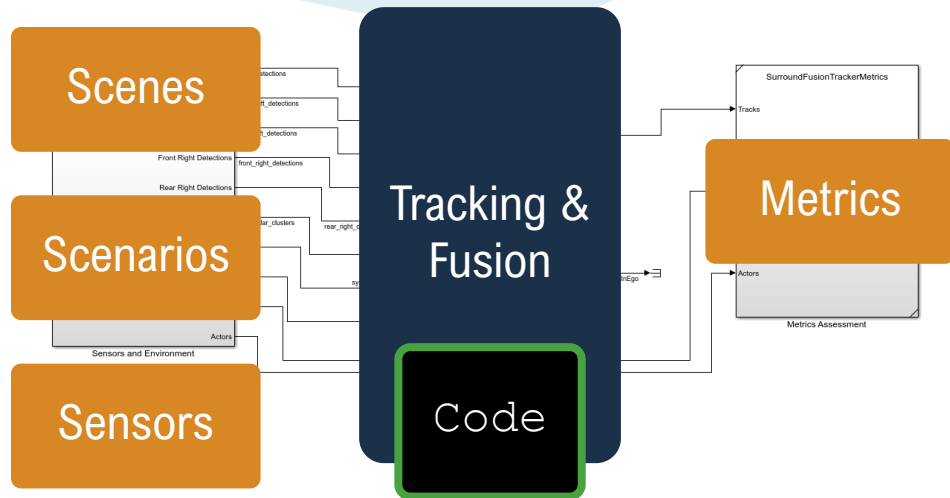
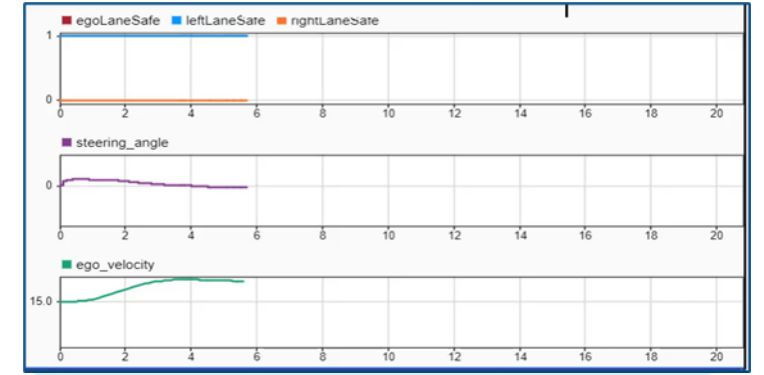
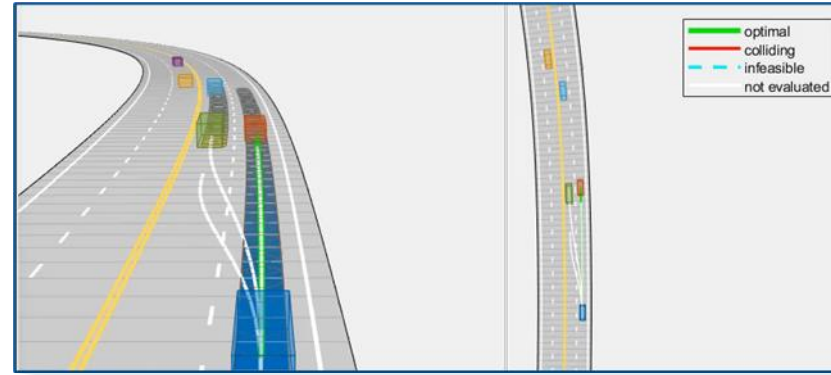
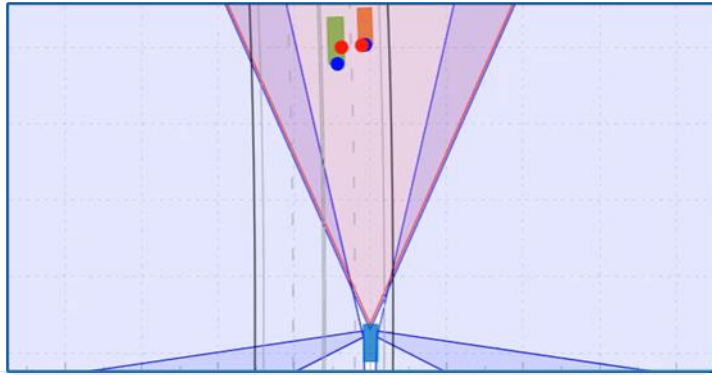


Develop algorithms for automated driving applications



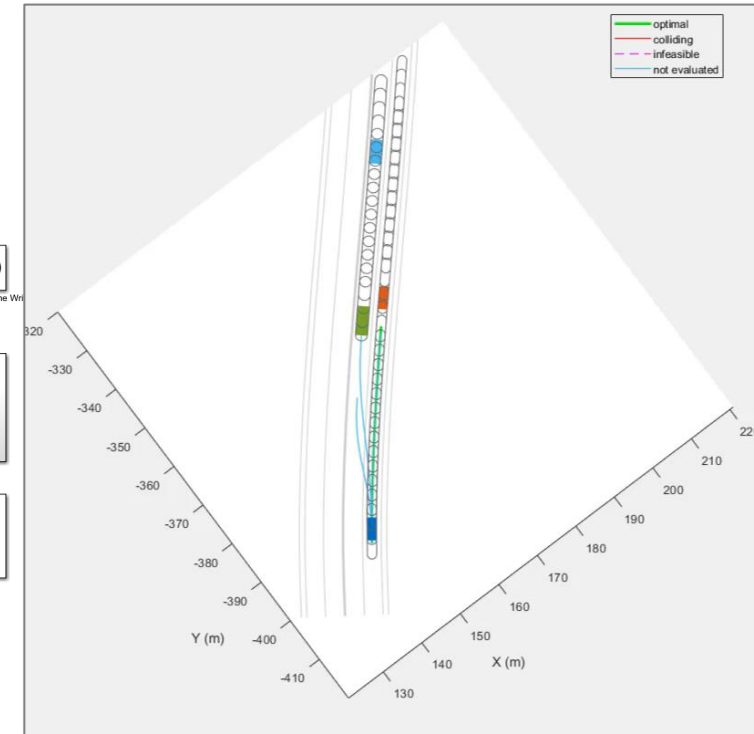
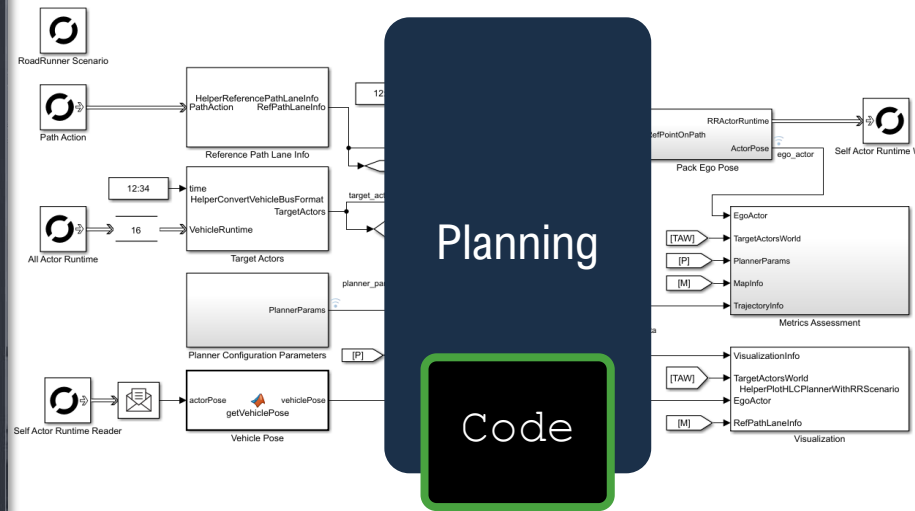
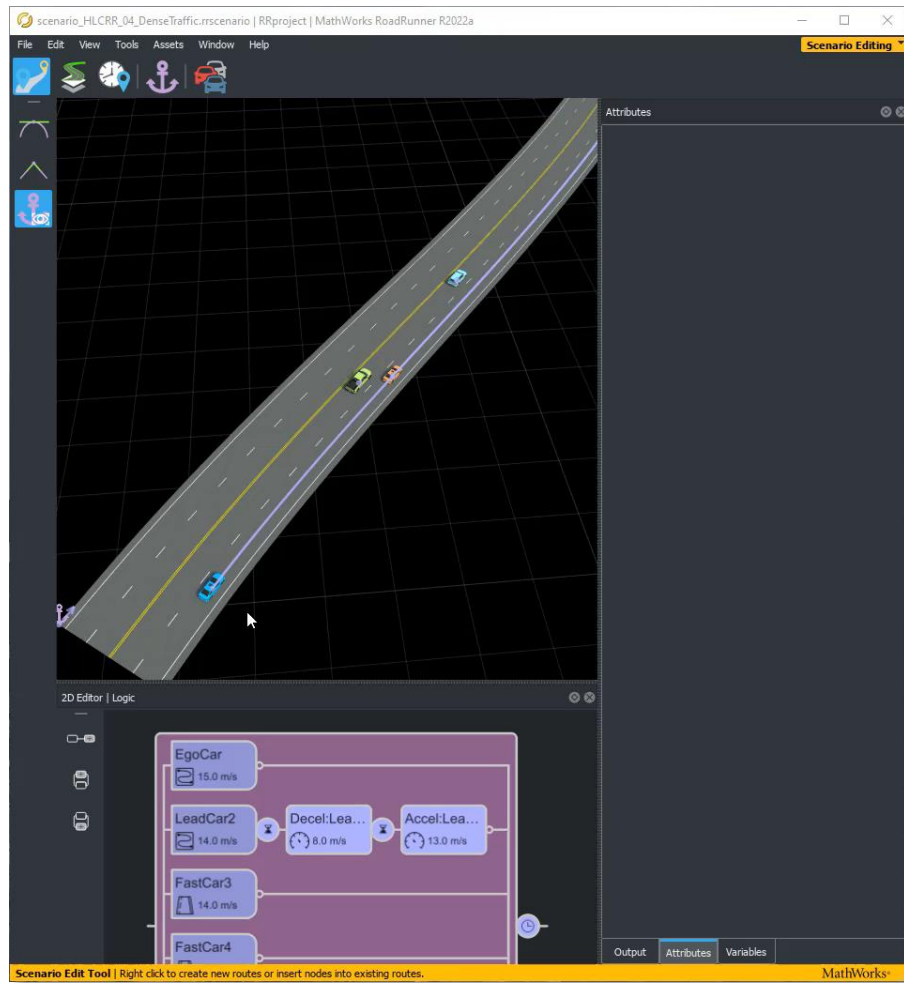
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Develop software for automated driving applications



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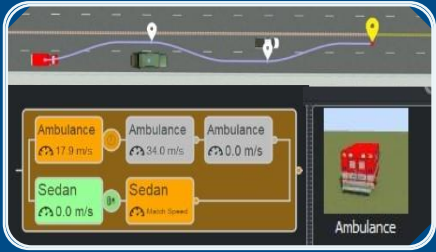
Develop scenarios for automated driving applications



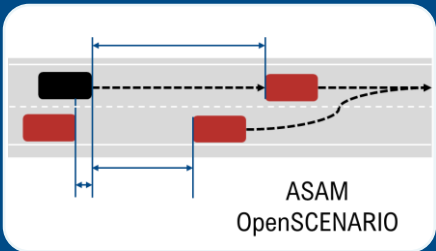
Set map-aware vehicle paths, scenario logic, conditions and goals

