

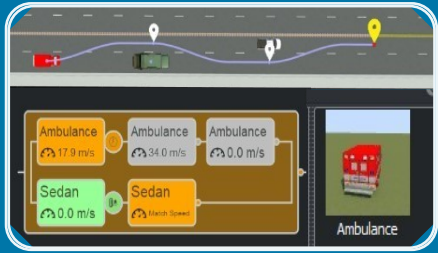
# 2022 MathWorks 中国汽车年会

## 设计和仿真面向自动驾驶应用的场景

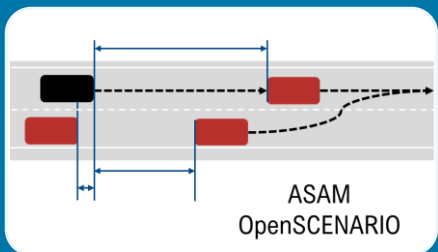
王鸿钧, MathWorks 中国



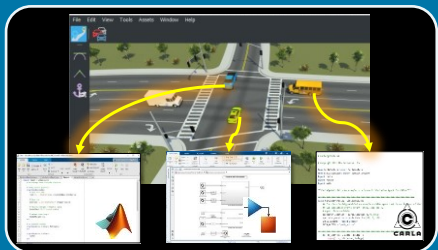
# 使用RoadRunner Scenario, 设计和仿真面向自动驾驶应用的场景



设计和仿真交通场景

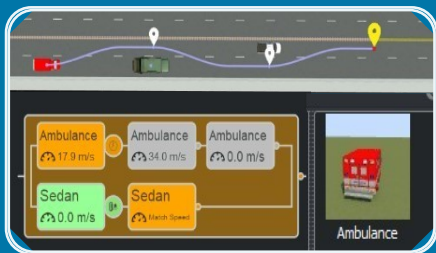


与OpenSCENARIO的接口

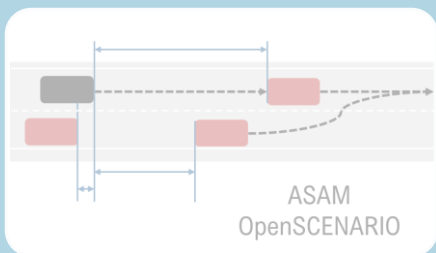


联合MATLAB, Simulink, 以及CARLA仿真

# 使用RoadRunner Scenario, 设计和仿真面向自动驾驶应用的场景



设计和仿真交通场景



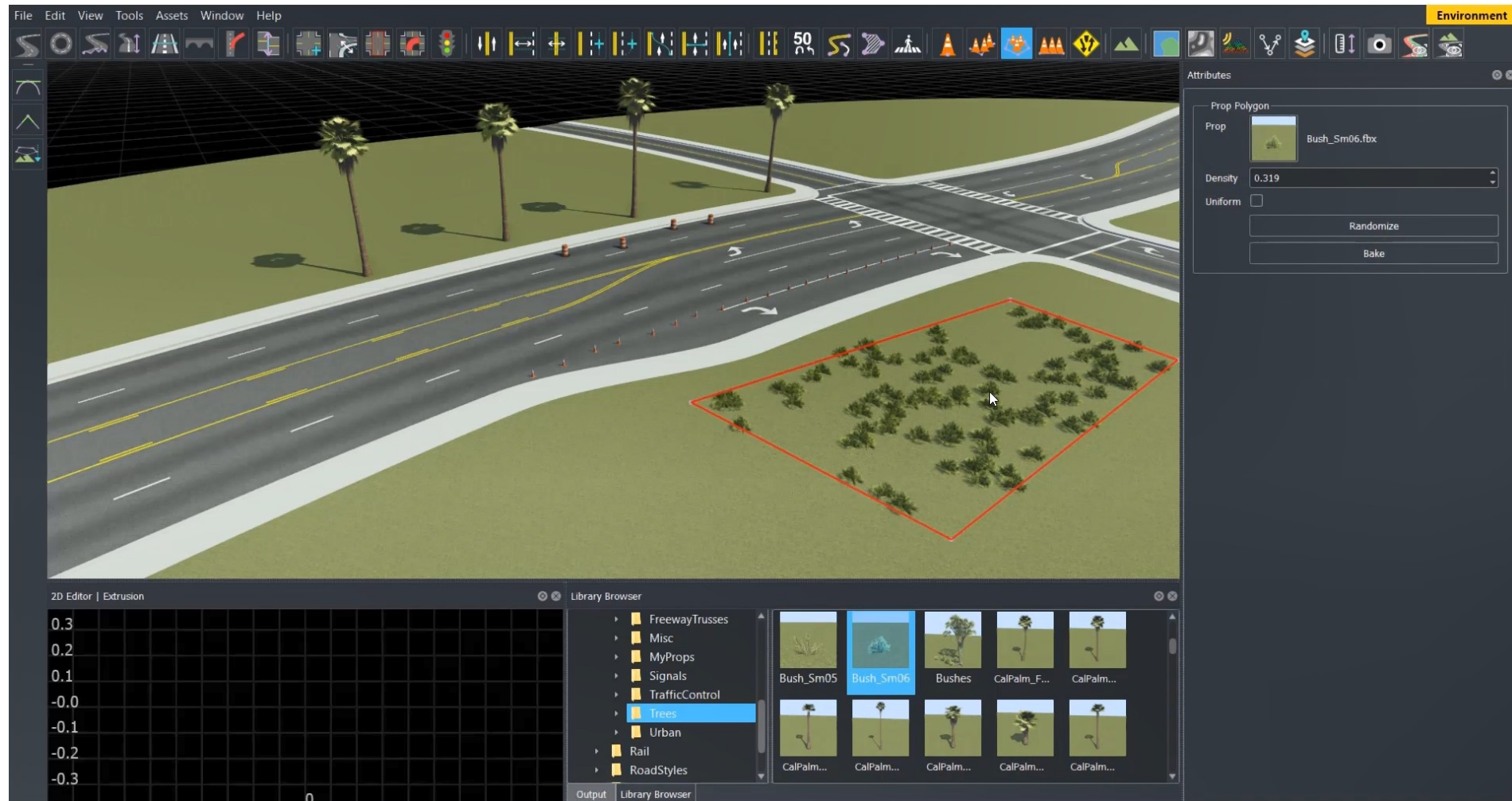
与OpenSCENARIO的接口



联合MATLAB, Simulink, 以及CARLA仿真

# 使用RoadRunner交互式设计道路环境

- 创建写实的道路和交叉路口
- 导入/导出 OpenDRIVE
- 导入 HD 地图
- 导入地理信息系统 (GIS) 文件
- 导出到常用的驾驶仿真环境





# 使用RoadRunner Scenario交互式设计交通场景

- 添加多种车辆
- 创建车辆轨迹
- 定义动作和逻辑
- 参数化调整变量

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

Variables

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

2D Editor | Logic Playback

Simulation Tool

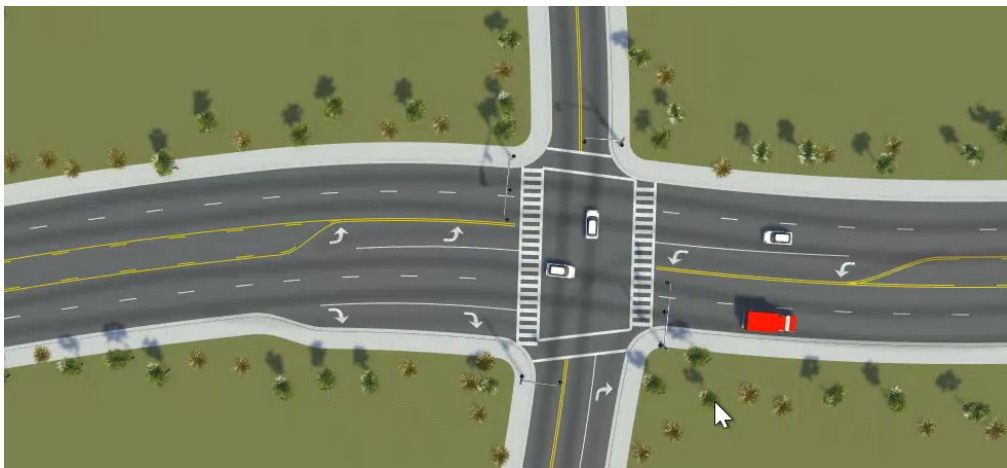
[Scenario Edit Tool](#)

