

MathWorks  
**AUTOMOTIVE  
CONFERENCE 2022**  
North America

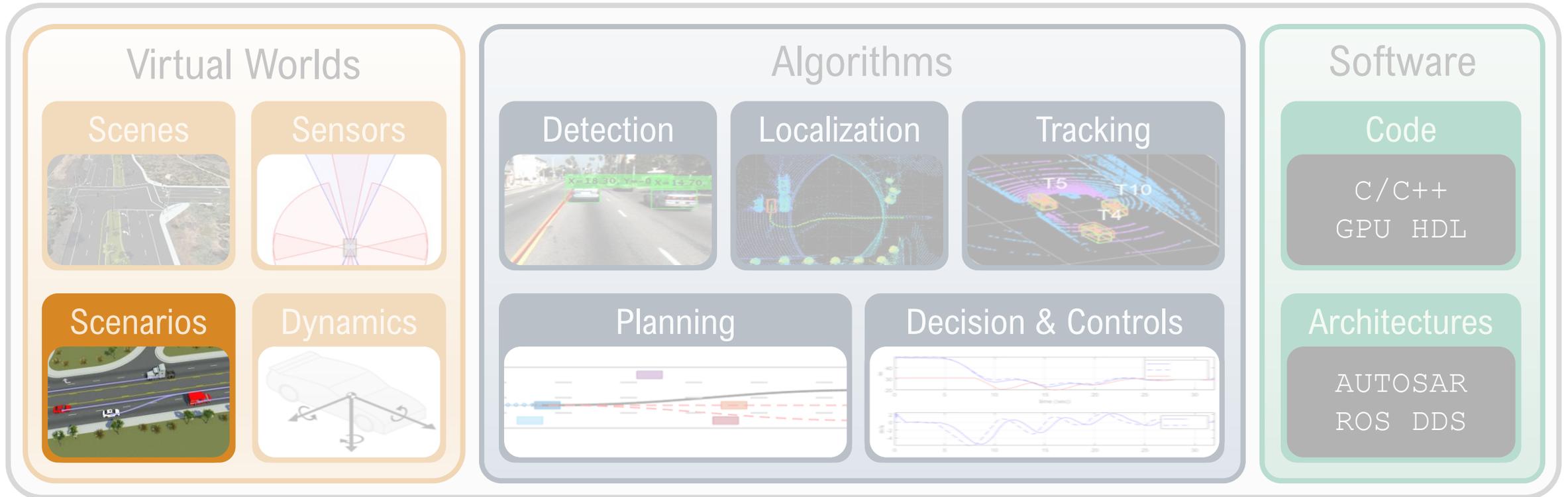
**Design and Simulate Scenarios for  
Automated Driving Applications**