[Highway Lane Change Planner with RoadRunner Scenario](#)

Develop Scenarios for Automated Driving Applications with RoadRunner Scenario



Design and Simulate Scenarios

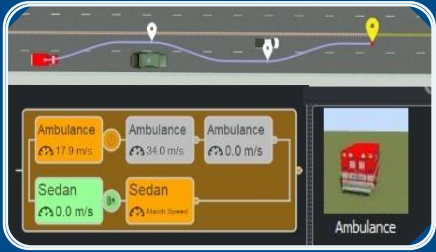


Interface with OpenSCENARIO

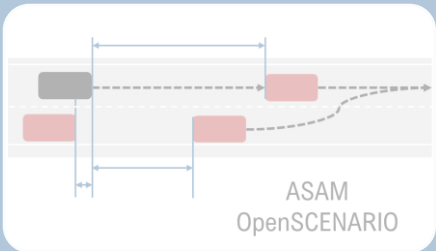


Simulate with MATLAB, Simulink, and CARLA

Develop Scenarios for Automated Driving Applications with RoadRunner Scenario



Design and Simulate Scenarios



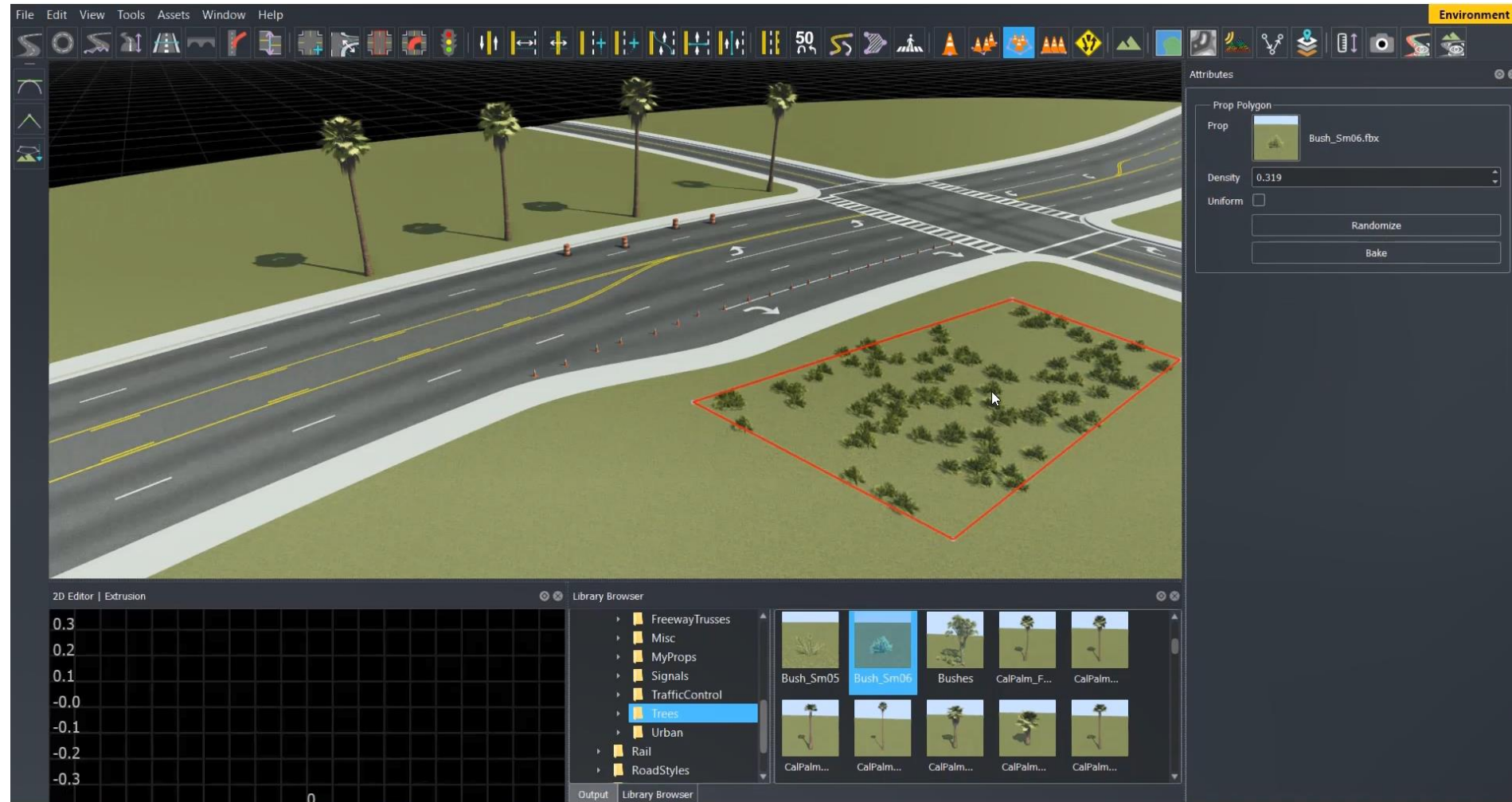
Interface with OpenSCENARIO



Simulate with MATLAB, Simulink, and CARLA

Interactively design scenes with RoadRunner

- Author realistic roads and intersections
- Import/export OpenDRIVE
- Import HD maps
- Import Geographic Information System (GIS) files
- Export to common driving simulation environments



Interactively design scenarios with RoadRunner Scenario

- Add various vehicles
- Author trajectories
- Specify actions and logic
- Parameterize variations

SpeedBump Actions.rsscenario | 22a Project | MathWorks RoadRunner R2022a

Simulation

Simulation Controls

Pause Step Forward Stop

Time: 1.640 s

Enable Pacing to Slow Down Simulation

Slower 0.05x 1x 20x Faster

Simulation Properties

Step Size: 0.02000 s Max Time: 1000.000

Camera

Camera View: Follow

Actor: Car

Distance: 5.000

Height: 3.000

Name	
1 Hatchback_InitialSpeed	14
2 Car_NumLanesToChange	2
3 Car_LaneChangeDirection	LeftOf
4 Car_DistanceBehindSpeedBump	-17.98385

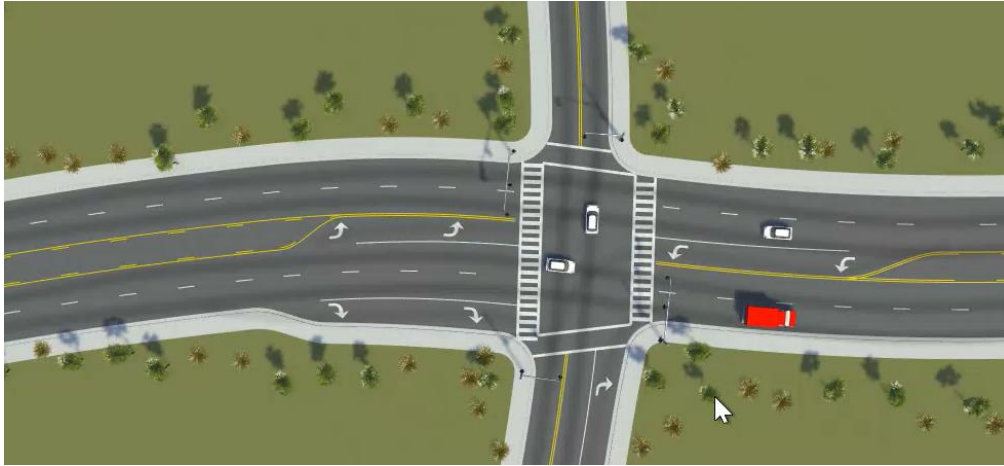
Simulation Tool

[Scenario Edit Tool](#)
RoadRunner Scenario

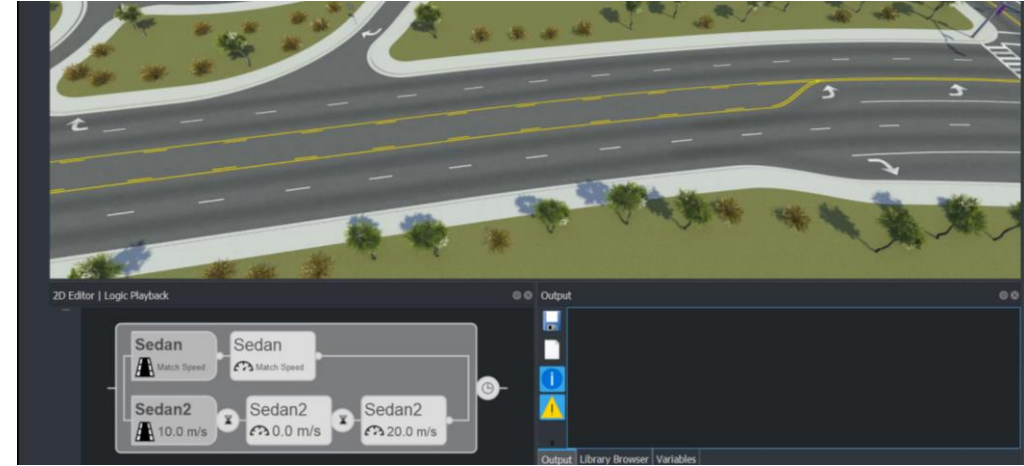
R2022a

Simulate map-aware paths and scenario logic

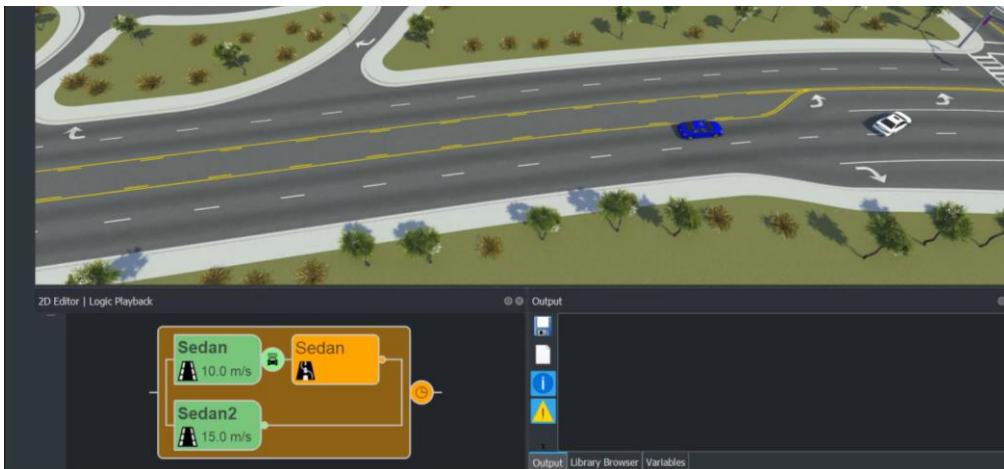
Follow lanes when no path is specified



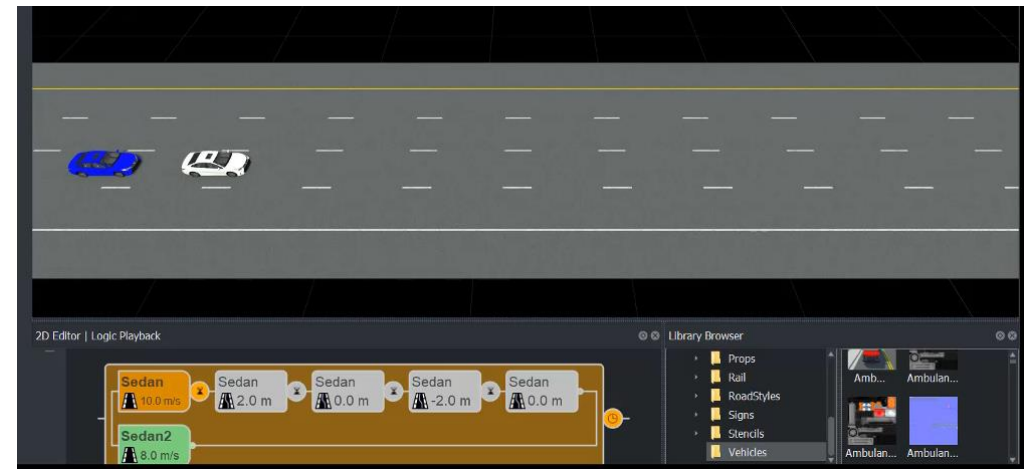
Speed actions



Lane change actions



Lateral offset actions



Design actor paths and trajectories

- Cubic interpolation
- Clothoid interpolation
- EuroNCAP
(clothoid-arc-clothoid)