RoadRunner Scenario

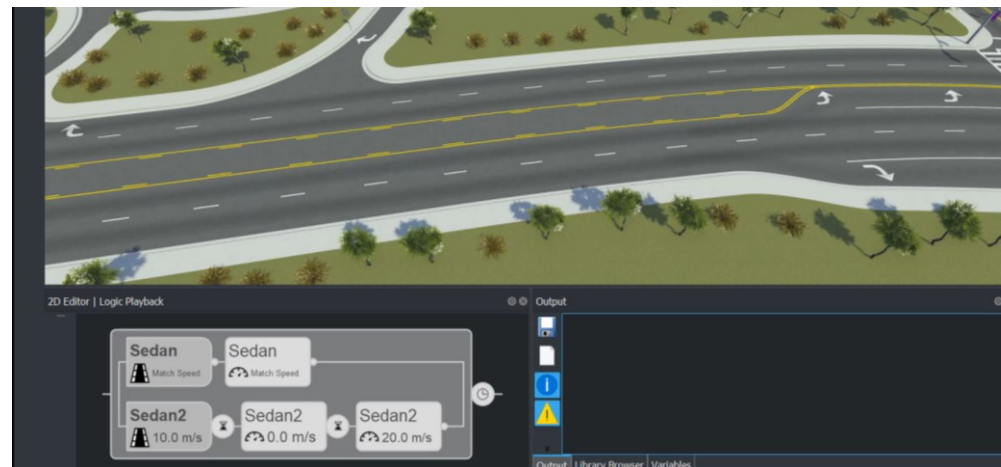
R2022a

# 仿真地图相关的车辆路径和场景逻辑

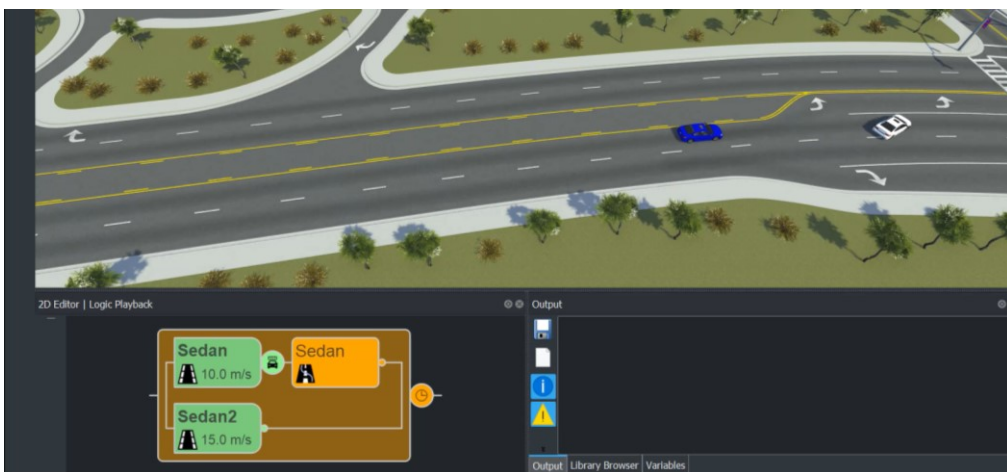
## 未定义路径时保持车道行驶



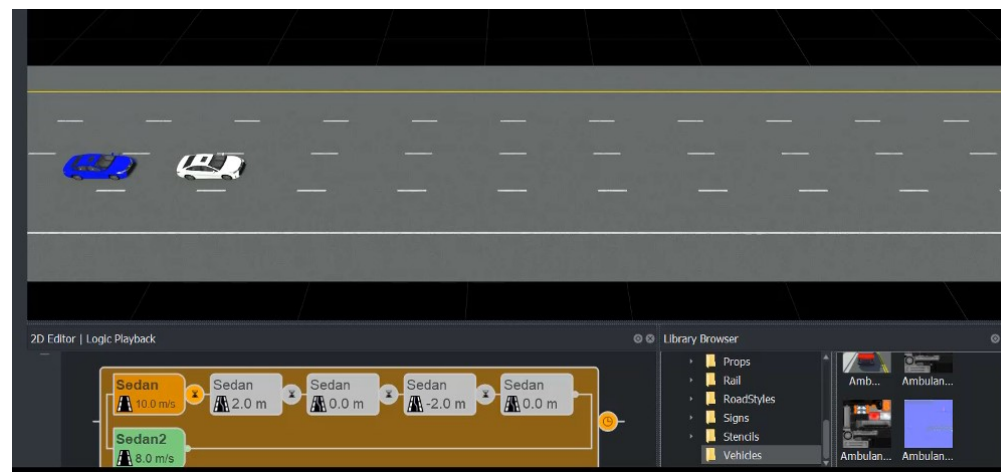
## 速度变换动作



## 车道变换动作



## 侧向偏移动作



# 设计交通参与者路径和生成轨迹

- 三次曲线插值
- 回旋曲线插值
- Euro NCAP  
(回旋-圆弧-回旋曲线  
clothoid-arc-clothoid)

NCAP\_example.rsscenario | Project\_Beta10 | MathWorks RoadRunner R2022a

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

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 $\alpha$ [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 Narside	1500	8.00	22.85	8.00	8.00	44.30	8.00	1500	22.85