*Shusen Zhang, MathWorks*



# Develop Automated Driving Applications

with MATLAB, Simulink, & RoadRunner



## Development Platform

Analyze

Simulate

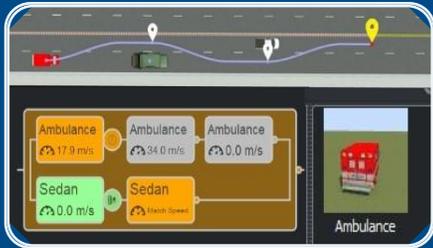
Design

Deploy

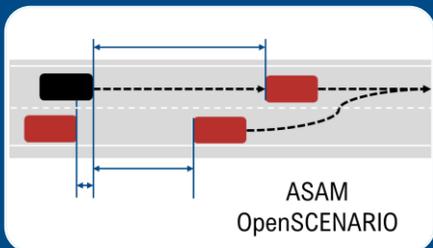
Integrate

Test

# Develop Scenarios for Automated Driving Applications with RoadRunner Scenario



**Design and Simulate Scenarios**

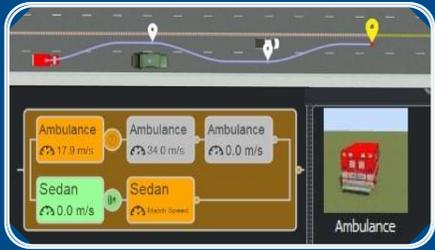


**Interface with OpenSCENARIO**

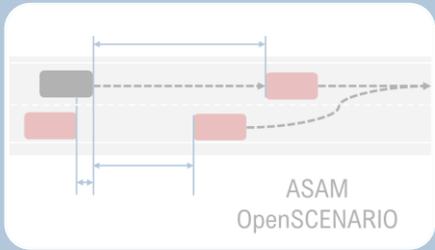


**Simulate with MATLAB, Simulink, and CARLA**

# Develop Scenarios for Automated Driving Applications with RoadRunner Scenario



**Design and Simulate Scenarios**

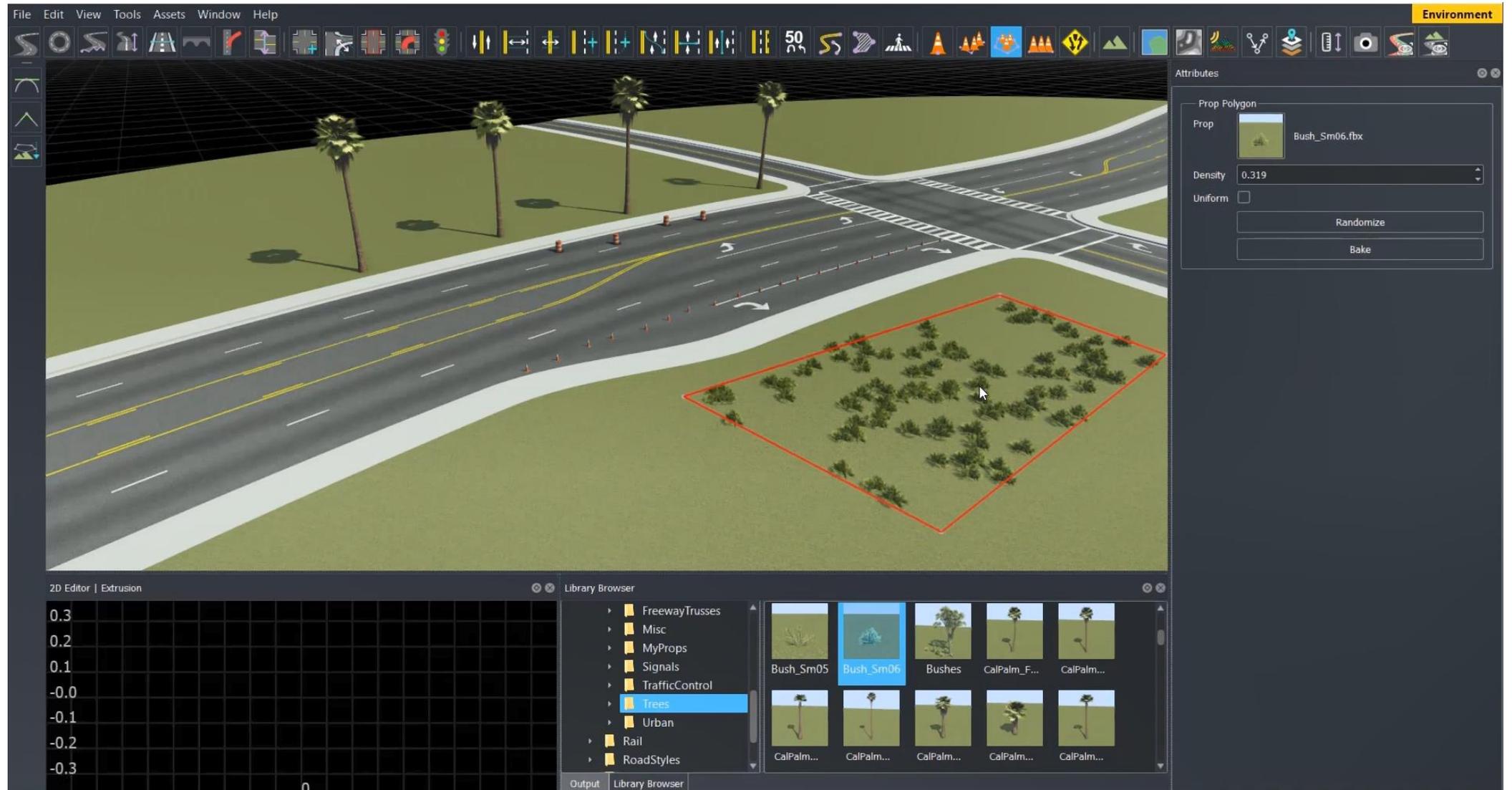


**Interface with OpenSCENARIO**



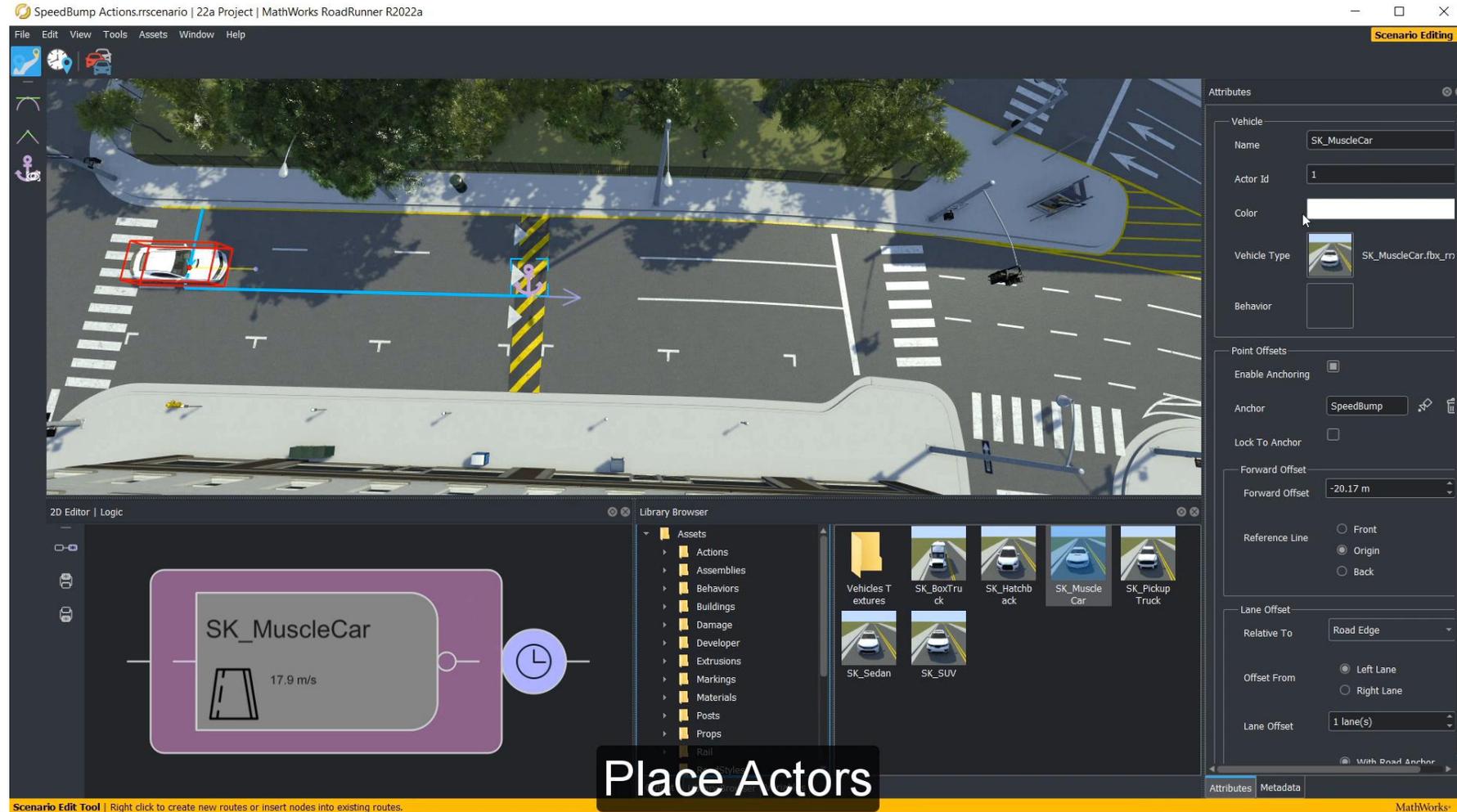
**Simulate with MATLAB, Simulink, and CARLA**

# Interactively design scenes with RoadRunner



# Interactively design scenarios with RoadRunner Scenario

- Add various vehicles
- Follow road network
- Speed change actions
- Lane change actions
- Lateral offset actions



[Scenario Edit Tool](#)  
*RoadRunner Scenario*

R2022a

# 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°

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

MathWorks

Test speed	Part 1 (clothoid)			Part 2 (constant radius)			Part 3 (clothoid)		
	Start Radius R1 [m]	End Radius R2 [m]	Angle $\alpha$ [deg]	Start Radius R2 [m]	End Radius R2 [m]	Angle $\beta$ [deg]	Start Radius R2 [m]	End Radius R1 [m]	Angle $\alpha$ [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 Nearside	1500	8.00	22.85	8.00	8.00	44.30	8.00	1500	22.85

B — Trajectory of pedestrian dummy H-point  
 — Axis of centerline of Vehicle under Test

Dimensions:  
 E = 6.00 m  
 2.00 m  
 G = 1.00 m  
 E = 9.50 m

Legend:  
 B — Trajectory of pedestrian dummy H-point  
 — Axis of centerline of Vehicle under Test

Dimensions:  
 E = 6.00 m  
 2.00 m  
 G = 1.00 m  
 E = 9.50 m

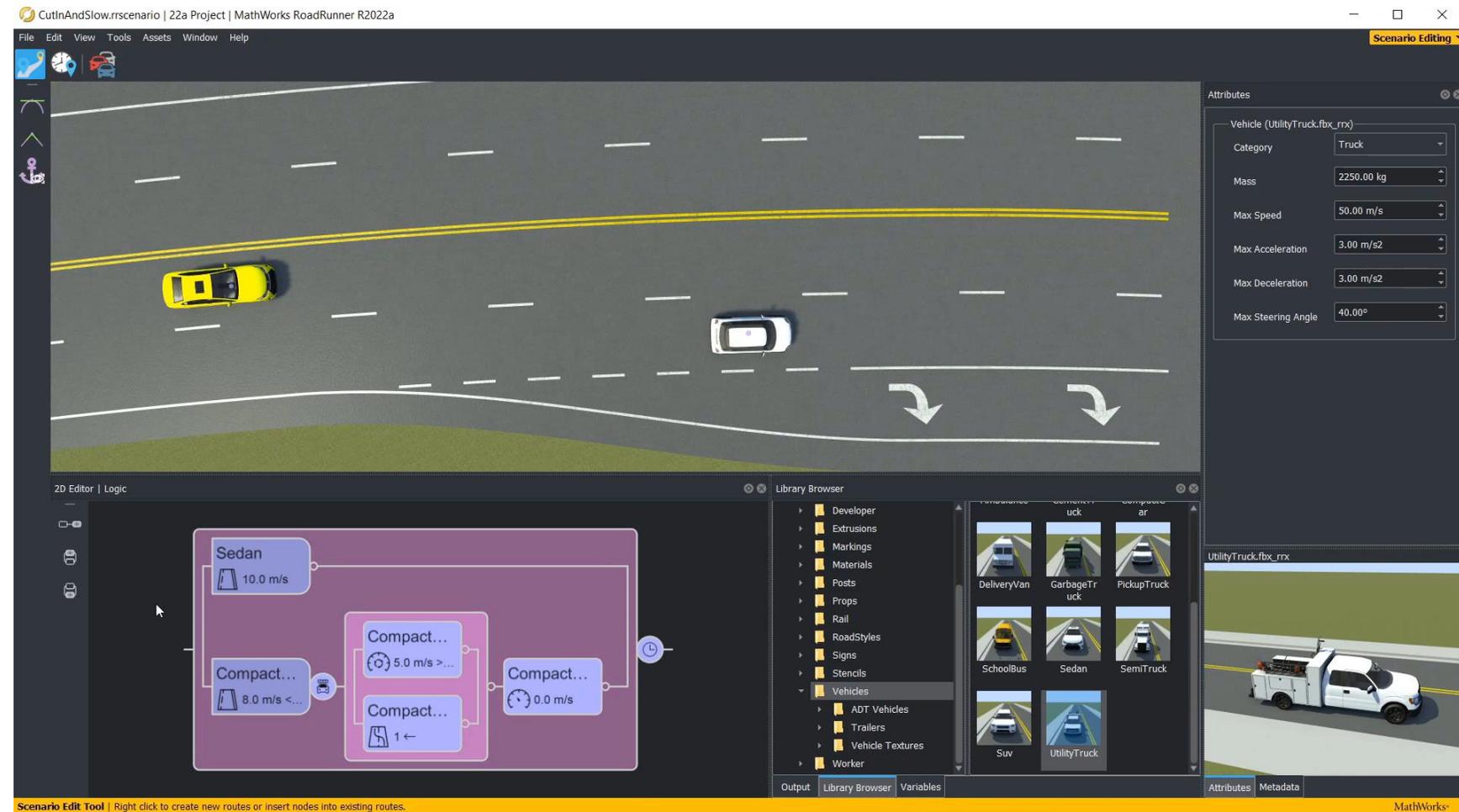
[Route Timing Tool](#)  
RoadRunner Scenario

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# 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

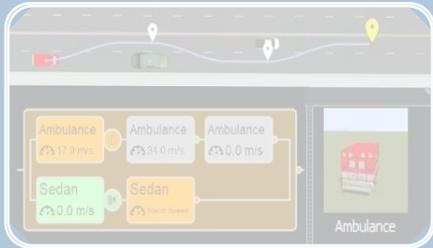


[Programmatic Scenario Interfaces](#)