NCAP_example.rsscenario | Project_Beta10 | MathWorks RoadRunner R2022a

Attributes

Route Parameters

- Name: CompactCar Route
- Lane Change Distance: 20.000 m

Route Segment Parameters

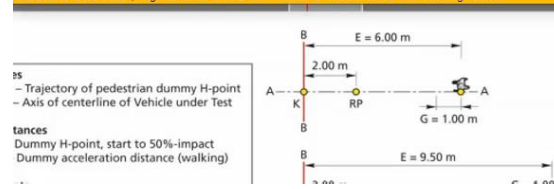
- Freeform:
- Curve Type: Clothoid Spline
- Preferred Arc Radius: 9.00 m
- Computed Arc Radius: 9.00 m
- Total Turn Angle: 90.00°
- Clothoid Proportion: 45%
- Circular Arc Angle: 48.76°
- Clothoid Angle: 20.62°

Library Browser

- Assets
 - Vehicle Textures: Ambulance, Cement Truck, CompactCar, DeliveryVan, Garbage Truck, Pickup Truck, SchoolBus

CompactCar 17.9 m/s

Scenario Edit Tool | Right click to create new routes or insert nodes into existing routes.



Test speed	Part 1 (clothoid)			Part 2 (constant radius)			Part 3 (clothoid)		
	Start Radius R1 [m]	End Radius R2 [m]	Angle α [deg]	Start Radius R2 [m]	End Radius R2 [m]	Angle β [deg]	Start Radius R2 [m]	End Radius R1 [m]	Angle α [deg]
10 km/h to Farside	1500	9.00	20.62	9.00	9.00	48.76	9.00	1500	20.62
15 km/h to Farside	1500	11.75	20.93	11.75	11.75	48.14	11.75	1500	20.93
20 km/h to Farside	1500	14.75	21.79	14.75	14.75	46.42	14.75	1500	21.79
10 km/h to Narside	1500	8.00	22.85	8.00	8.00	44.30	8.00	1500	22.85

[Route Timing Tool](#)
RoadRunner Scenario

R2022a

Programmatically vary scenario parameters

MATLAB, gRPC, and Command-line APIs

- Define scenario variables in editor
- Set variables programmatically from API



[Programmatic Scenario Interfaces](#)

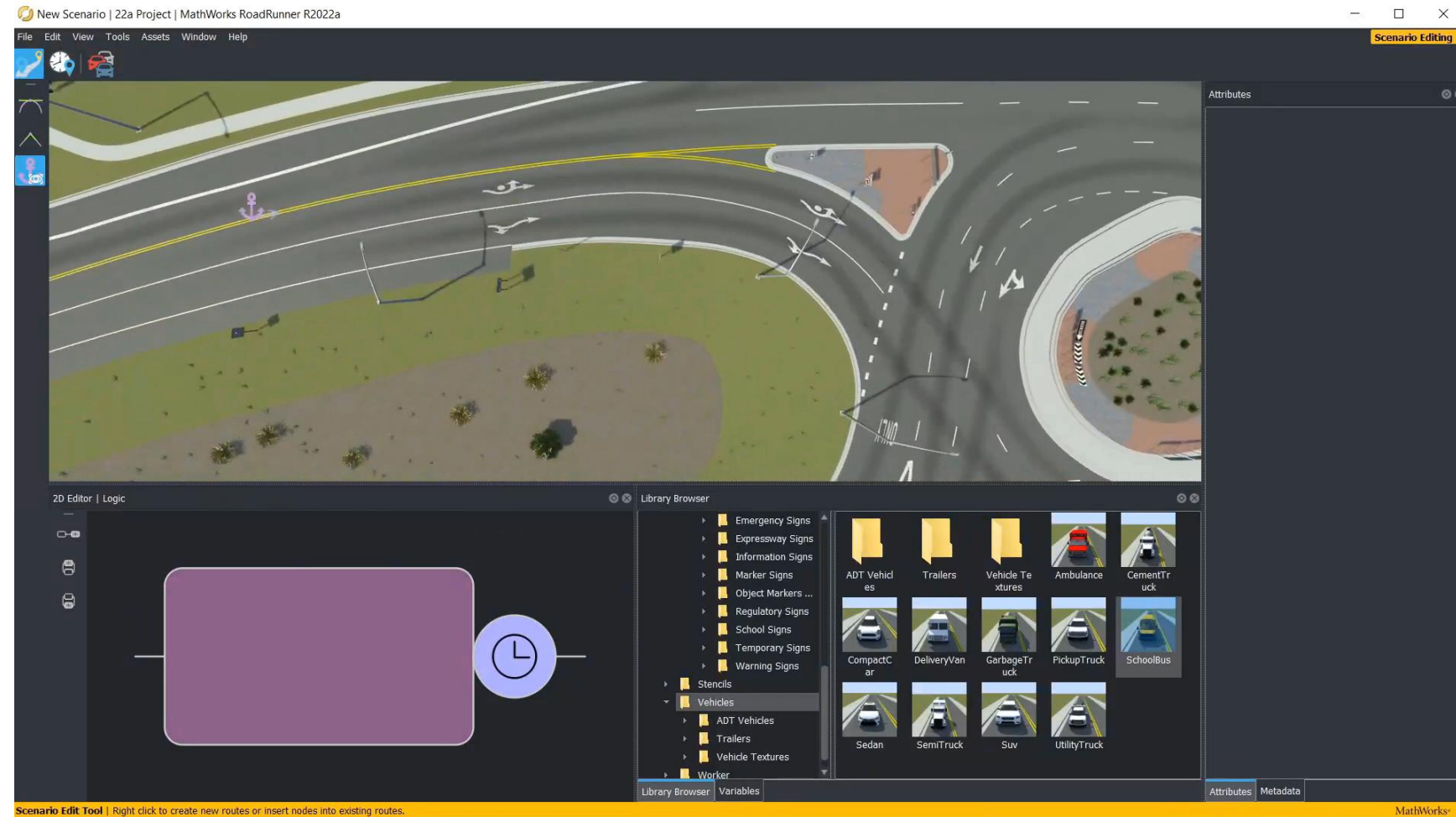
RoadRunner Scenario

R2022a

Programmatically vary scenario parameters

MATLAB, gRPC, and Command-line APIs

- Define scenario variables in editor
- Set variables programmatically from API
- Run simulations
- Export to OpenSCENARIO

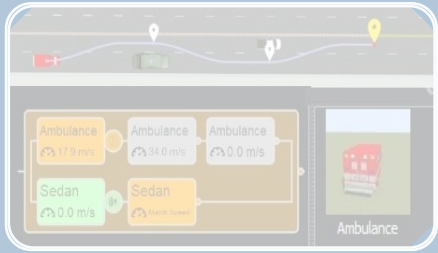


Programmatic Scenario Interfaces

RoadRunner Scenario

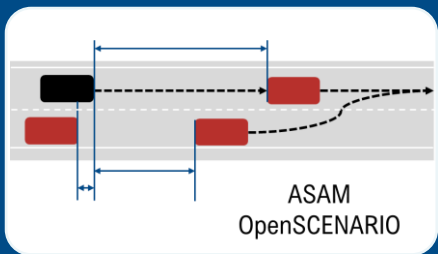
R2022a

Develop Scenarios for Automated Driving Applications with RoadRunner Scenario



Design and Simulate Scenarios

- Design paths and scenario logic
- Relocate scenarios to different scenes
- Programmatically vary parameters

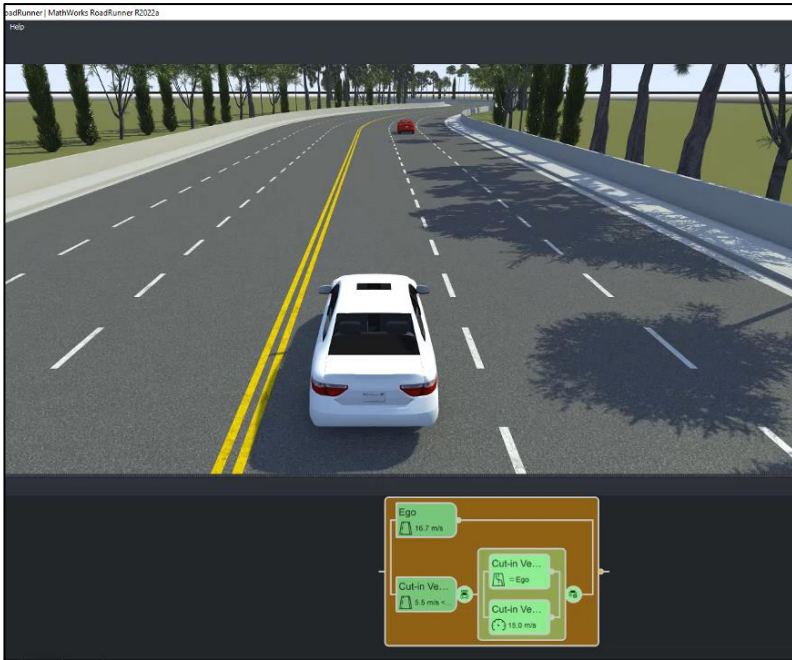


Interface with OpenSCENARIO



Simulate with MATLAB, Simulink, and CARLA

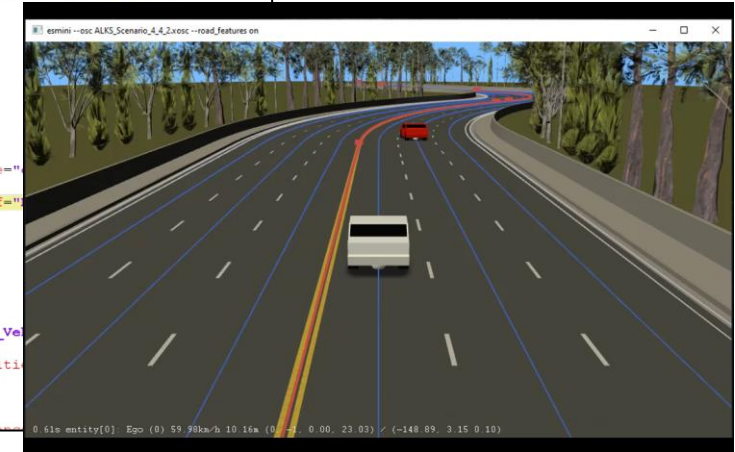
Export scenarios to OpenSCENARIO V1.x and V2.0