[Route Timing Tool](#)  
RoadRunner Scenario

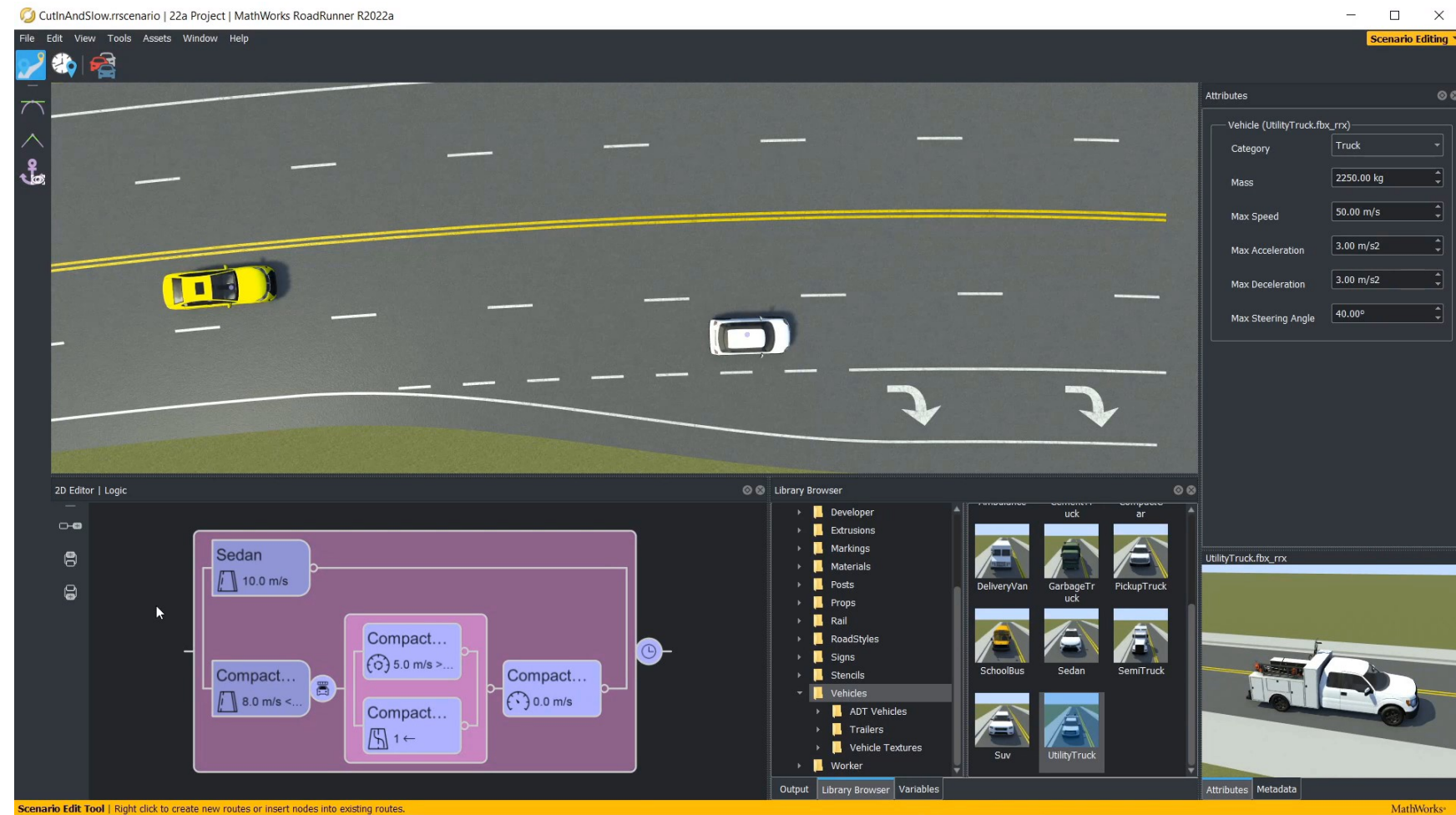
R2022a



# 通过编程方式泛化场景参数

## RoadRunner Scenario提供 MATLAB/gRPC 命令行API

- 定义编辑器中的场景变量
- 通过API编程设定变量
- 运行仿真
- 导出到OpenSCENARIO

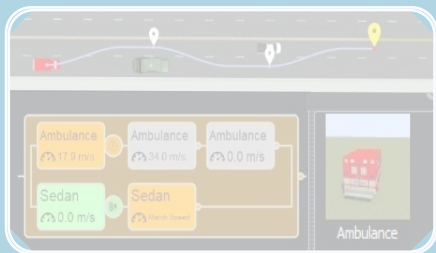


[Programmatic Scenario Interfaces](#)