RoadRunner Scenario

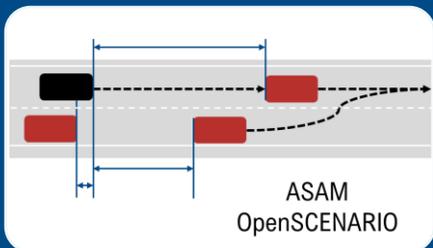
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# Develop Scenarios for Automated Driving Applications with RoadRunner Scenario



## Design and Simulate Scenarios

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

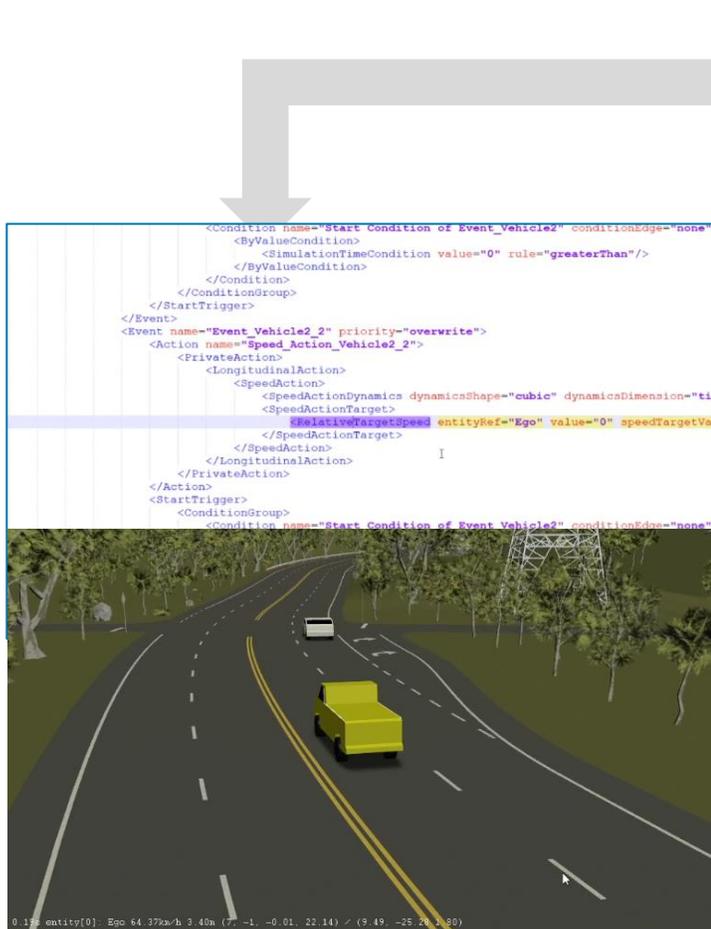


## Interface with OpenSCENARIO



## Simulate with MATLAB, Simulink, and CARLA

# Export scenarios to OpenSCENARIO V1.x and V2.0



```
1 # Vendor="MathWorks" Program="RoadRunner" Version="R2022a"
2
3 reference_map: map.map_file = "SwervingLeadVehicle.xodr"
4
5 scenario swerving_lead_vehicle:
6
7     sedan: vehicle
8     compact_car: vehicle
9
10    sedan_route: route = map.odr_to_route_point(road_id:
11    compact_car_route: route = map.odr_to_route_point(road_id:
12
13    do parallel():
14        sedan.drive() with:
15            along(sedan_route)
16            speed(10mps, at: start)
17    serial:
18        compact_car.drive(duration: 1s) with:
19            along(compact_car_route)
20            speed(0mps, faster_than: sedan, at: start)
```

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

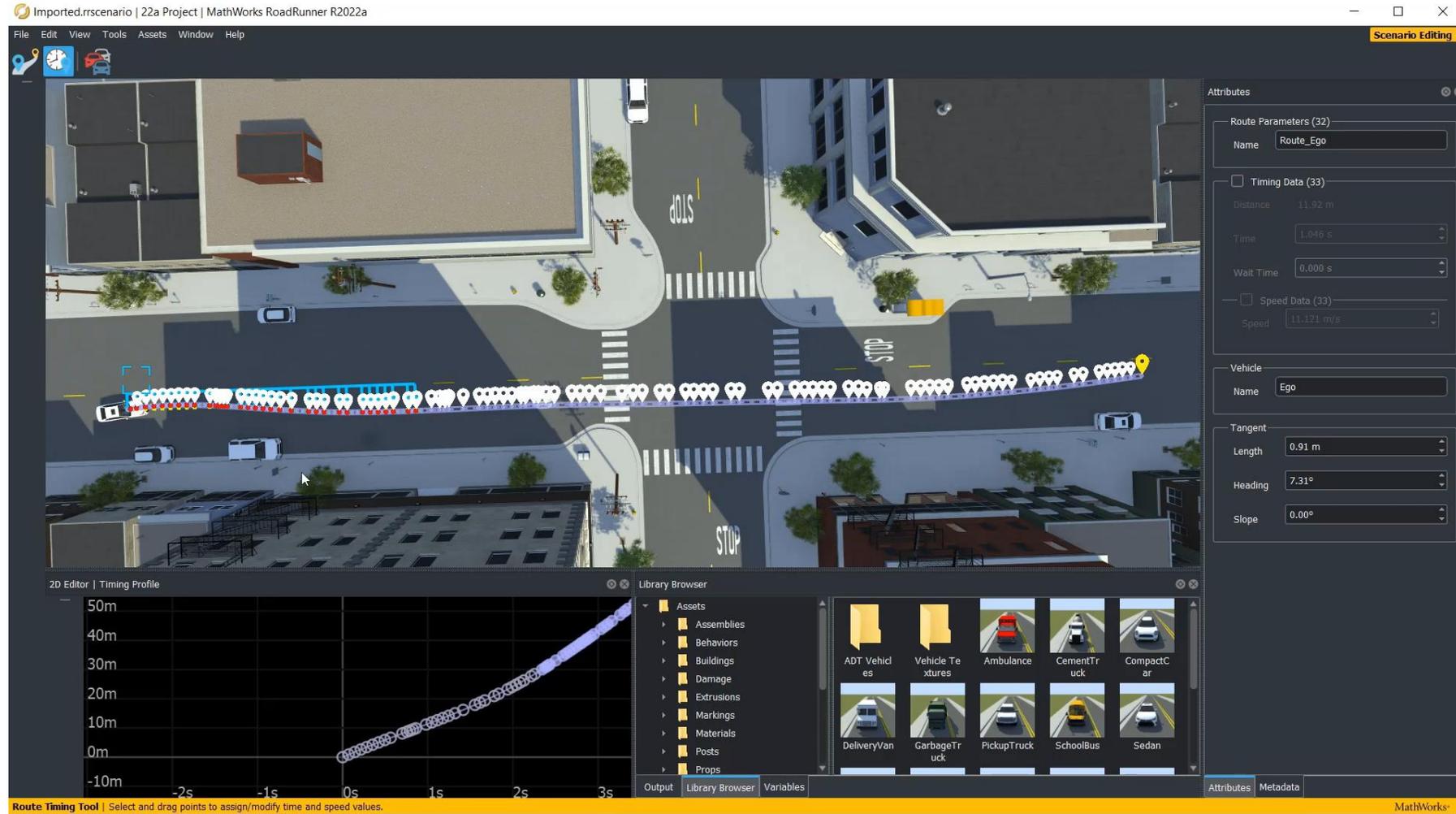
[Export to ASAM OpenSCENARIO](#)