OpenSCENARIO
V1.x

```
<Condition name="Start Condition of Event_Vehicle2" conditionEdge="none"
  <ByValueCondition>
    <SimulationTimeCondition value="0" rule="greaterThan"/>
  </ByValueCondition>
</Condition>
</ConditionGroup>
</StartTrigger>
</Event>
<Event name="Event_Vehicle2_2" priority="overwrite">
  <Action name="Speed_Action_Vehicle2_2">
    <LongitudinalAction>
      <SpeedAction>
        <SpeedActionDynamics dynamicsShape="
        <SpeedActionTarget>
          <RelativeTargetSpeed entityRef="
        </SpeedActionTarget>
      </SpeedAction>
    </LongitudinalAction>
  </PrivateAction>
</Action>
<StartTrigger>
  <ConditionGroup>
    <Condition name="Start Condition of Event_Ve
      <ByEntityCondition>
        <TriggeringEntities triggeringEntiti
          <EntityRef entityRef="Ego"/>
        </TriggeringEntities>
        <EntityCondition>
          <SpeedRelativeCondition value="

```



<https://github.com/esmini/esmini>

OpenSCENARIO
V2.0

```
81 do parallel:
82   ego.drive() with:
83     along(sedan__route)
84     speed(16.66mps, at: start)
85   serial:
86     cut-in_vehicle.drive() with:
87       along(sedan2__route)
88       speed(5.5mps, slow)
89       until (cut-in_v
90   parallel:
91     cut-in_vehicle.
92     cut-in_vehicle.
93     speed(15mps,
94   with:
95     until (ego.time
96
```

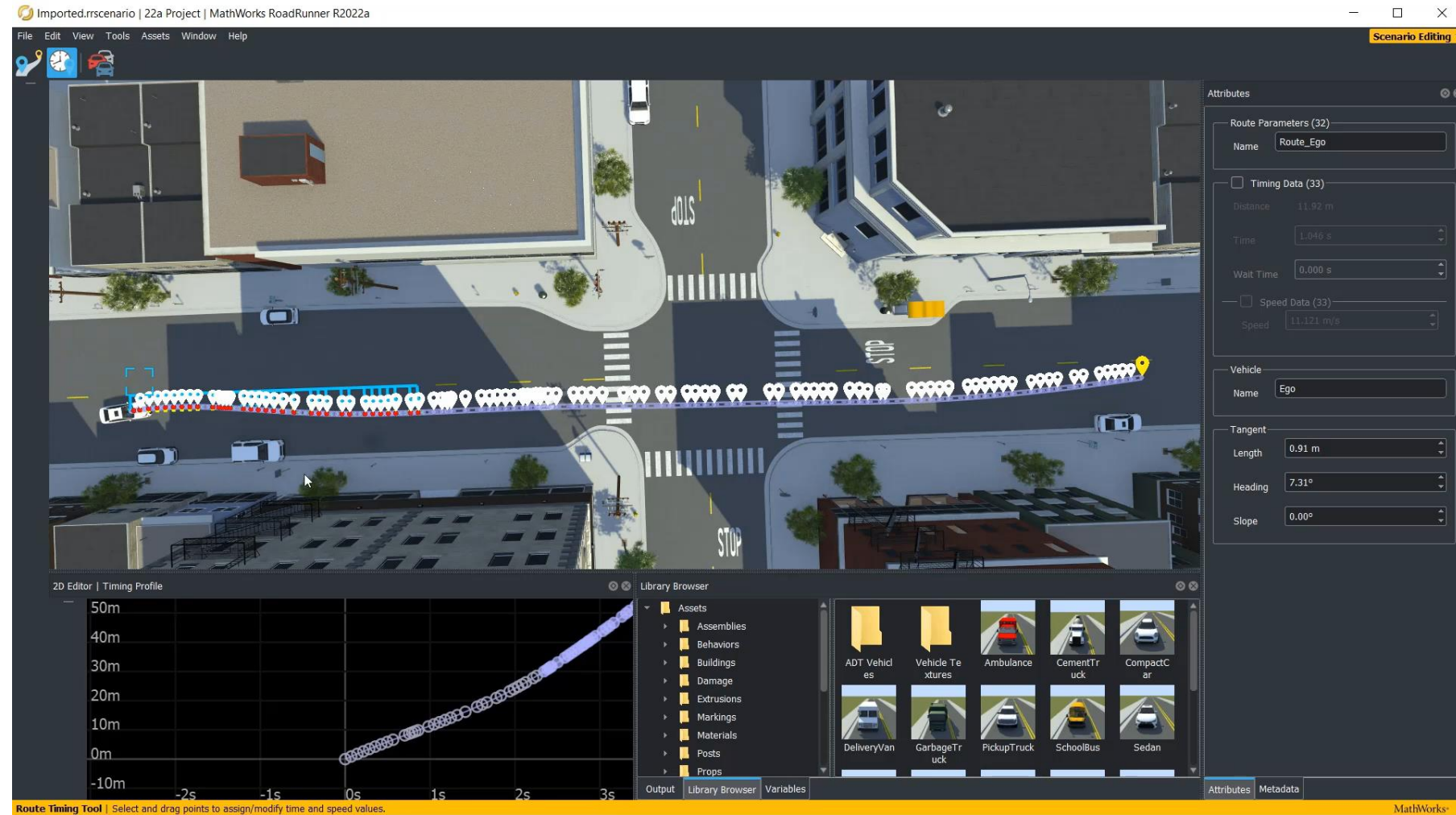
MathWorks is an ASAM Member and actively participates in the **OpenSCENARIO 2.0 Implementers Forum**

[Export to ASAM OpenSCENARIO](#)
RoadRunner Scenario

R2022a

Import and edit trajectories from OpenSCENARIO V1.x

- Import trajectories from OpenSCENARIO V1.x
- Interactive edit trajectories
- Relocate trajectories in different scenes
- Extract the path for use with scenario logic

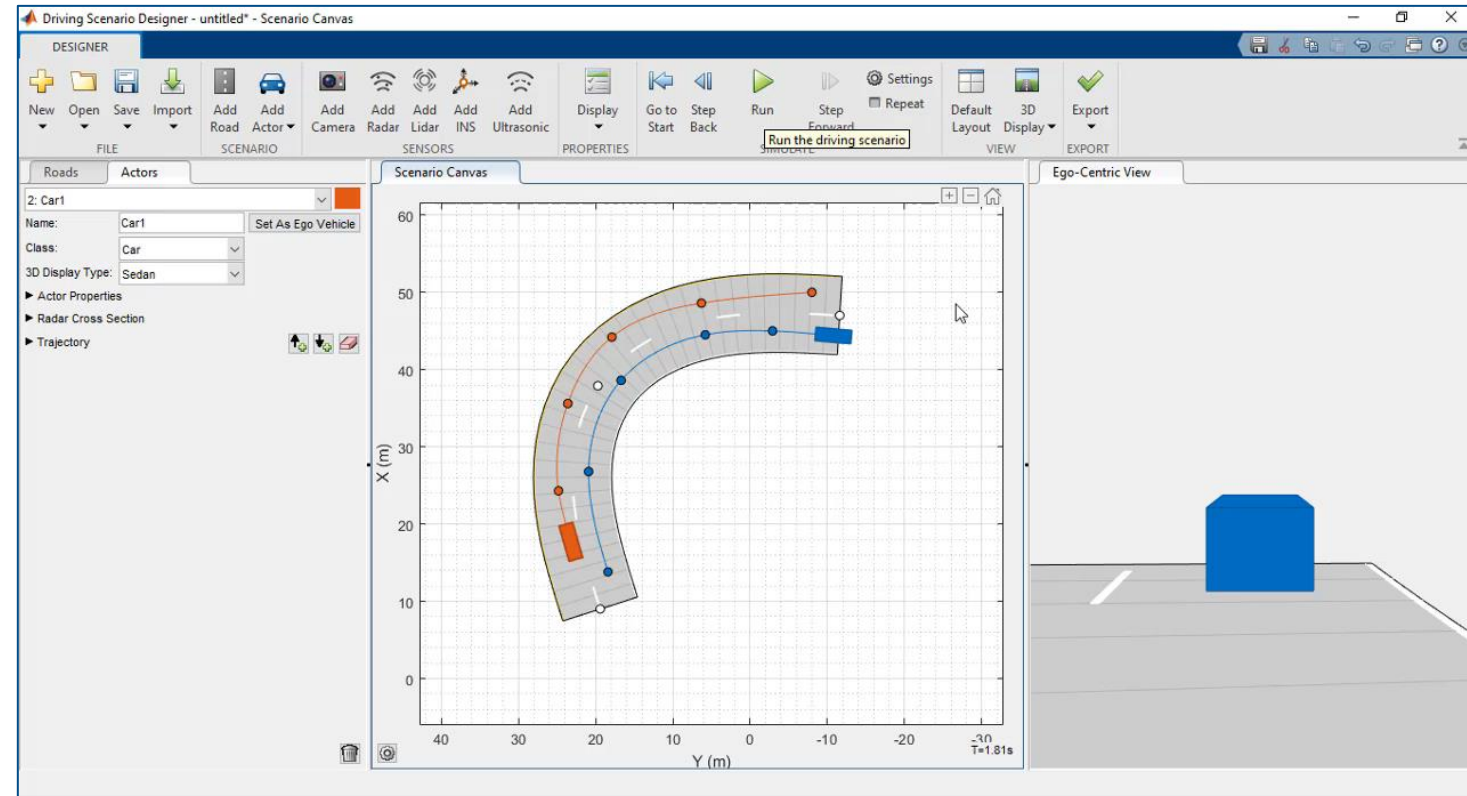
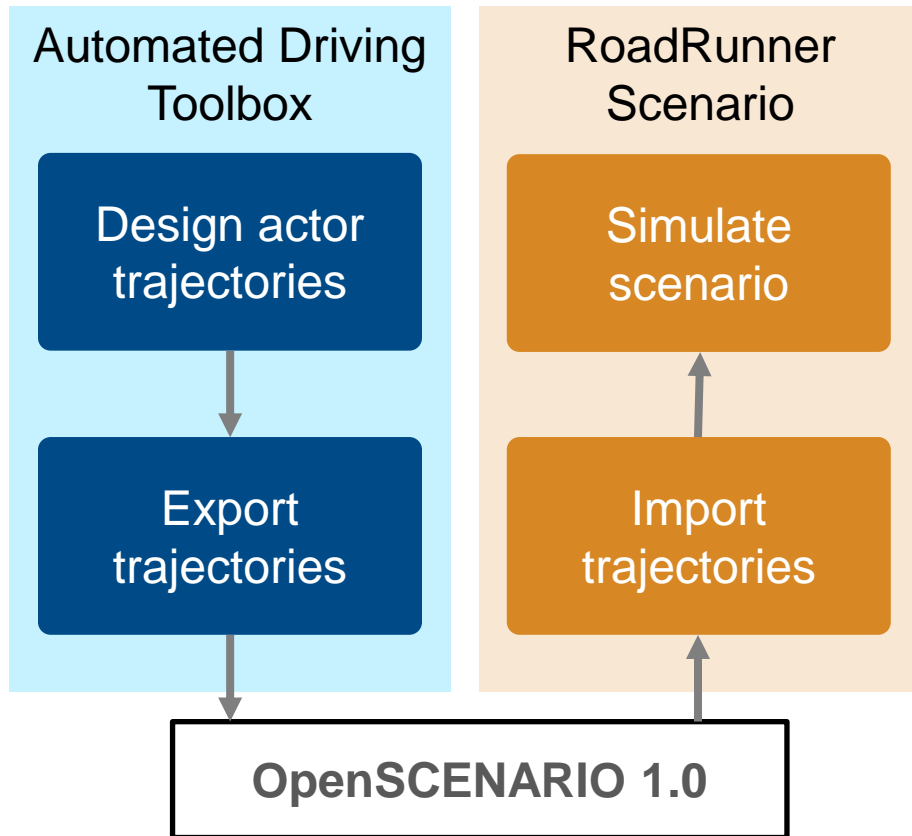