RoadRunner Scenario

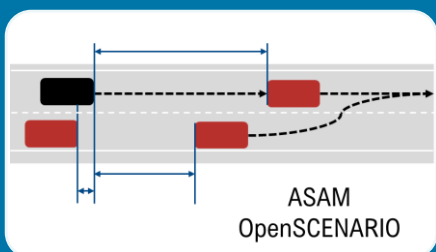
R2022a

# 使用RoadRunner Scenario, 设计和仿真面向自动驾驶应用的场景

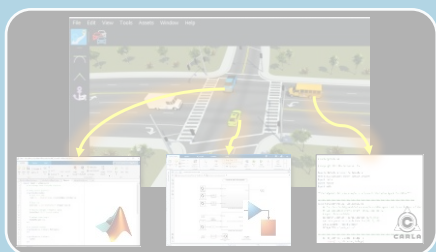


设计和仿真交通场景

- 设计车辆路径和场景逻辑
- 在不同的道路中重用场景设计
- 通过编程方式泛化场景参数

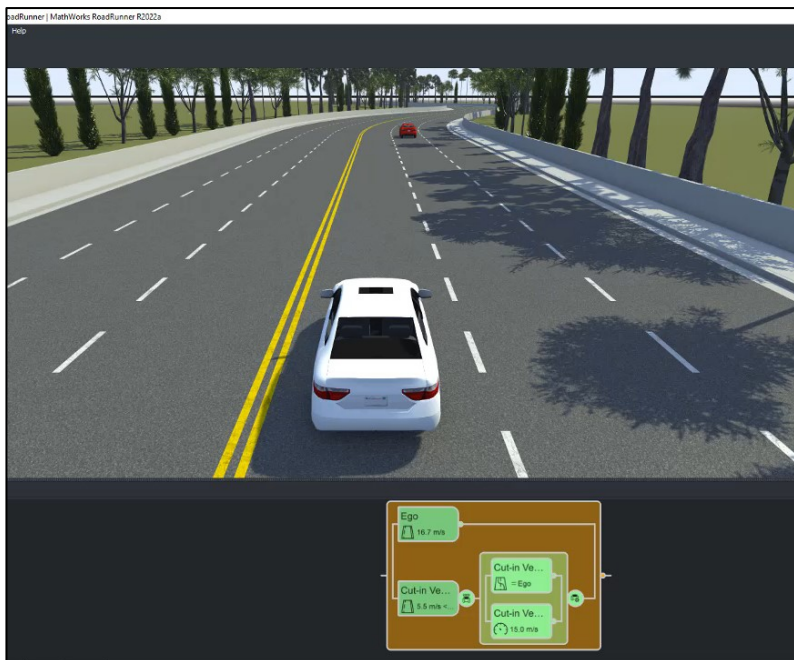


与OpenSCENARIO的接口



联合MATLAB, Simulink, 以及CARLA仿真

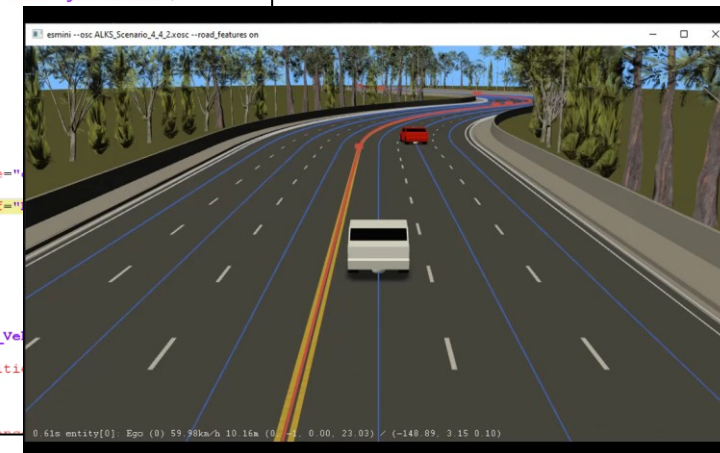
# 导出场景到 OpenSCENARIO V1.x 和 V2.0



OpenSCENARIO  
V1.x

```
<Condition name="Start Condition of Event_Vehicle2" conditionEdge="none"
  <ByValueCondition>
    <SimulationTimeCondition value="0" rule="greaterThan"/>
  </ByValueCondition>
</Condition>
</StartTrigger>
</Event>
<Action name="Speed_Action_Vehicle2_2">
  <PrivateAction>
    <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是ASAM会员，  
正积极参与  
OpenSCENARIO 2.0  
执行论坛

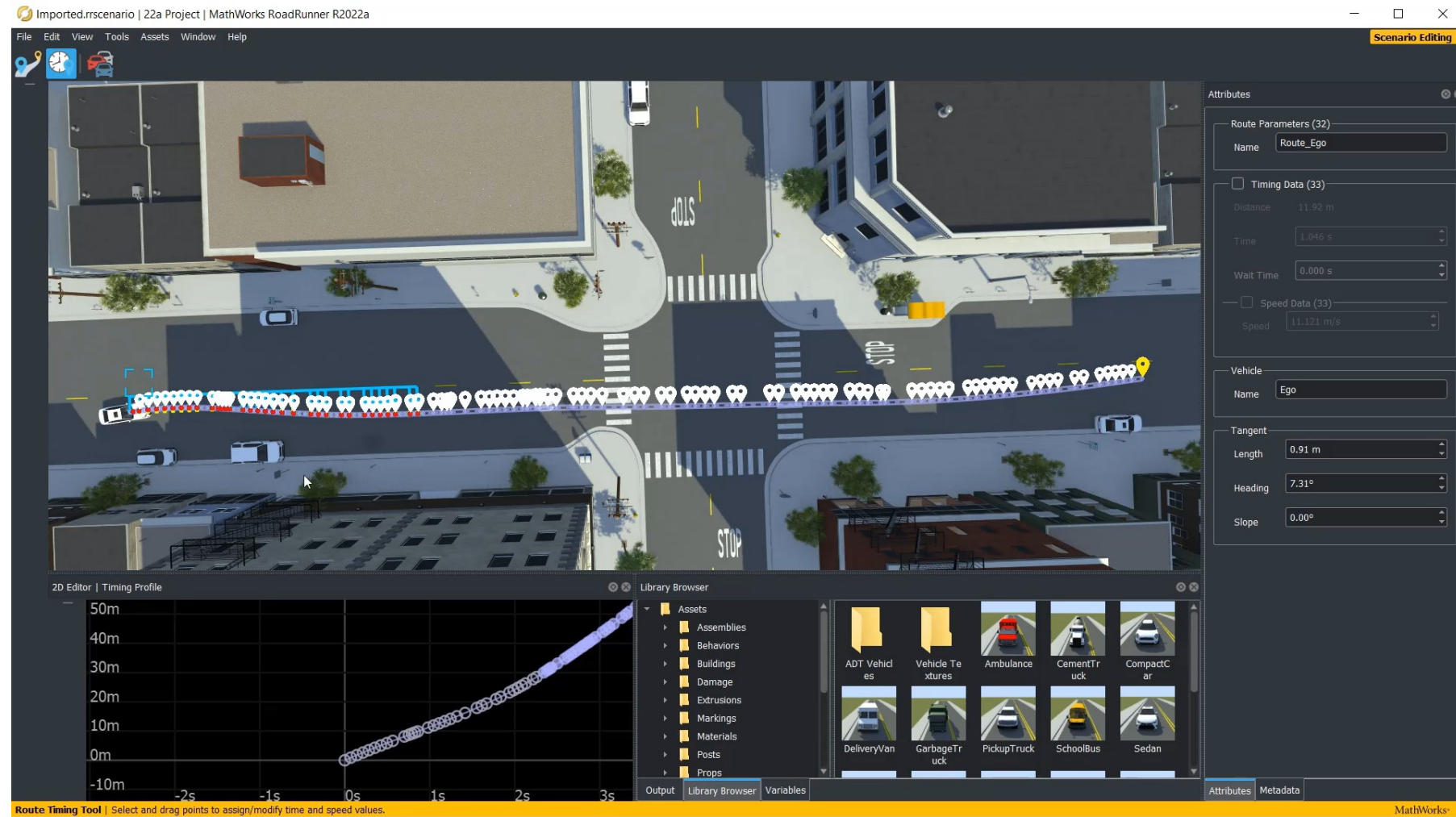
[Export to ASAM OpenSCENARIO](#)  
RoadRunner Scenario

R2022a



# 导入和编辑来自 OpenSCENARIO V1.x 的轨迹

- 从OpenSCENARIO V1.x 导入轨迹
- 交互式编辑轨迹
- 在不同的道路环境中重新放置导入的轨迹
- 抽取路径片段并添加场景逻辑

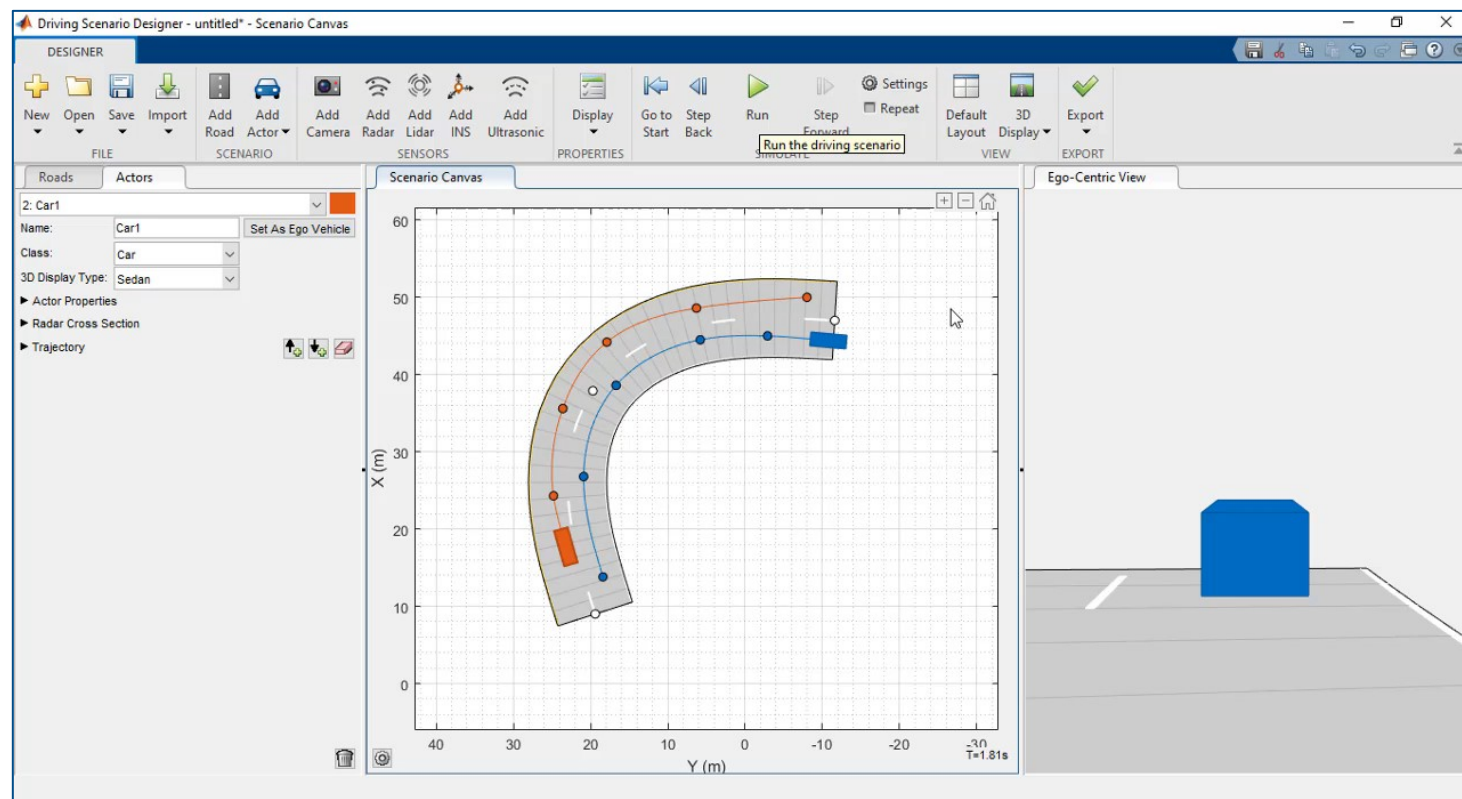
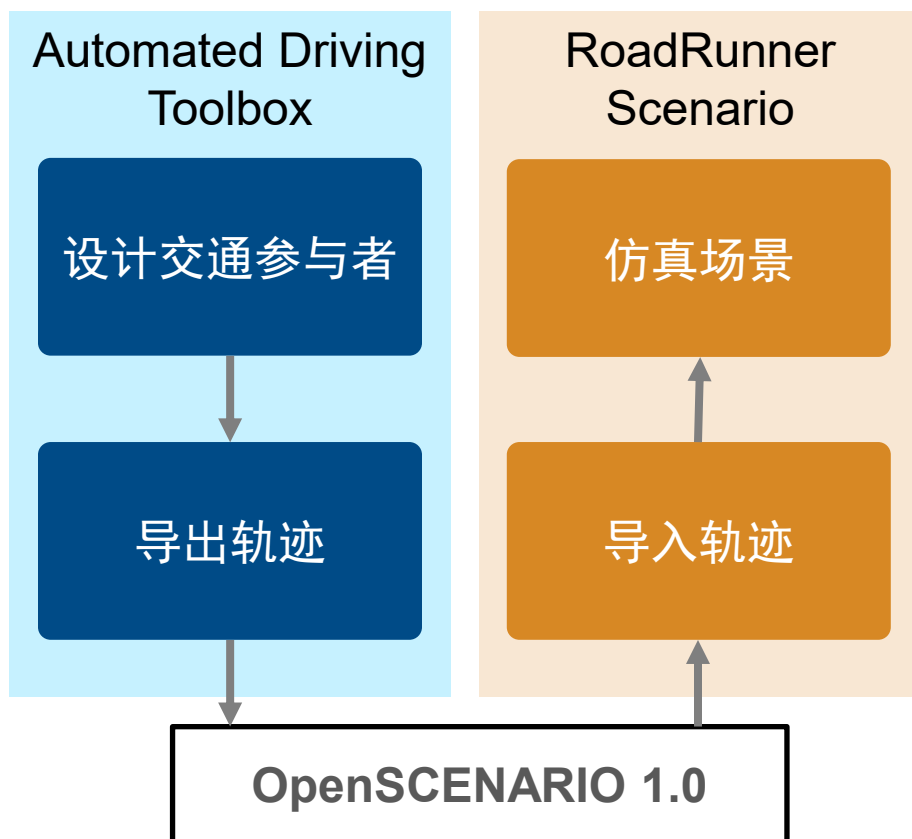


[Import Trajectories from ASAM OpenSCENARIO Files](#)

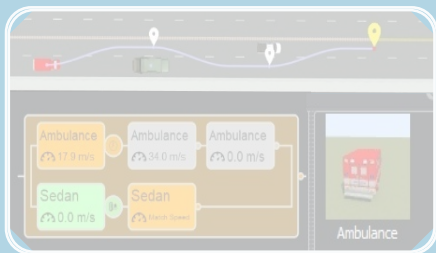
*RoadRunner Scenario*

R2022a

# 从Driving Scenario Designer (DSD) 迁移到RoadRunner Scenario

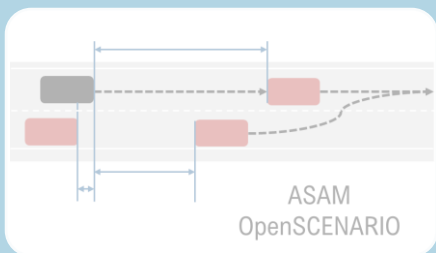


# 使用RoadRunner Scenario, 设计和仿真面向自动驾驶应用的场景



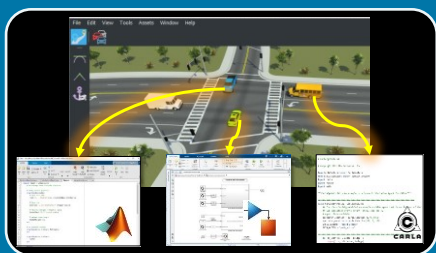
## 设计和仿真交通场景

- 设计车辆路径和场景逻辑
- 在不同的道路中重用场景设计
- 通过编程方式泛化场景参数



## 与OpenSCENARIO的接口

- 导出到 OpenSCENARIO v2.0
- 导出到 OpenSCENARIO v1.x
- 导入来自 OpenSCENARIO v1.x 的轨迹



## 联合MATLAB, Simulink, 以及CARLA仿真

# 仿真含有不同来源的交通参与者行为的交通场景

RoadRunner Scenario可以连接来自MATLAB, Simulink, 以及CARLA的交通参与者

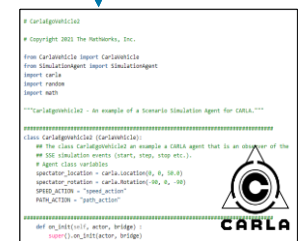
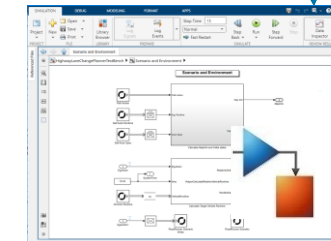
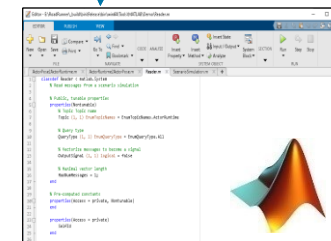
RoadRunner Scenario可以作为一个仿真服务器，交通参与者客户端相当于该智能系统中的智能体（Agent）

交通参与者可在场景中设定自身状态

- 包括当前时刻自身的位姿和速度

交通参与者可以获取场景状态

- 动作命令，包括路径、速度、换道、偏移
- 场景中所有交通参与者的位姿和速度
- 场景中所有交通参与者的尺寸
- 地图中的车道和车道边界



# 在MATLAB中编写交通参与者行为

在Automated Driving Toolbox中提供了MATLAB API，实现RoadRunner Scenario接口

- 连接到仿真场景
- 从场景读取世界状态
- 从场景读取交通参与者动作命令
- 向场景写入交通参与者状态
- 向场景报告Error或Warning

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');
```