*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

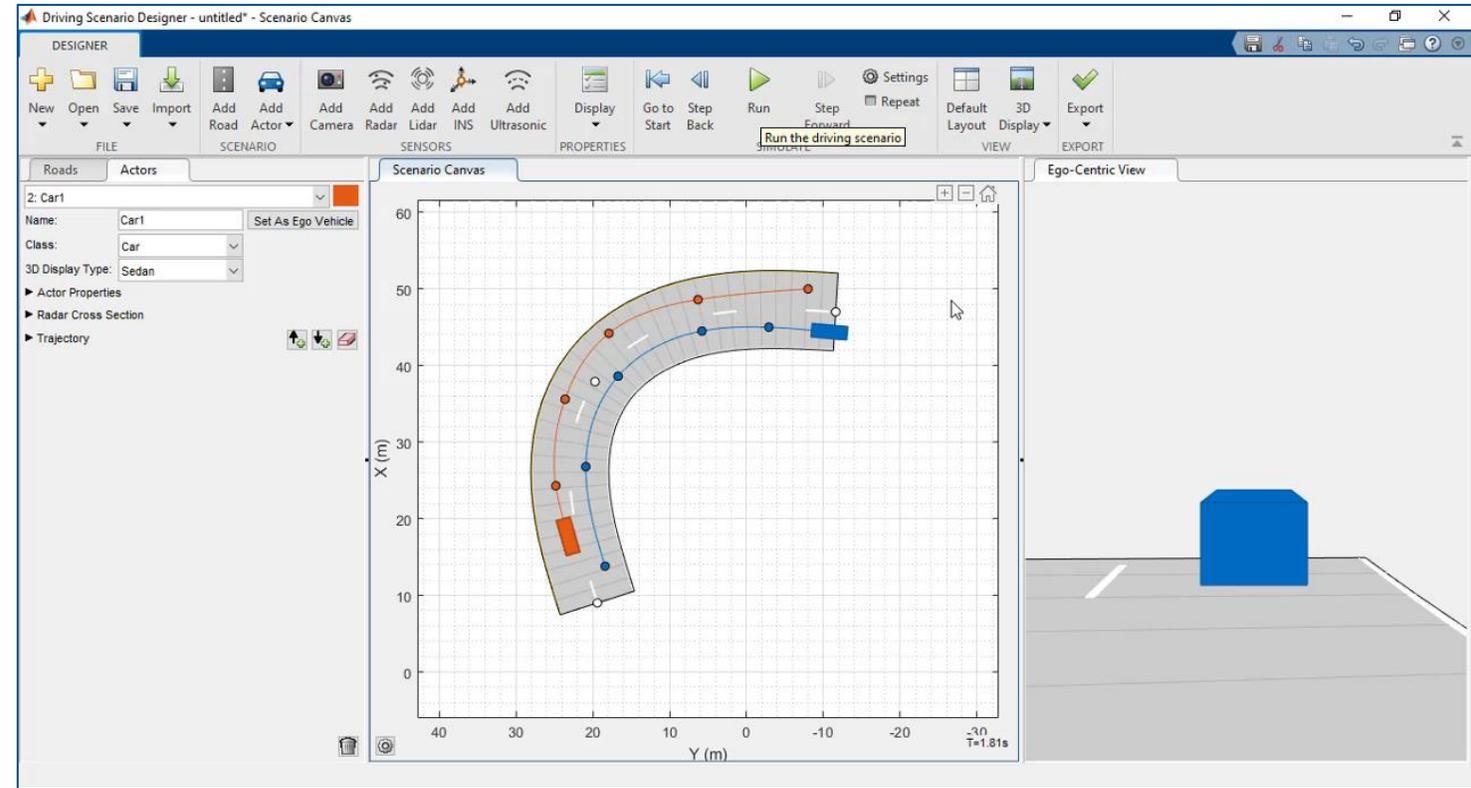
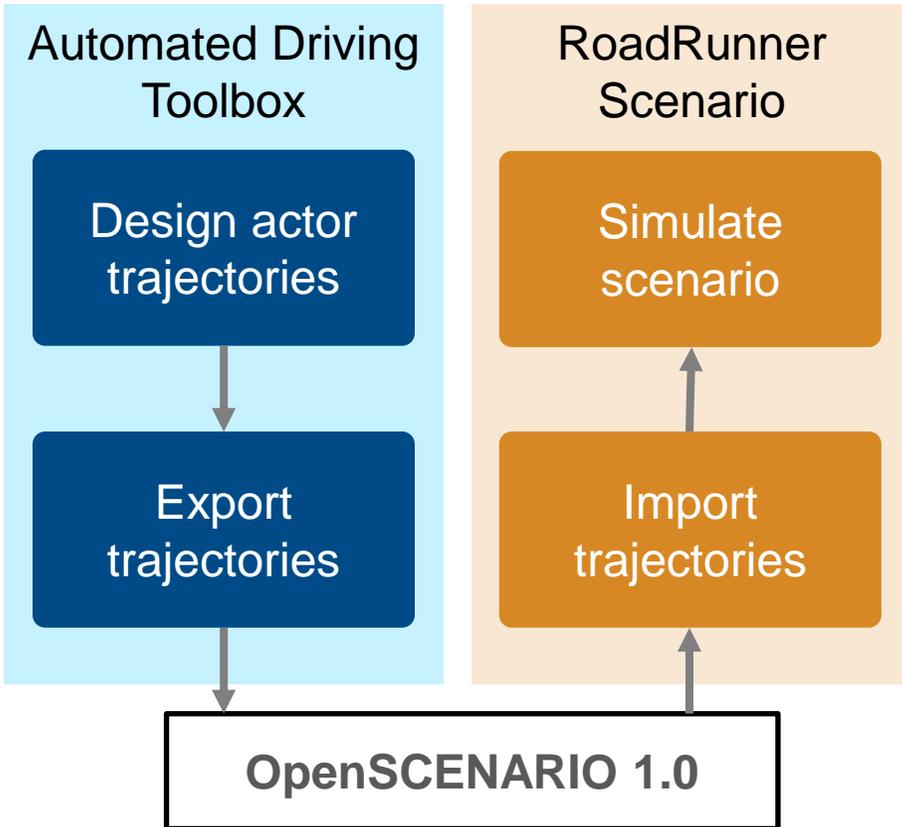


[Import Trajectories from ASAM OpenSCENARIO Files](#)

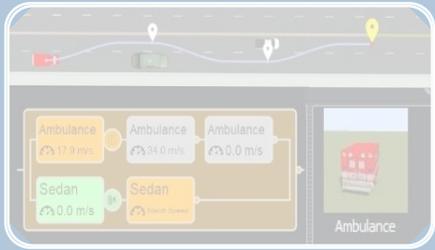
*RoadRunner Scenario*

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

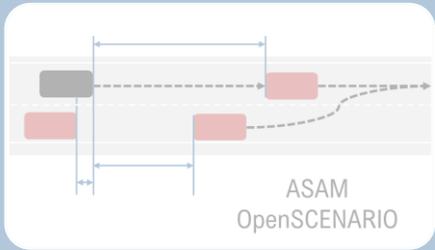


# Develop Scenarios for Automated Driving Applications with RoadRunner Scenario



## 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 write scenario states

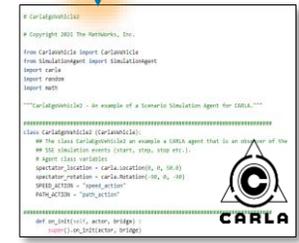
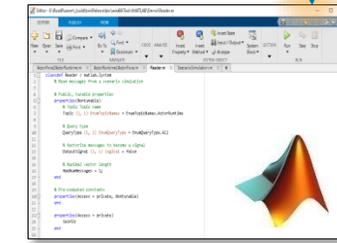
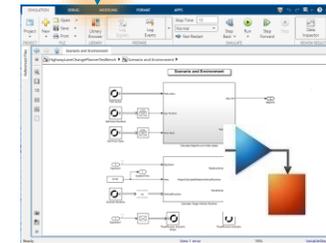
- Their pose and velocity for each scenario simulation step

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



Built-in Agents



# 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

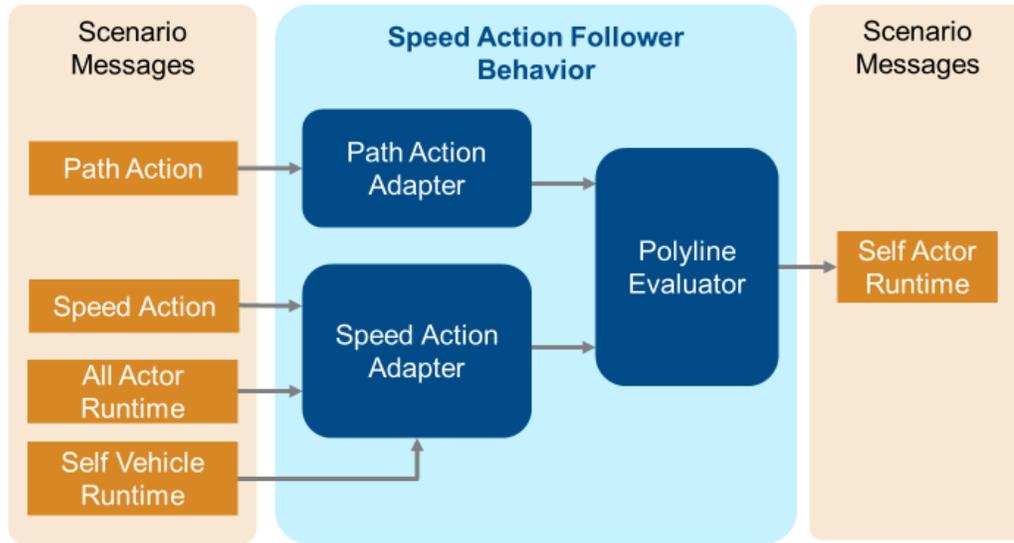
```
obj.mScenarioSimulationHdl = ...  
    Simulink.ScenarioSimulation.find( ...  
        'ScenarioSimulation', 'SystemObject', obj);  
  
obj.mActorSimulationHdl = Simulink.ScenarioSimulation.find( ...  
    'ActorSimulation', 'SystemObject', obj);  
  
obj.mActor.pose = ...  
    obj.mActorSimulationHdl.getAttribute('Pose');  
  
obj.mActor.velocity = ...  
    obj.mActorSimulationHdl.getAttribute('Velocity');
```