[Import Trajectories from ASAM OpenSCENARIO Files](#)

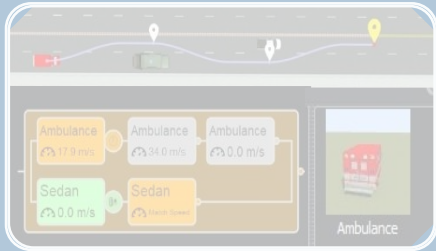
RoadRunner Scenario

R2022a

Migrate trajectories from Driving Scenario Designer (DSD) to RoadRunner Scenario

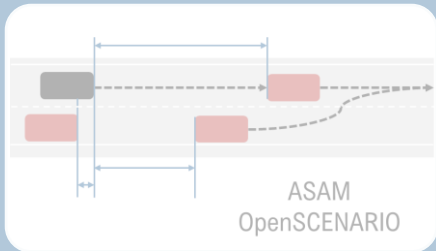


Develop Scenarios for Automated Driving Applications with RoadRunner Scenario



Design and Simulate Scenarios

- Design paths and scenario logic
- Relocate scenarios to different scenes
- Programmatically vary parameters



Interface with OpenSCENARIO

- Export to OpenSCENARIO v2.0
- Export to OpenSCENARIO v1.x
- Import trajectories from OpenSCENARIO v1.0



Simulate with MATLAB, Simulink, and CARLA

Simulate scenarios with actor behaviors in multiple simulators

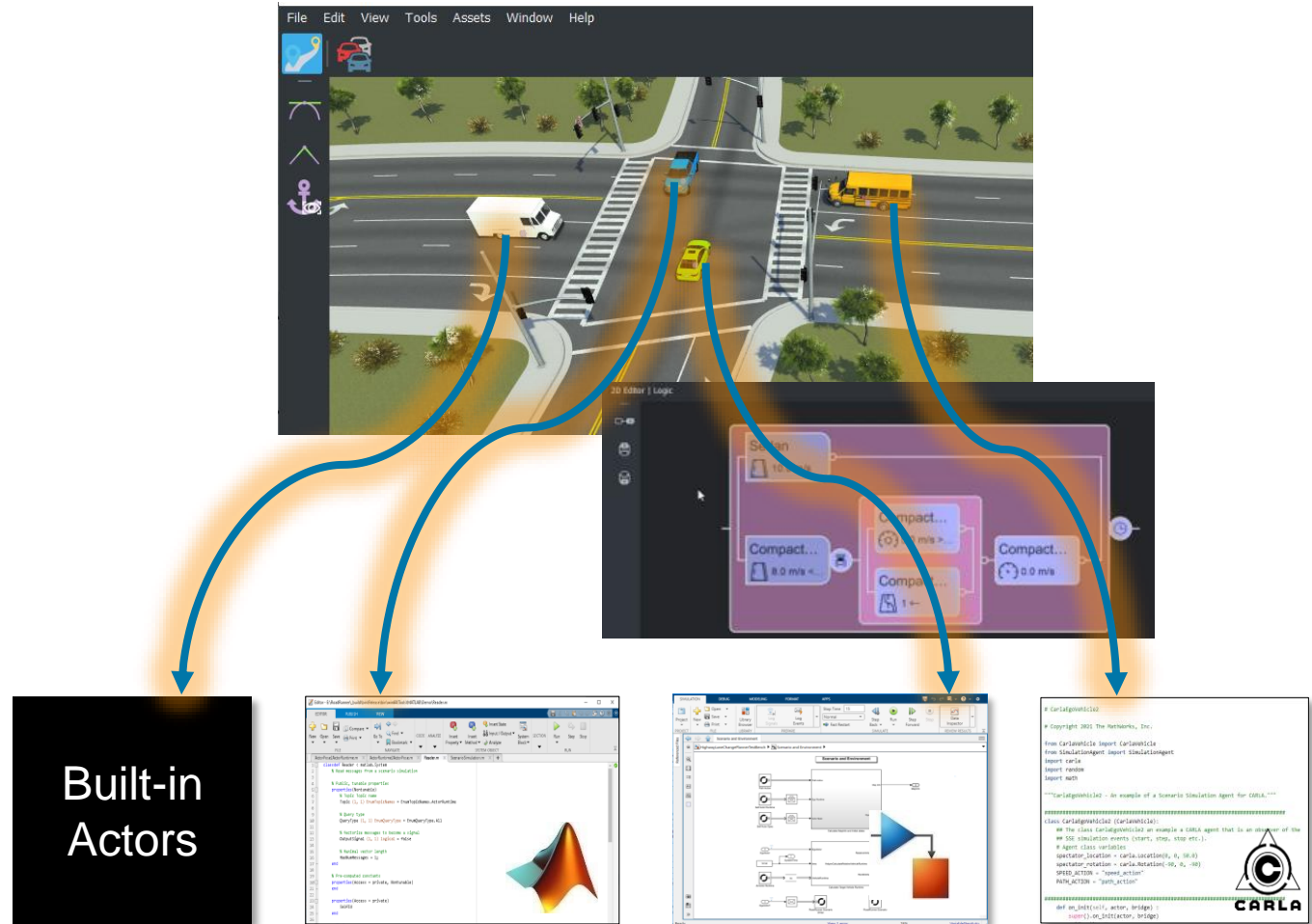
RoadRunner Scenario connects with actors in MATLAB, Simulink, and CARLA

Actors can read scenario states

- Action commands (path, speed, lane change, lateral offset)
- Pose and velocity of all actors in the scenario
- Dimensions of all actors
- Map lanes and lane boundaries

Actors write scenario states

- Their pose and velocity for each scenario simulation step



Design actor behaviors in MATLAB

Interface with RoadRunner scenario through MATLAB APIs with Automated Driving Toolbox

- Connect to scenario simulation
- Read world state from the scenario
- Read actor specific supervisory actions from scenario
- Write actor states to the scenario
- Report errors, warnings to the scenario

Scenario Simulation	
<code>Simulink.ScenarioSimulation</code>	Create, access, and control scenario simulation

Actor Modeling	
<code>convertToStruct</code>	Convert actor to MATLAB structure
<code>get</code>	Get scenario or static attribute of actor
<code>getAction</code>	Get actions associated with actor
<code>getAttribute</code>	Get runtime attribute of actor
<code>setAttribute</code>	Set runtime attribute of actor
<code>getAttribute</code>	Return static attribute of actor

```
obj.mScenarioSimulationHdl = ...
    Simulink.ScenarioSimulation.find( ...
        'ScenarioSimulation', 'SystemObject', obj);

obj.mActorSimulationHdl = Simulink.ScenarioSimulation.find( ...
    'ActorSimulation', 'SystemObject', obj);

obj.mActor.pose = ...
    obj.mActorSimulationHdl.getAttribute('Pose');

obj.mActor.velocity = ...
    obj.mActorSimulationHdl.getAttribute('Velocity');
```

[Simulate RoadRunner Scenarios with Actors Modeled in MATLAB](#)

RoadRunner Scenario, Automated Driving Toolbox™

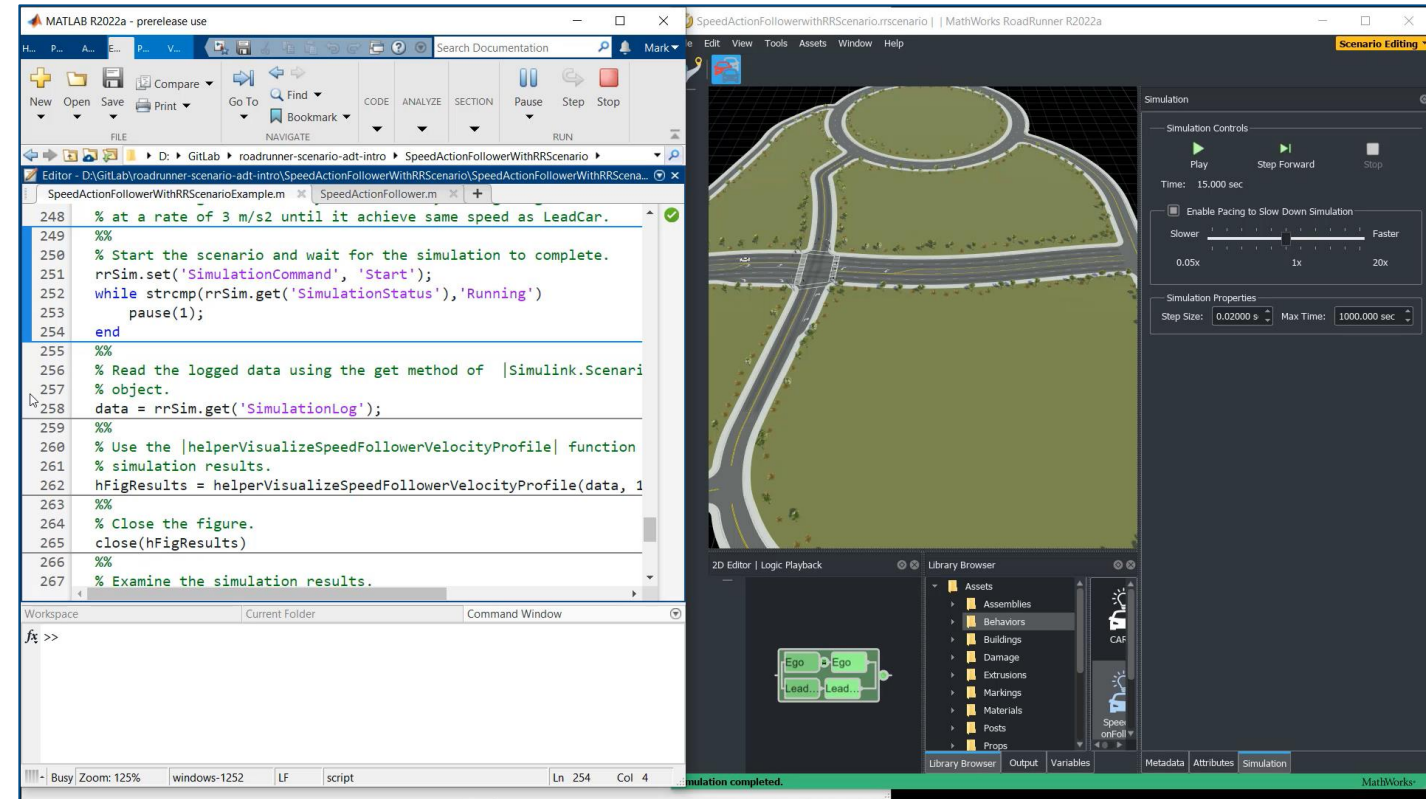
Simulate with speed action follower designed in MATLAB

Scenario Messages

Speed Action Follower Behavior

Scenario Messages

- Design speed action follower behavior in MATLAB
- Associate MATLAB behavior with actor in RoadRunner Scenario
- Simulate and visualize results



[Speed Action Follower with RoadRunner Scenario](#)