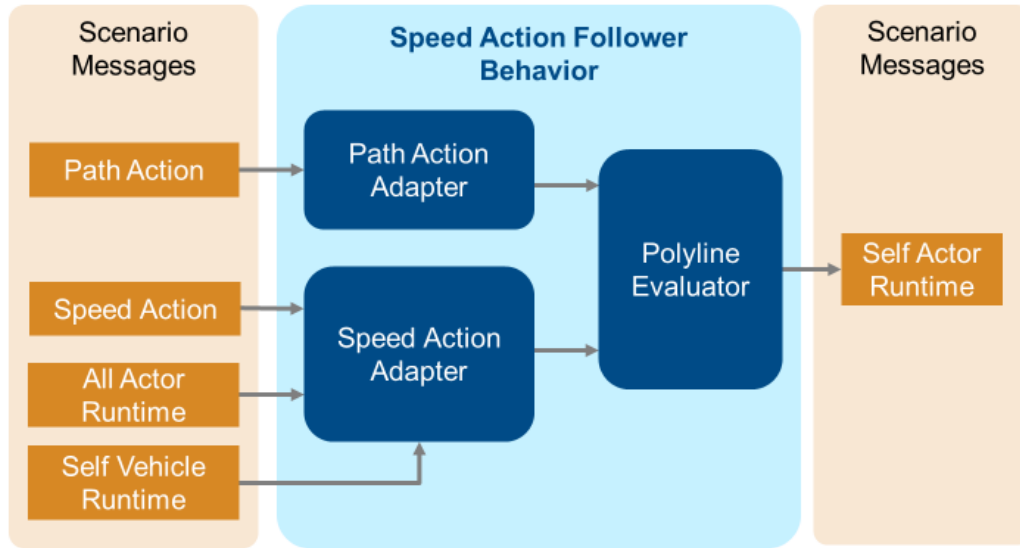
[Simulate RoadRunner Scenarios with Actors Modeled in MATLAB](#)