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

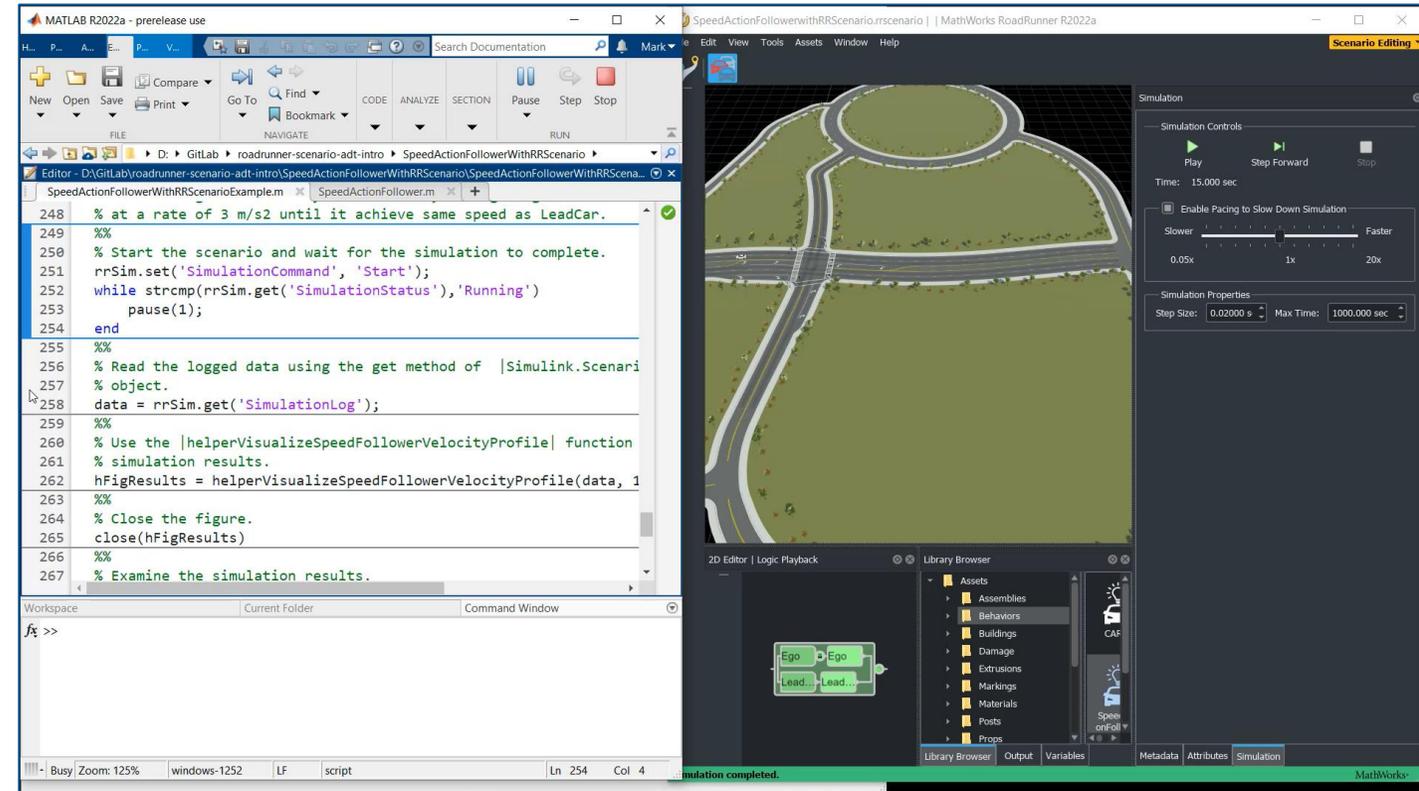
RoadRunner Scenario, Automated Driving Toolbox™

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# Simulate with speed action follower designed in MATLAB



- 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](#)

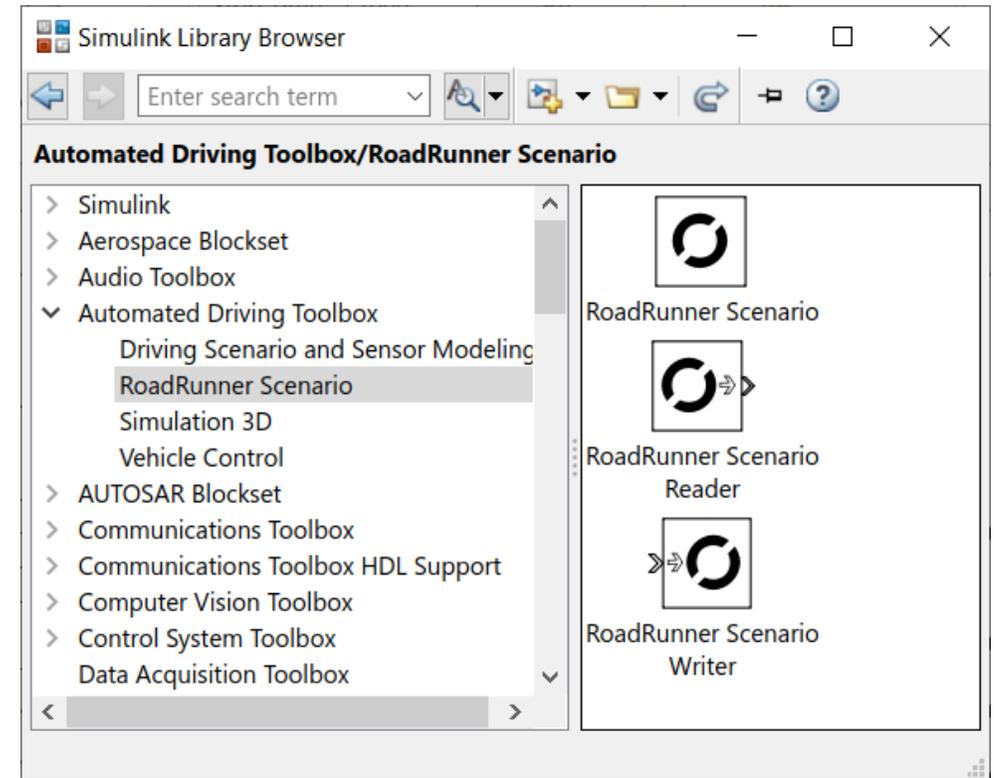
RoadRunner Scenario, Automated Driving Toolbox™

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# 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

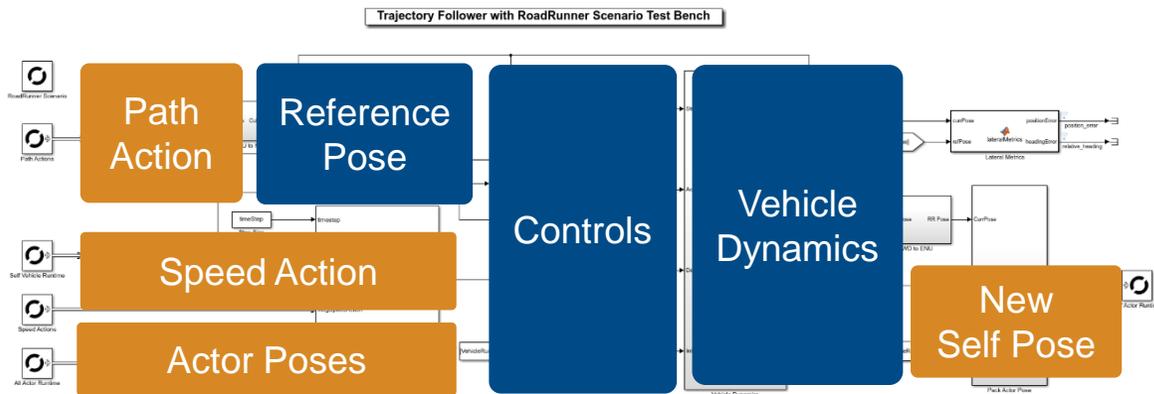


[Simulate RoadRunner Scenarios with Actors Modeled in Simulink](#)