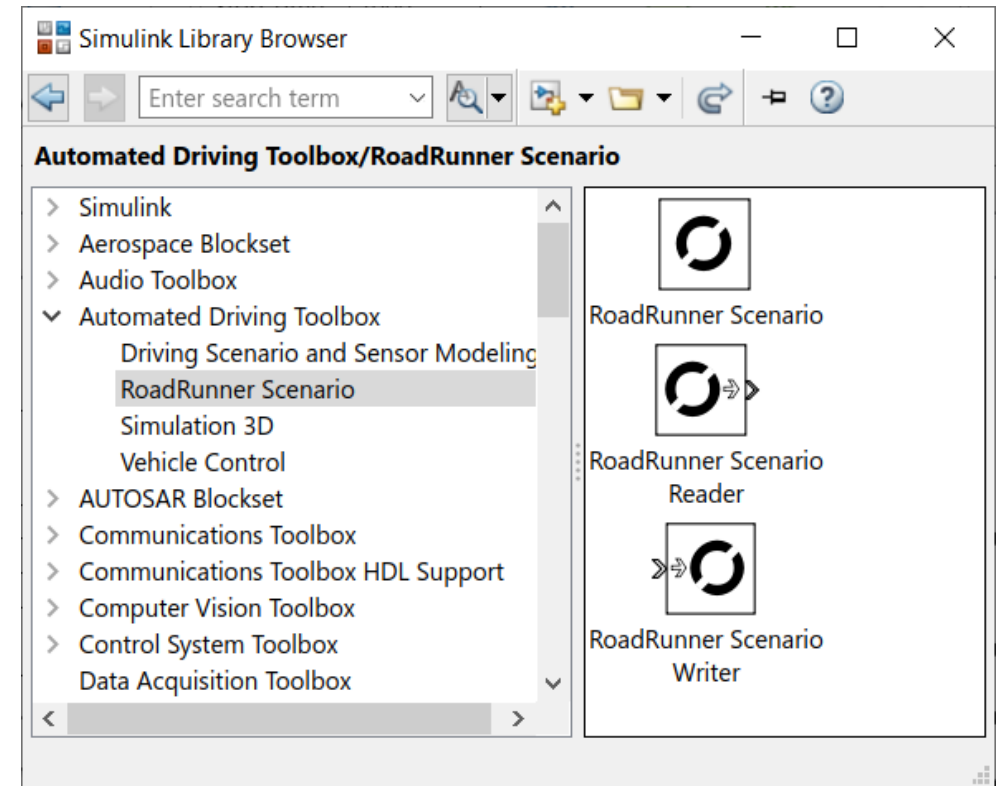
RoadRunner Scenario, Automated Driving Toolbox™

R2022a

Design actor behaviors in Simulink

Interface with RoadRunner Scenario using blocks from Automated Driving Toolbox

- *RoadRunner Scenario*
 - Establish a model's interface with scenario
- *RoadRunner Scenario Reader*
 - Read the world state: Actor pose, velocity, color, supervisory actions
- *RoadRunner Scenario Writer*
 - Write an actor's state to scenario
 - Report errors, warnings to scenario



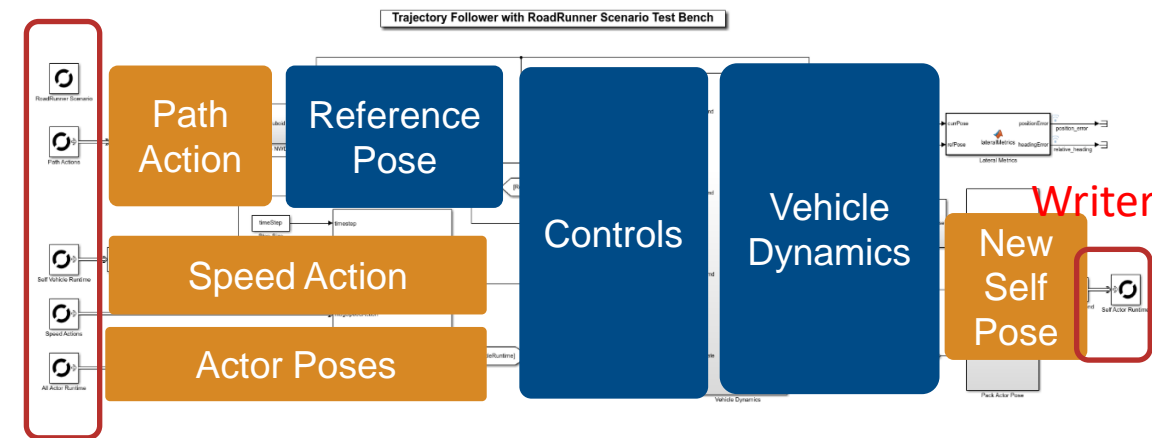
[Simulate RoadRunner Scenarios with Actors Modeled in Simulink](#)

RoadRunner Scenario, Automated Driving Toolbox™

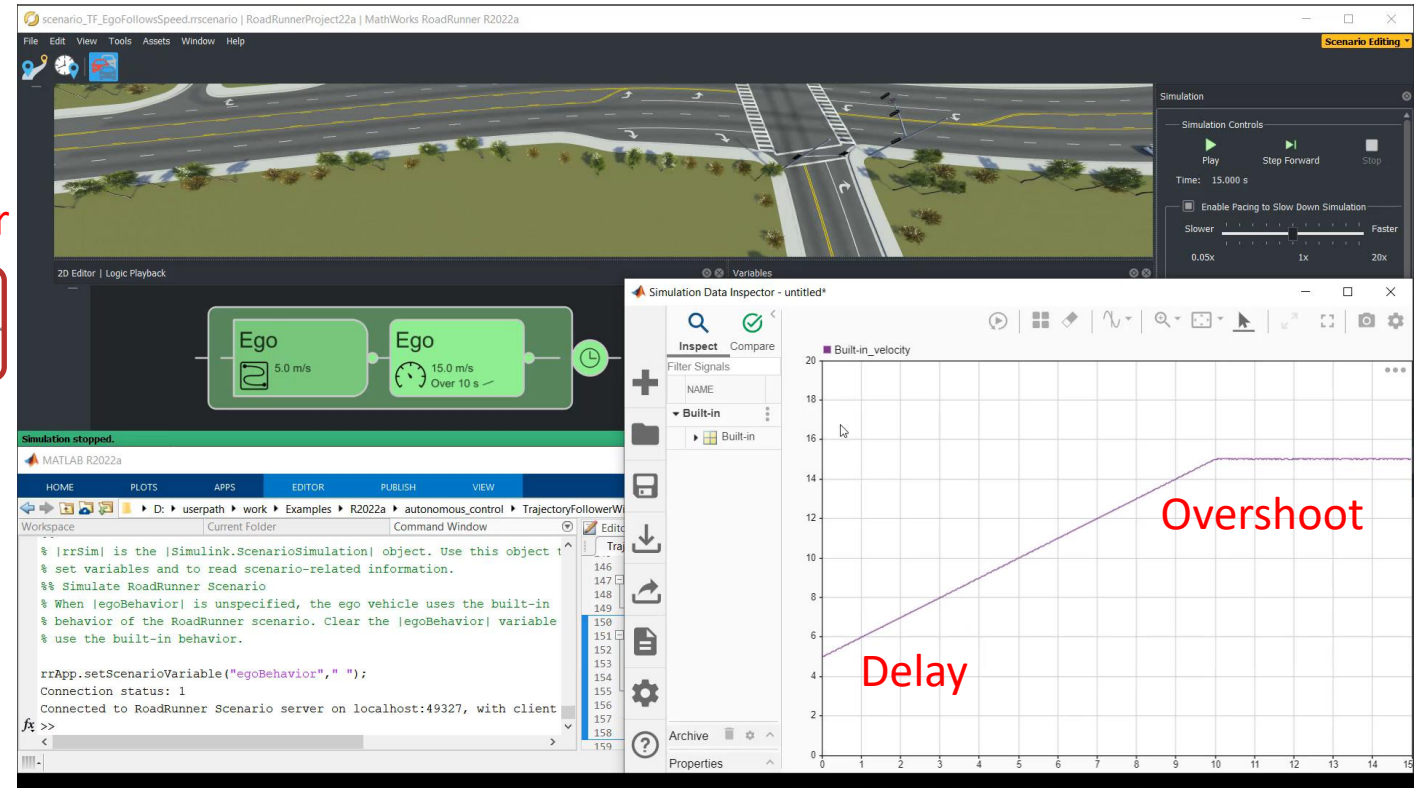
R2022a

Simulate with trajectory follower designed in Simulink

Reader



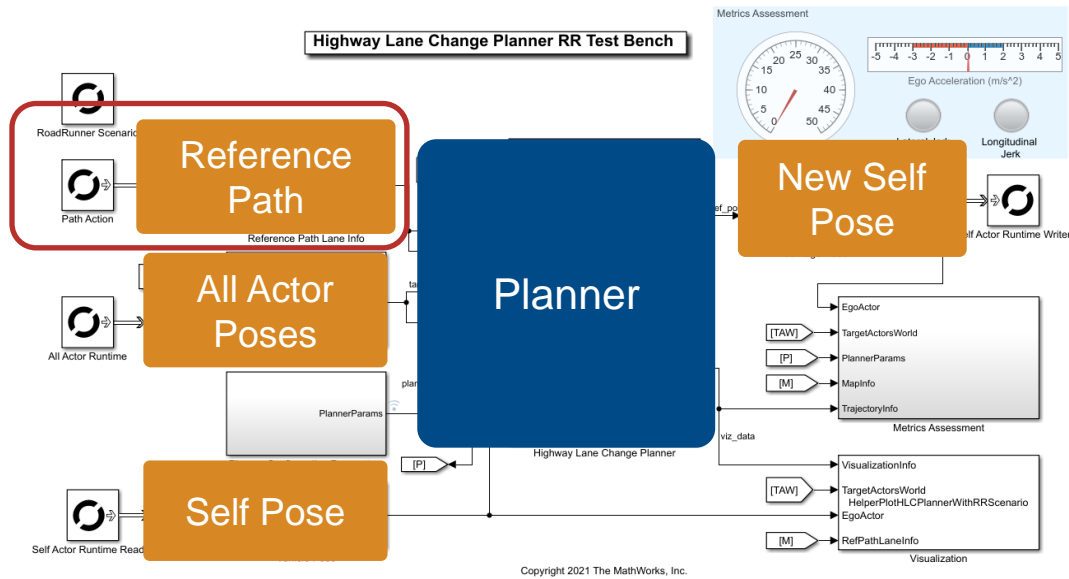
- Explore built-in trajectory following behavior with linear velocity
- Design actor behavior in Simulink which includes controls and dynamics
- Simulate and compare results