RoadRunner Scenario, Automated Driving Toolbox™

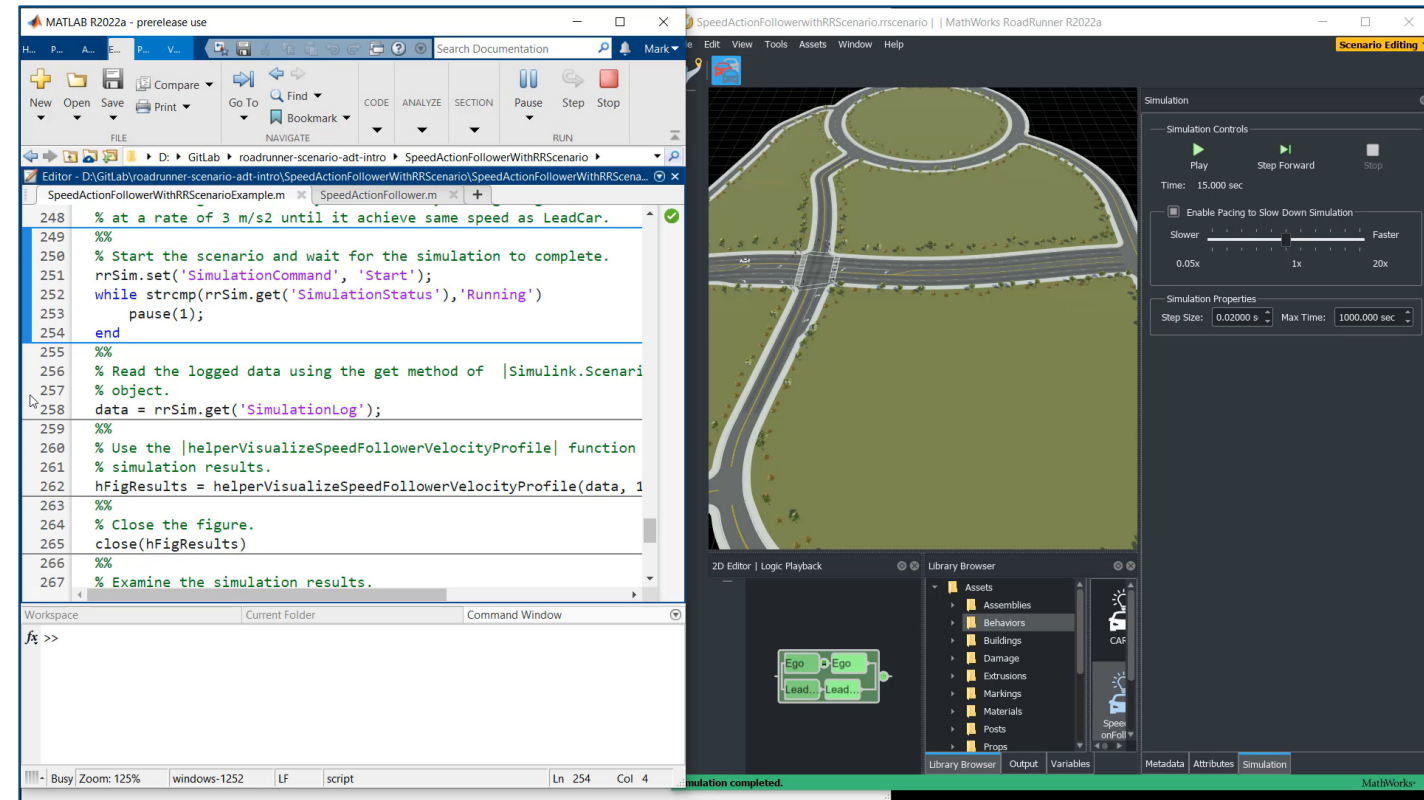
R2022a



# 在MATLAB中实现速度动作跟随并仿真场景



- 在MATLAB中实现交通参与者的速度动作跟随行为
- 关联MATLAB中的参与者与RoadRunner Scenario中的参与者
- 仿真并可视化结果



## [Speed Action Follower with RoadRunner Scenario](#)

RoadRunner Scenario, Automated Driving Toolbox™

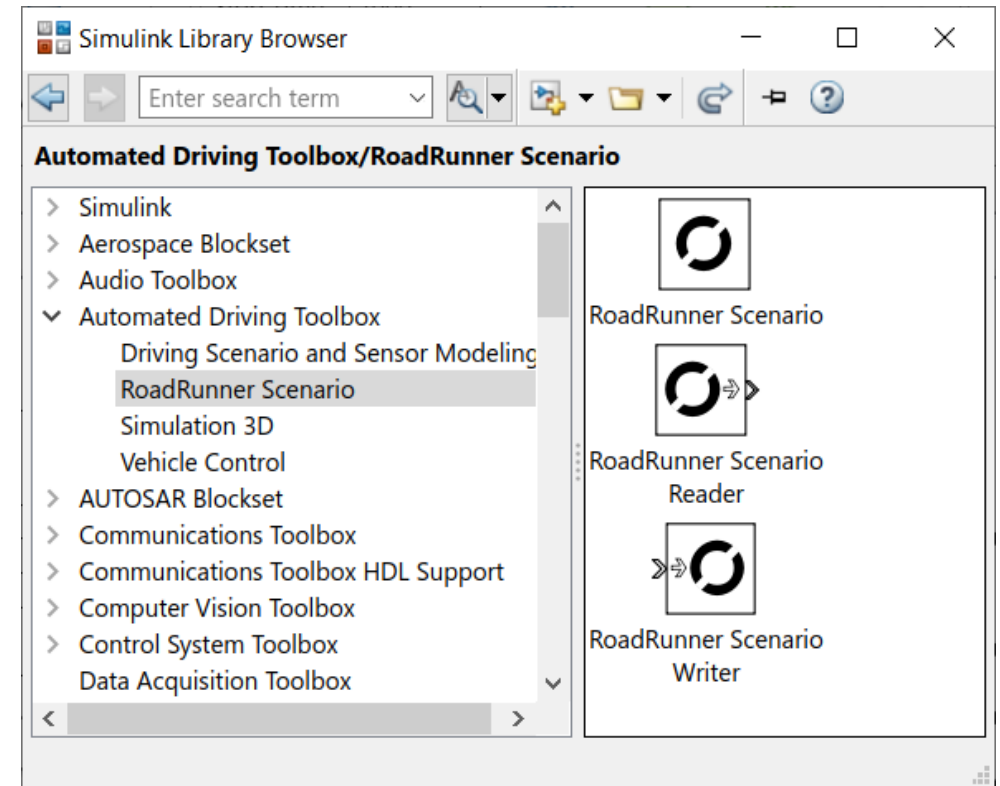
R2022a



# 在Simulink中编写交通参与者行为

在Automated Driving Toolbox中提供了Simulink相关模块，实现RoadRunner Scenario接口

- *RoadRunner Scenario*
  - 建立一个模型与场景间的接口
- *RoadRunner Scenario Reader*
  - 读取世界状态: 交通参与者位姿、速度、颜色和动作命令
- *RoadRunner Scenario Writer*
  - 向场景写入交通参与者状态
  - 向场景报告Error或Warning

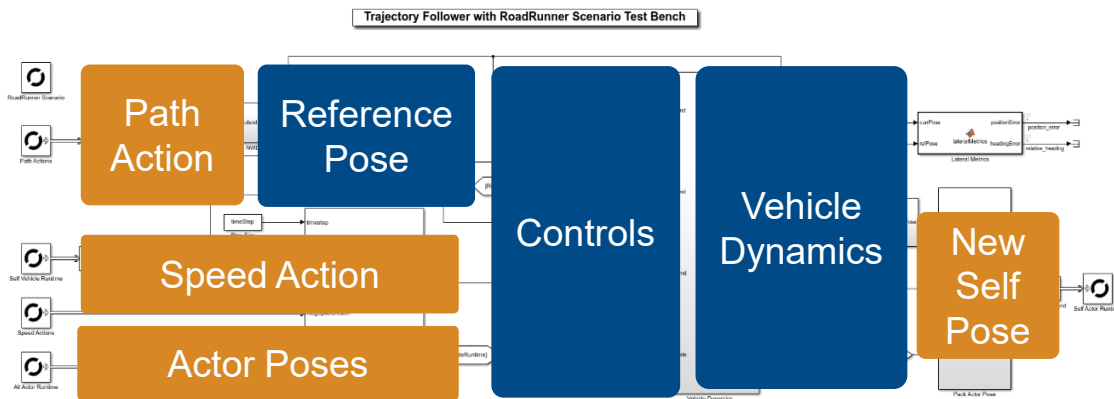


[Simulate RoadRunner Scenarios with Actors Modeled in Simulink](#)