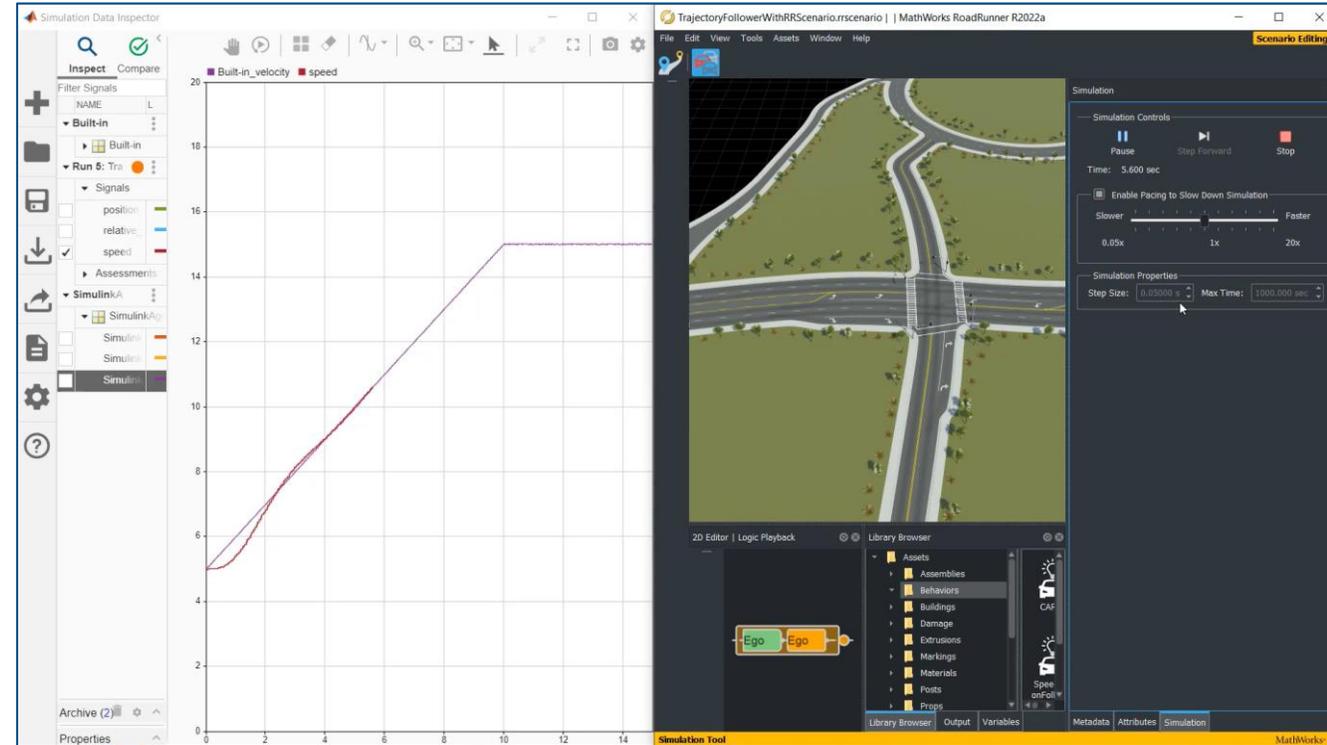
*RoadRunner Scenario, Automated Driving Toolbox™*

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# Simulate with trajectory follower designed in Simulink



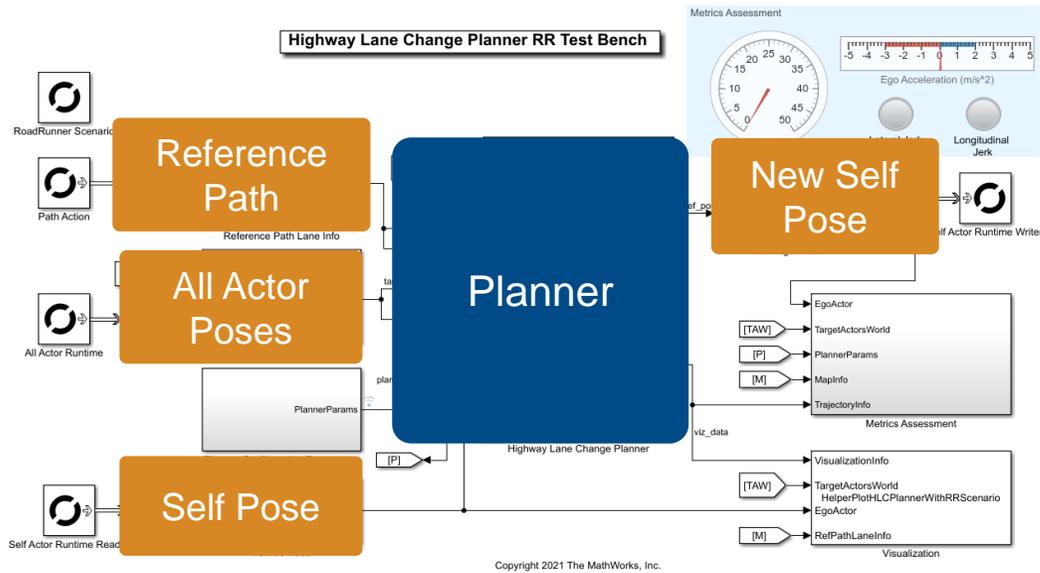
- Explore built-in trajectory following behavior with linear velocity
- Design actor behavior in Simulink which includes controls and dynamics
- Simulate and compare results



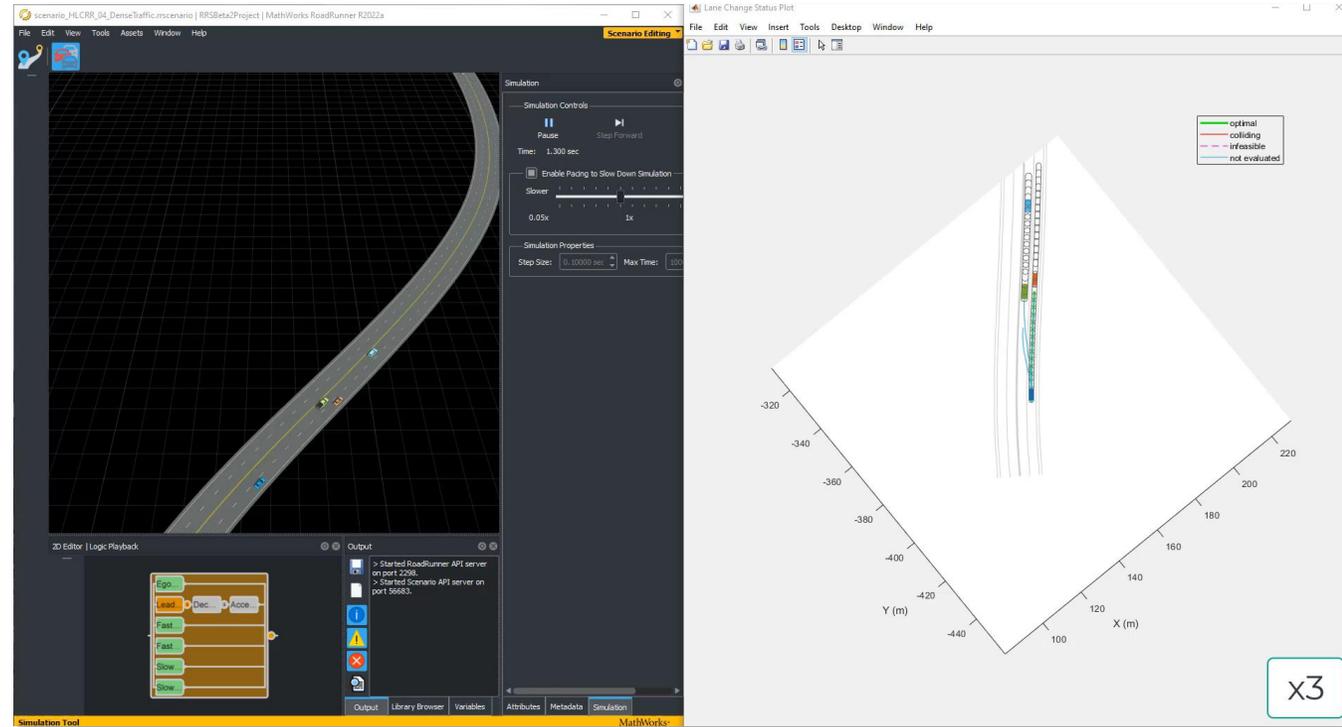
[Trajectory Follower with RoadRunner Scenario](#)  
*RoadRunner Scenario, Automated Driving Toolbox™*

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# 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