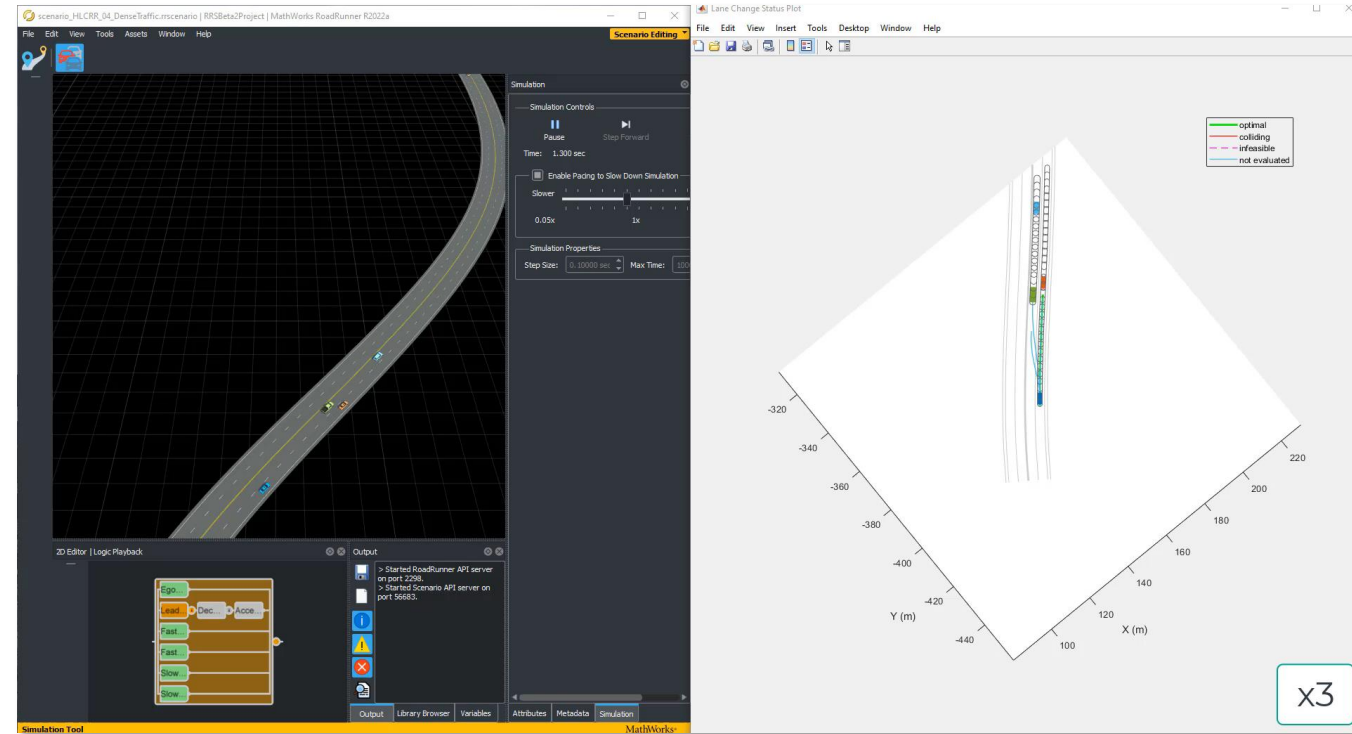
[Trajectory Follower with RoadRunner Scenario](#)
RoadRunner Scenario, Automated Driving Toolbox™

R2022a

Simulate with lane change planner designed in Simulink



- Design ego actor to implement planner
- Define trajectories and logic for target actors
- Visualize possible and selected ego trajectories

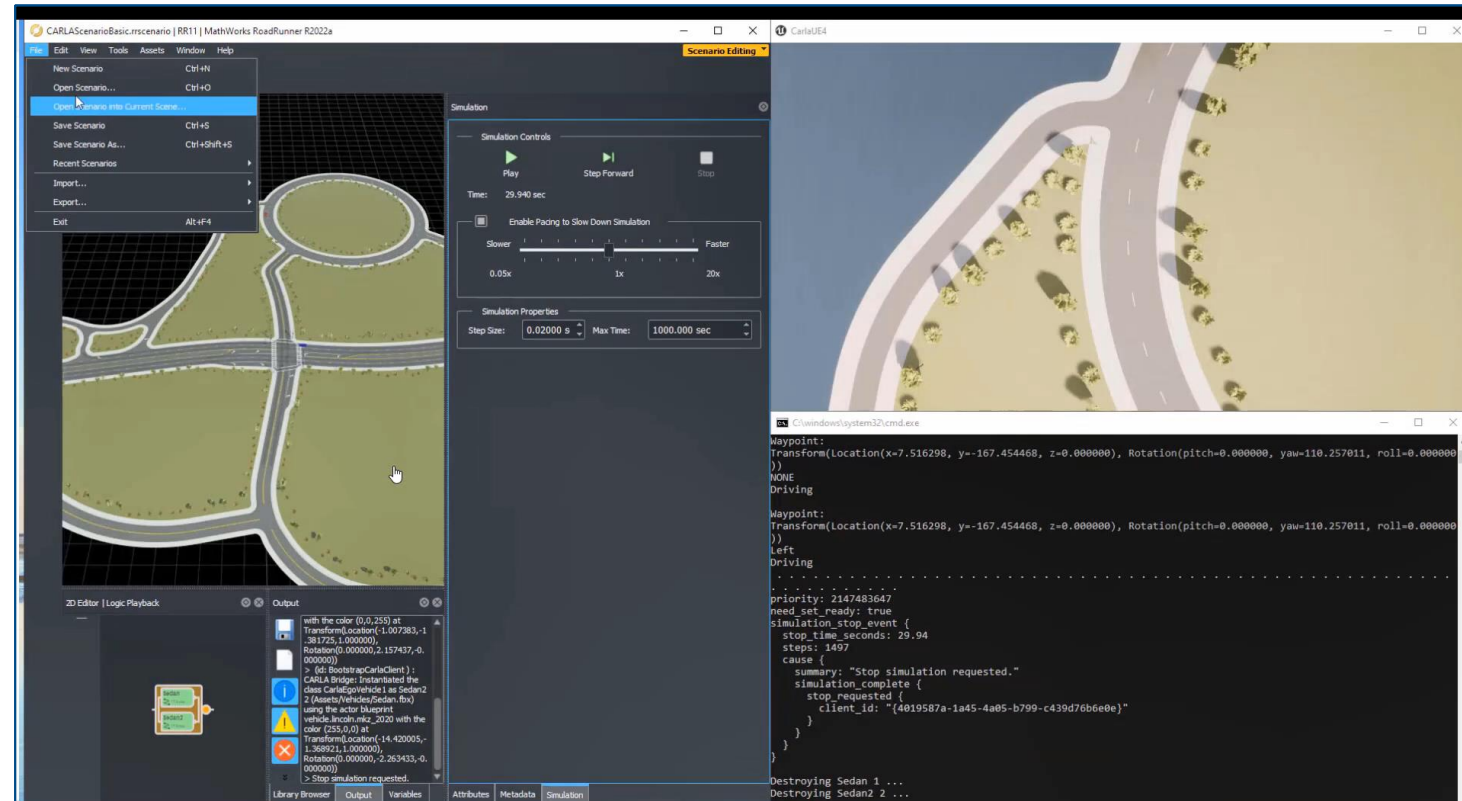
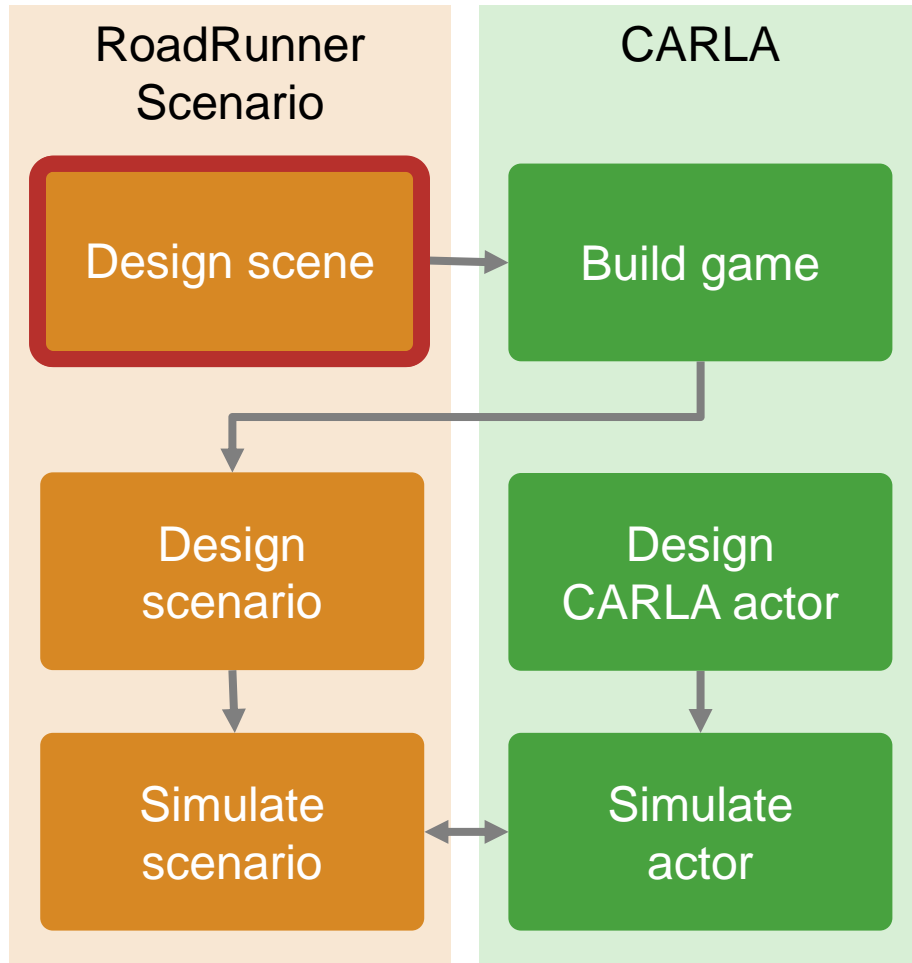


[Highway Lane Change Planner with RoadRunner Scenario](#)

RoadRunner Scenario, Automated Driving Toolbox™, Navigation Toolbox™

R2022a

Simulate with actor behaviors designed in CARLA

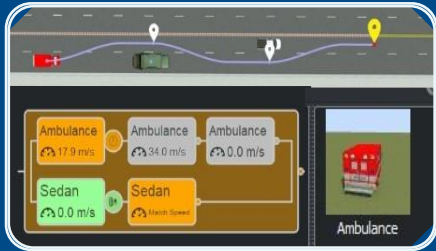


[Cosimulate Actors with CARLA](#)

RoadRunner Scenario

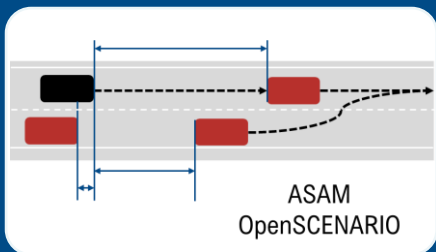
R2022a

Develop Scenarios for Automated Driving Applications with RoadRunner Scenario



Design and Simulate Scenarios

- Design paths and scenario logic
- Relocate scenarios to different scenes
- Programmatically vary parameters