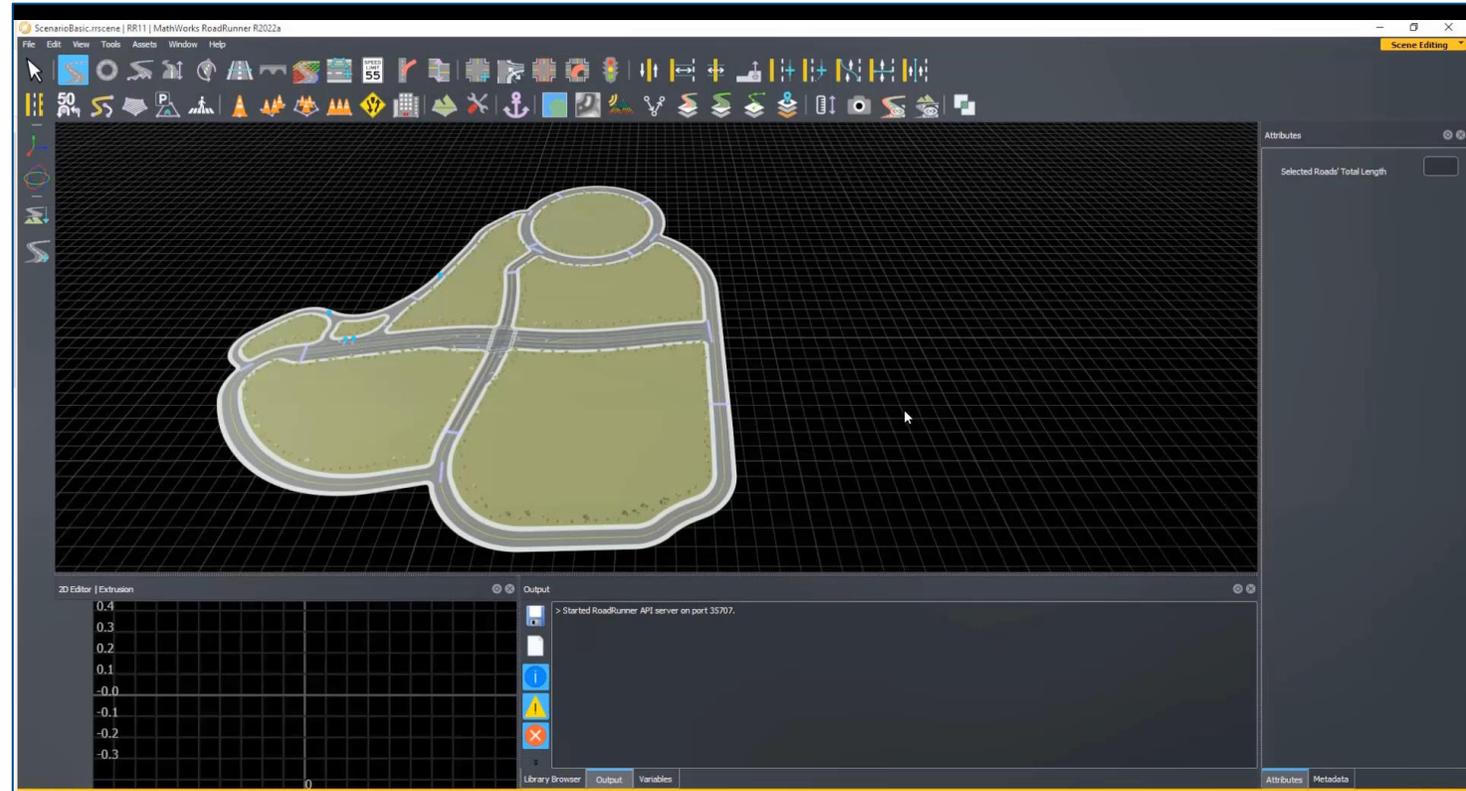
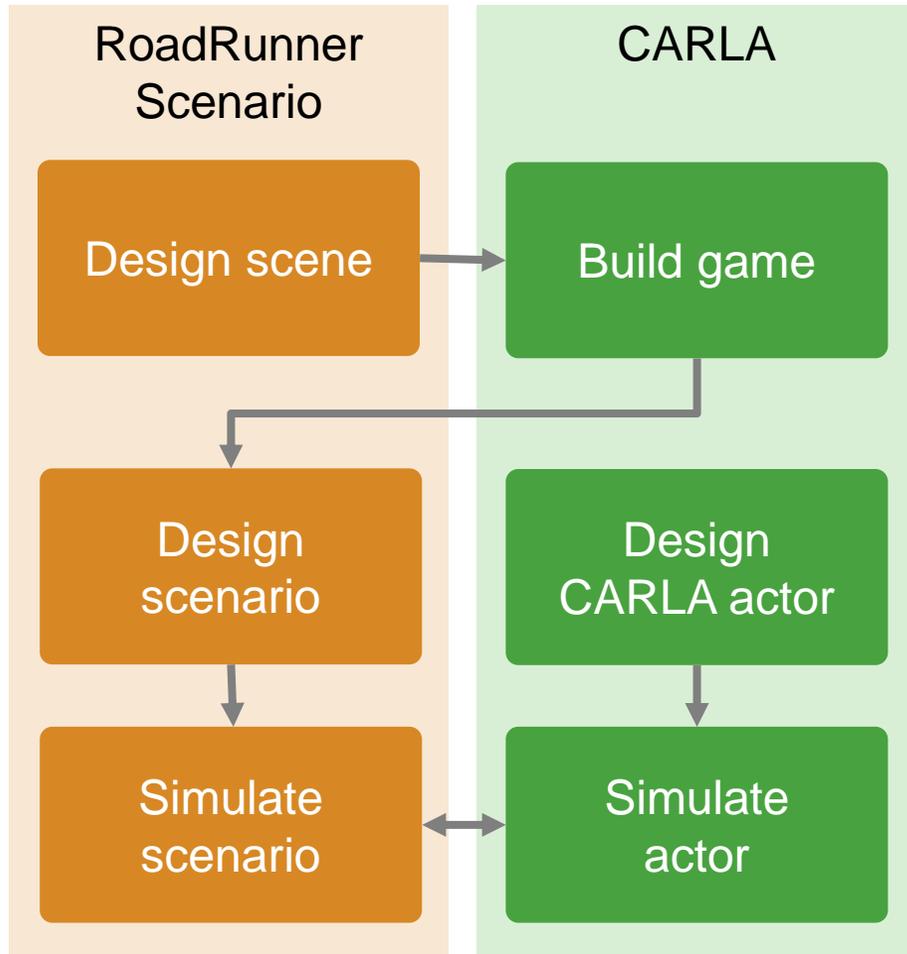


[Highway Lane Change Planner with RoadRunner Scenario](#)

RoadRunner Scenario, Automated Driving Toolbox™, Navigation Toolbox™

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# Simulate with actor behaviors designed in CARLA

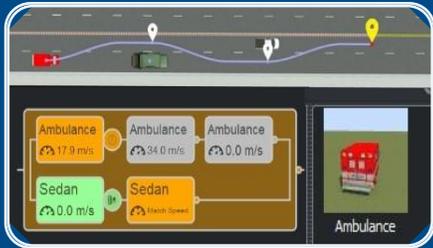


[Cosimulate Actors with CARLA](#)

*RoadRunner Scenario*

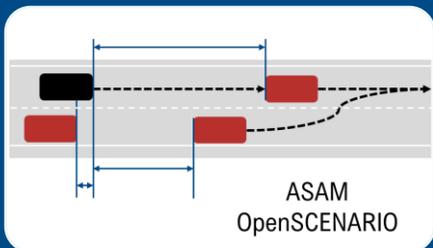
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# Develop Scenarios for Automated Driving Applications with RoadRunner Scenario



## Design and Simulate Scenarios

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



## Interface with OpenSCENARIO

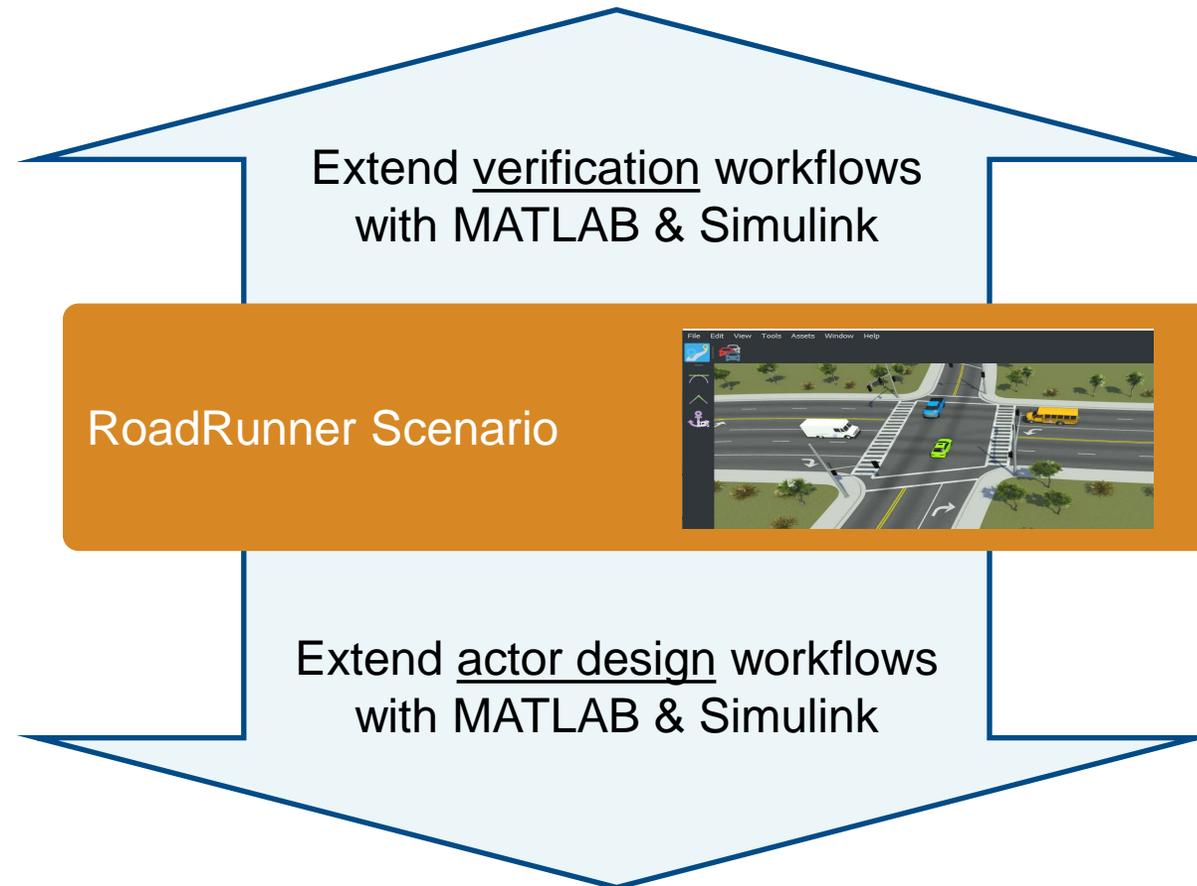
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## Simulate with MATLAB, Simulink, and CARLA

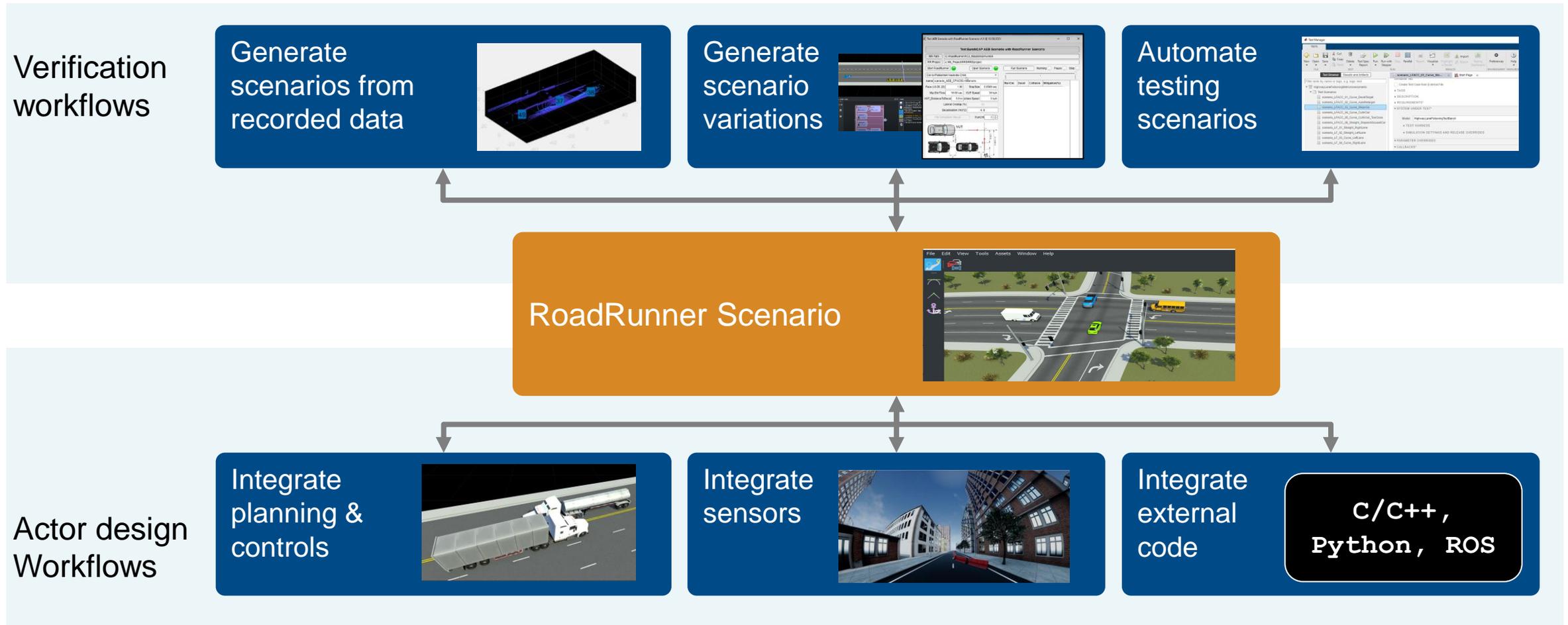
- Author actor behaviors in MATLAB
- Author actor behaviors in Simulink
- Author actor behaviors in CARLA

# Partner with MathWorks to extend scenario workflows



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

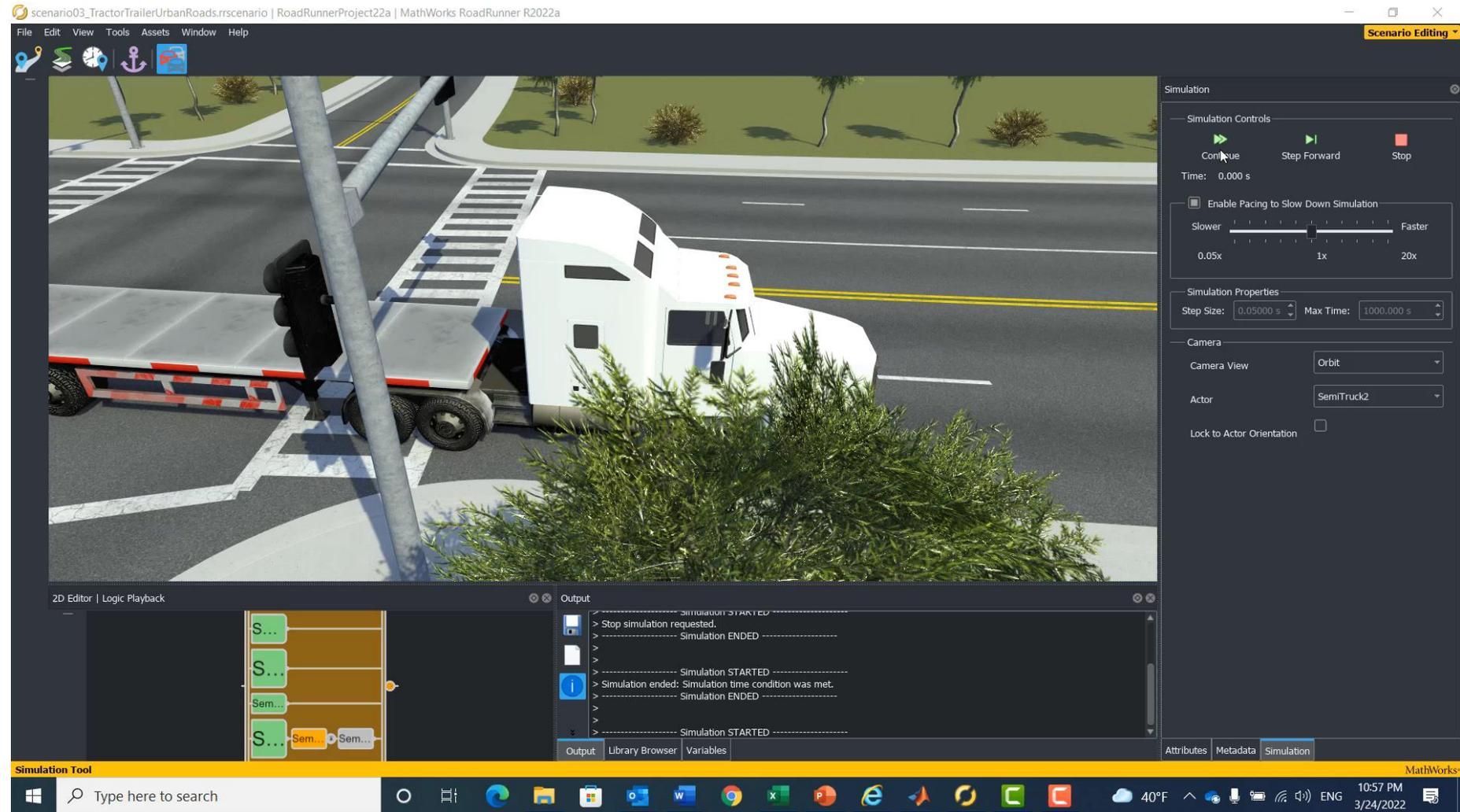
# Partner with MathWorks to extend scenario workflows



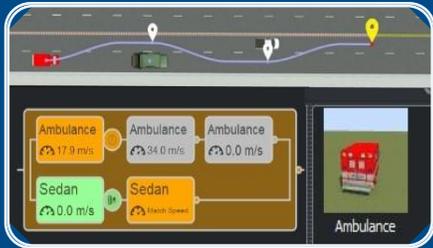
Engage with MathWorks engineers through proof-of-concept projects or Consulting Services to extend scenario workflows

# 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

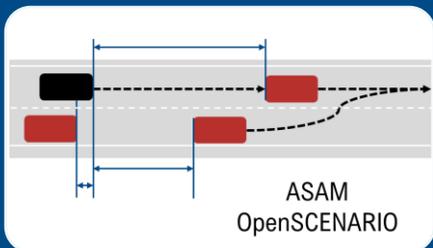


# Develop Scenarios for Automated Driving Applications with RoadRunner Scenario



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## Interface with OpenSCENARIO

- Export to OpenSCENARIO v2.0
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## Simulate with MATLAB, Simulink, and CARLA

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

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**Thank you**