Interface with OpenSCENARIO

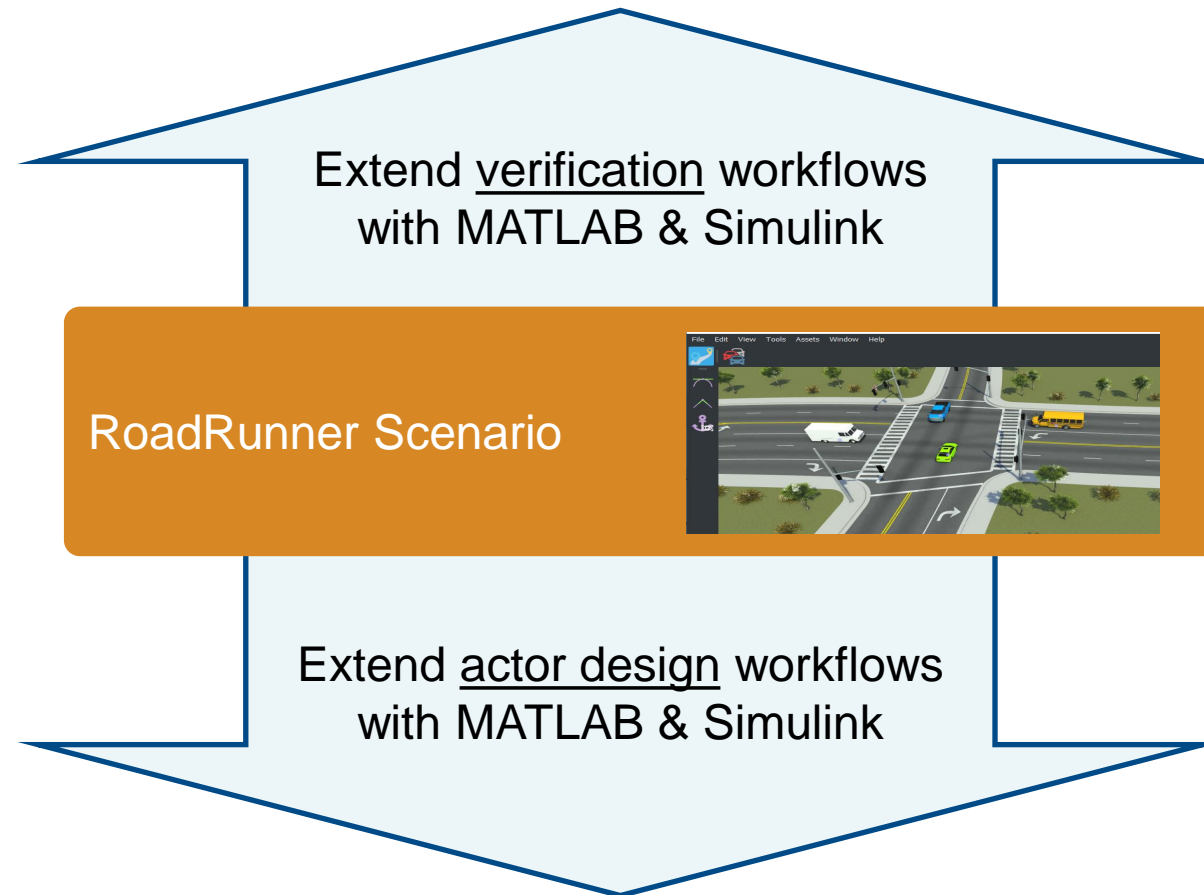
- Export to OpenSCENARIO v2.0
- Export to OpenSCENARIO v1.x
- Import trajectories from OpenSCENARIO v1.0



Simulate with MATLAB, Simulink, and CARLA

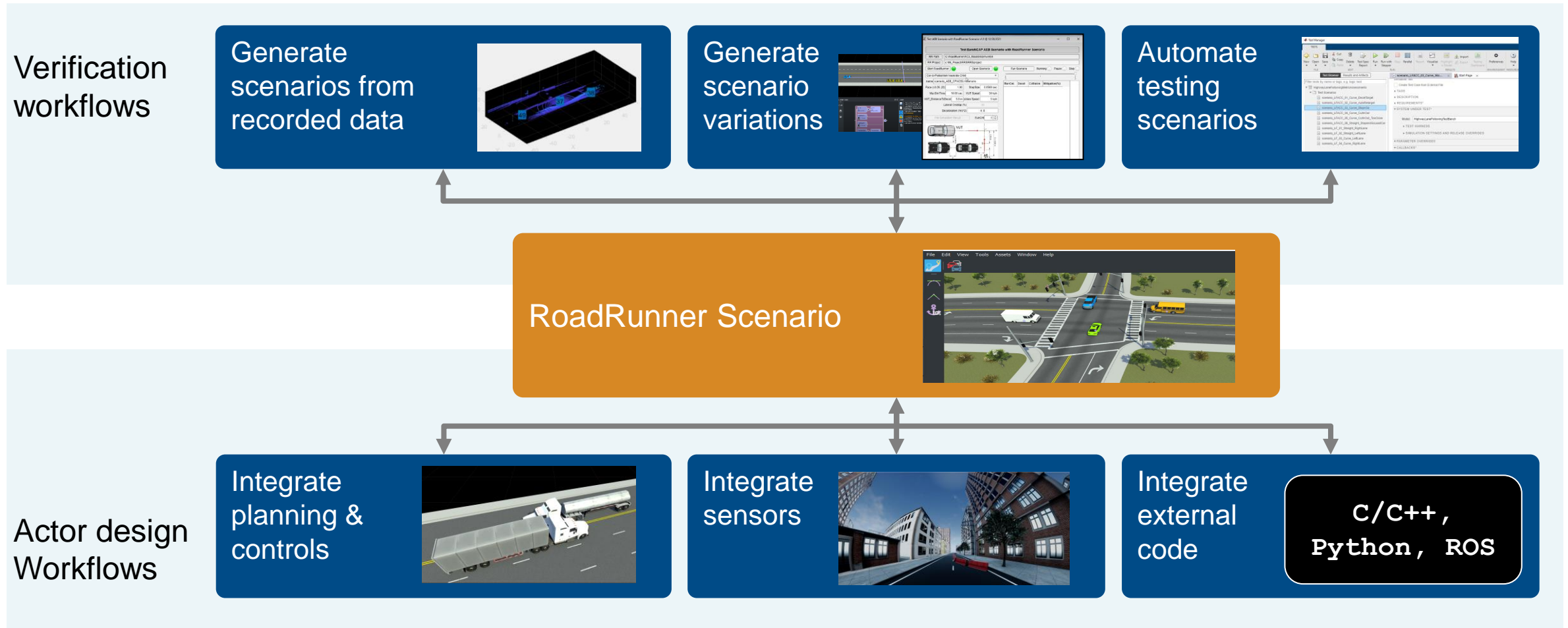
- Author actor behaviors in MATLAB
- Author actor behaviors in Simulink
- Author actor behaviors in CARLA

Partner with MathWorks to extend scenario workflows



Engage with MathWorks engineers through proof-of-concept projects or Consulting Services to extend scenario workflows

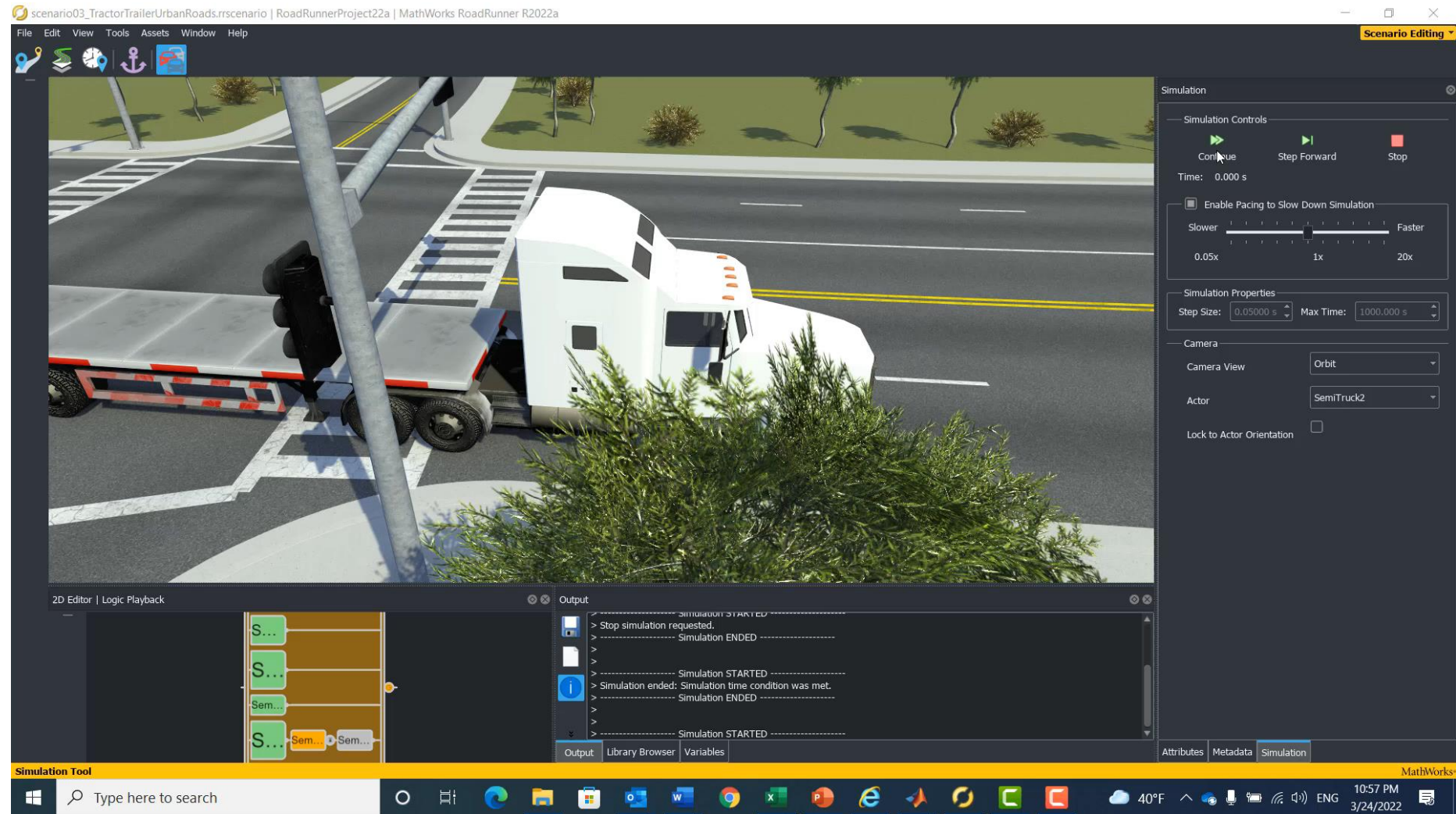
Partner with MathWorks to extend scenario workflows



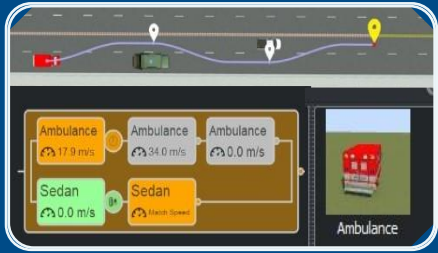
Engage with MathWorks engineers through proof-of-concept projects or Consulting Services to extend scenario workflows

Partner with MathWorks to extend workflows for tractor trailer

Engage with MathWorks engineers through proof-of-concept projects or Consulting Services to extend scenario workflows

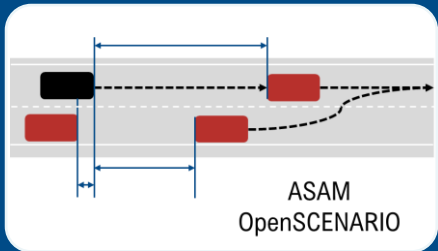


Develop Scenarios for Automated Driving Applications with RoadRunner Scenario



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Interface with OpenSCENARIO

- Export to OpenSCENARIO v2.0
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- Import trajectories from OpenSCENARIO v1.0



Simulate with MATLAB, Simulink, and CARLA

- Author actor behaviors in MATLAB
- Author actor behaviors in Simulink
- Author actor behaviors in CARLA

MATLAB EXPO

Thank you



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