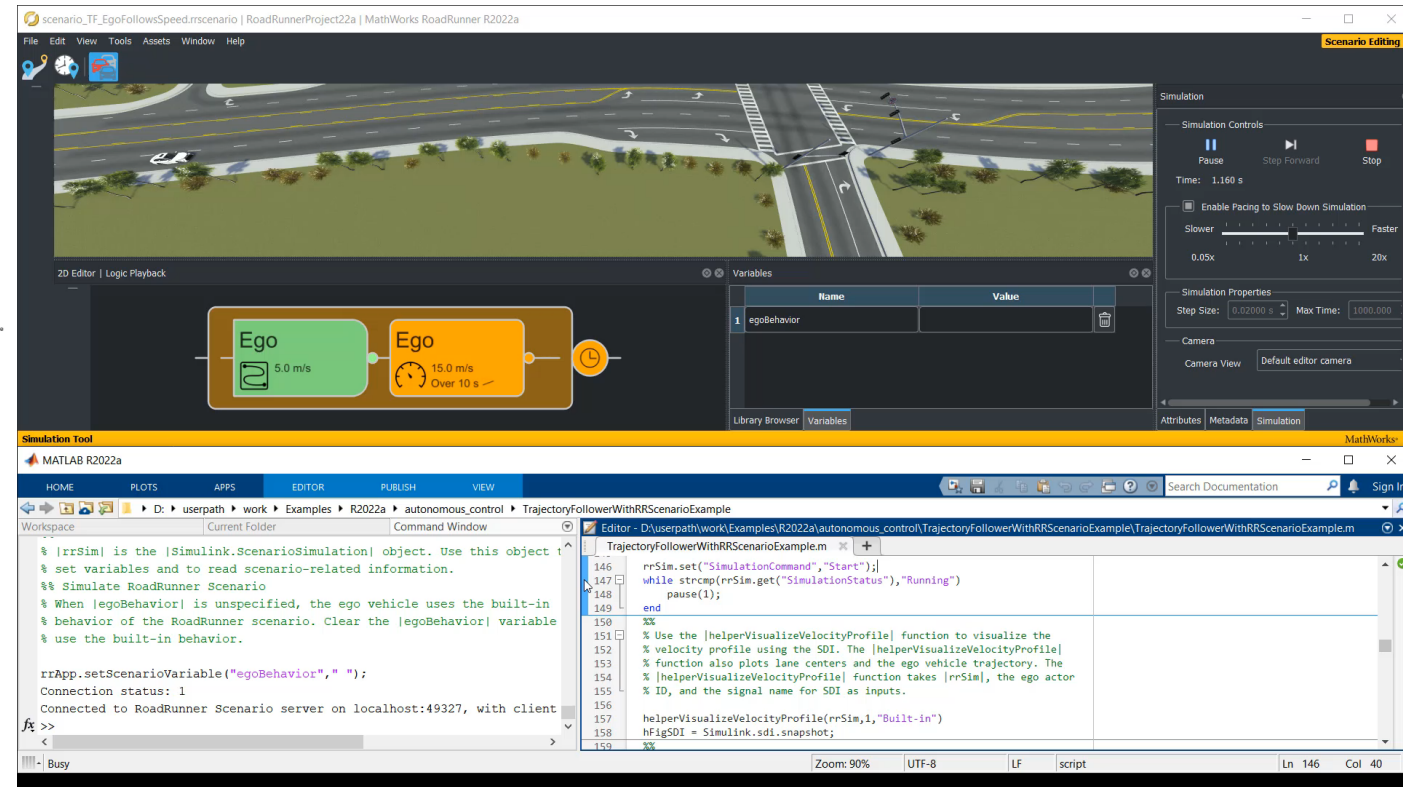
*RoadRunner Scenario, Automated Driving Toolbox™*

R2022a

# 在Simulink中实现轨迹跟随并仿真场景



- 观察RoadRunner Scenario内置的对线性加速的轨迹跟随行为（理想控制）
- 在Simulink中设计交通参与者行为，包括真实控制和车辆动力学（实际控制）
- 仿真和对比结果



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

R2022a

# 实现Simulink与RoadRunner Scenario的接口

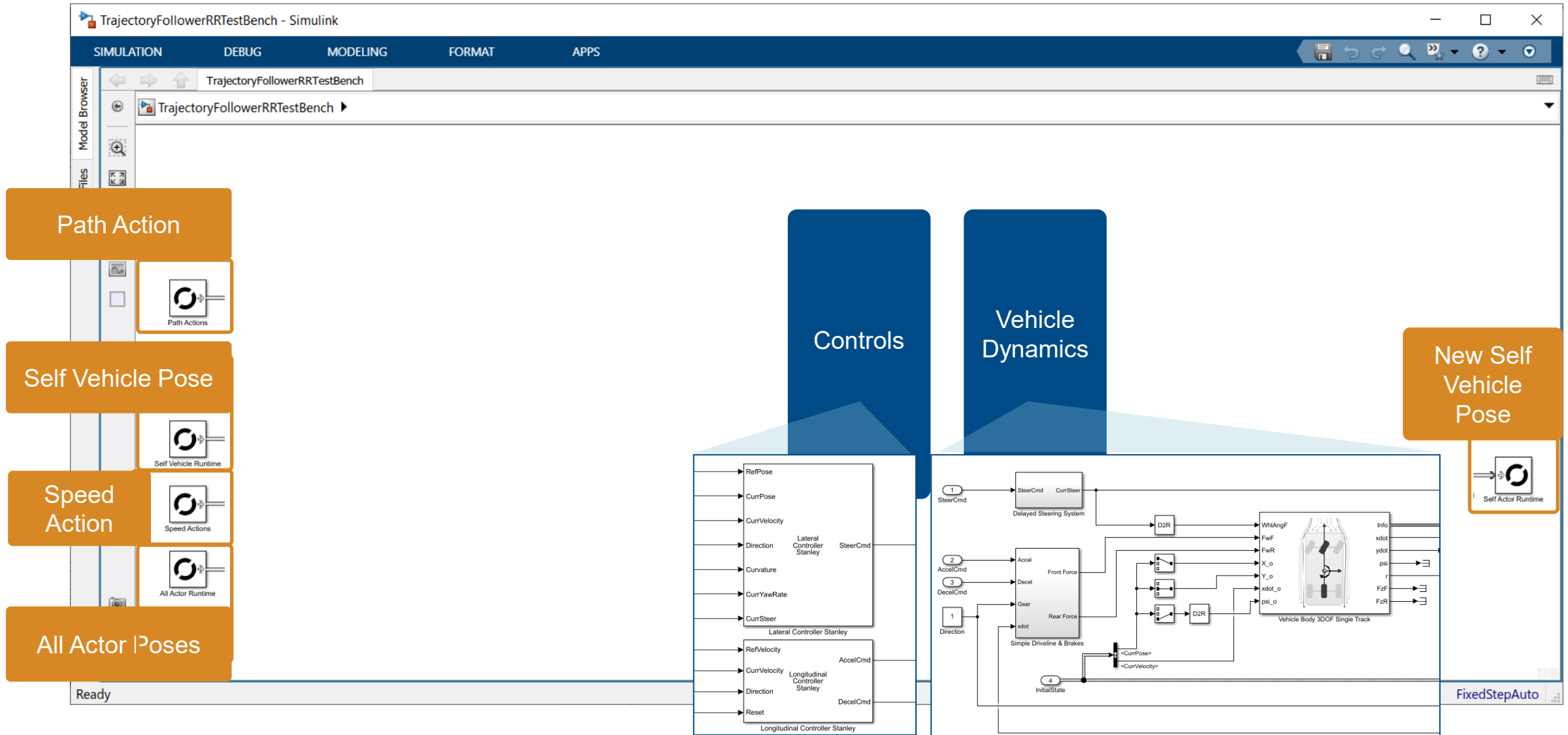
The screenshot displays the Simulink environment for a project named 'TrajectoryFollowerRRTestBench'. The interface is divided into several panes:

- Model Browser:** Shows the project structure with 'TrajectoryFollowerRRTestBench' and its sub-components: 'Path Actions', 'Self Vehicle Runtime', 'Speed Actions', and 'All Actor Runtime'.
- Block Parameters: Path Actions:** This window is open, showing the configuration for the 'Path Actions' block. It includes:
  - RoadRunner Scenario Reader:** Reads the selected topic type from RoadRunner Scenario.
  - Parameters:**
    - Topic Category: Action
    - Action Type: Path Following (selected in a dropdown menu)
    - Filter: Self
    - Sample time: 0
- Block Parameters: Self Vehicle Runtime:** This window is open, showing the configuration for the 'Self Vehicle Runtime' block. It includes:
  - RoadRunner Scenario Reader:** Reads the selected topic type from RoadRunner Scenario.
  - Parameters:**
    - Topic Category: Actor
    - Actor Type: Vehicle
    - Topic: Vehicle Pose
    - Filter: Self
- Block Parameters: New Self Vehicle Runtime:** This window is open, showing the configuration for the 'New Self Vehicle Runtime' block. It includes:
  - RoadRunner Scenario Writer:** Writes selected topic type to RoadRunner Scenario. Before you use this block, load the [load function](#).
  - Parameters:**
    - Topic Category: Actor
    - Actor Type: Vehicle
    - Topic: Vehicle Pose
- Bus Structure:** A separate window shows the bus structure for 'BusVehicleRuntime', which includes:
  - ActorRuntime
    - ActorID
    - Pose
    - Velocity
    - AngularVelocity
  - NumWheels
  - WheelPoses

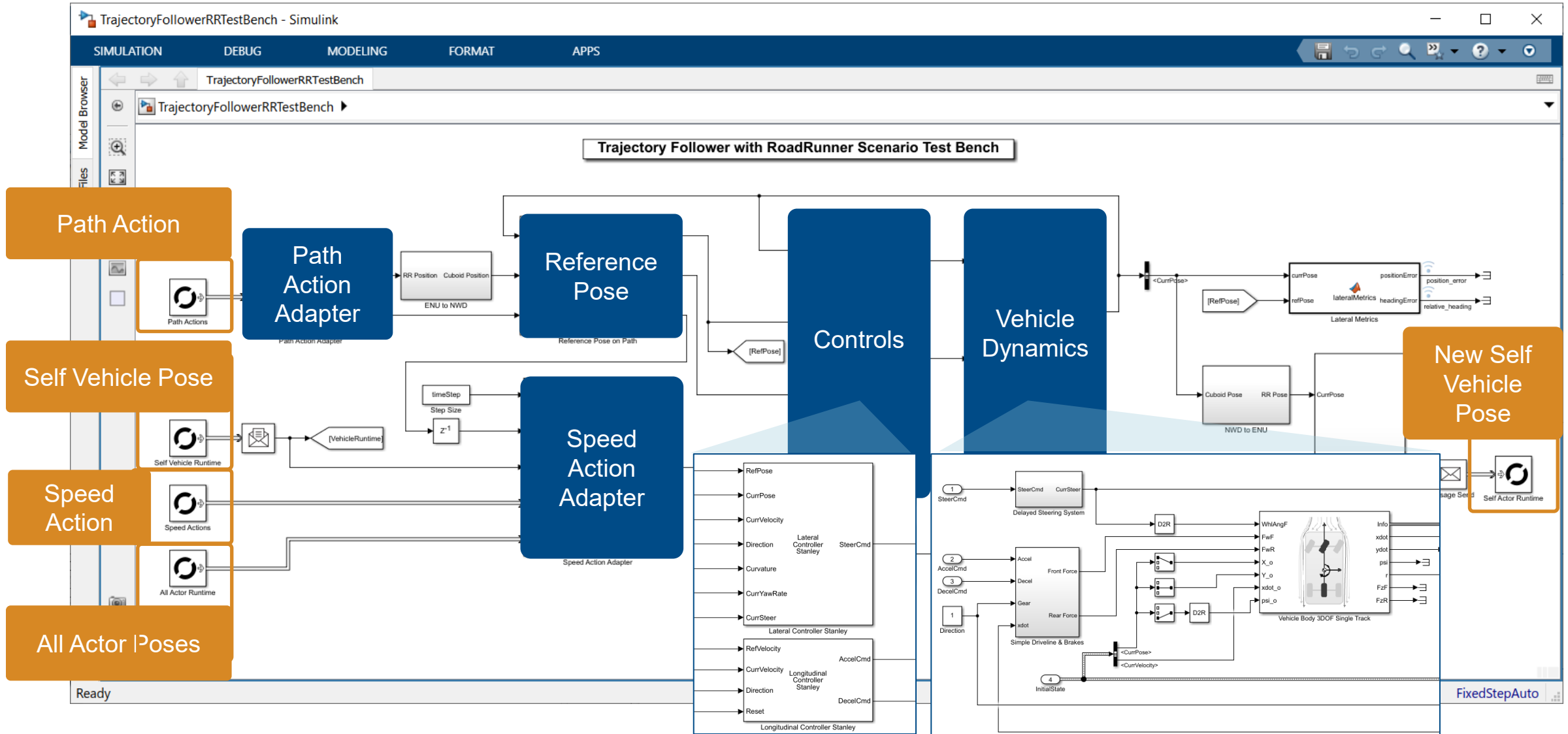
Callouts in orange boxes highlight specific elements:

- Path Action:** Points to the 'Path Actions' block in the Model Browser.
- Self Vehicle Pose:** Points to the 'Self Vehicle Runtime' block in the Model Browser.
- New Self Vehicle Pose:** Points to the 'New Self Vehicle Runtime' block in the Model Browser.

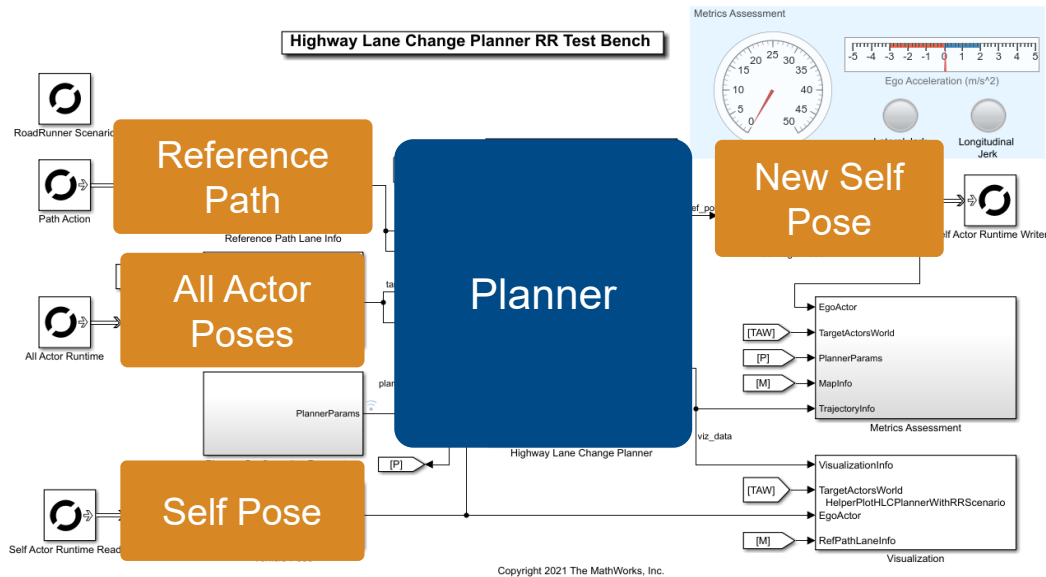
# 实现Simulink与RoadRunner Scenario的接口



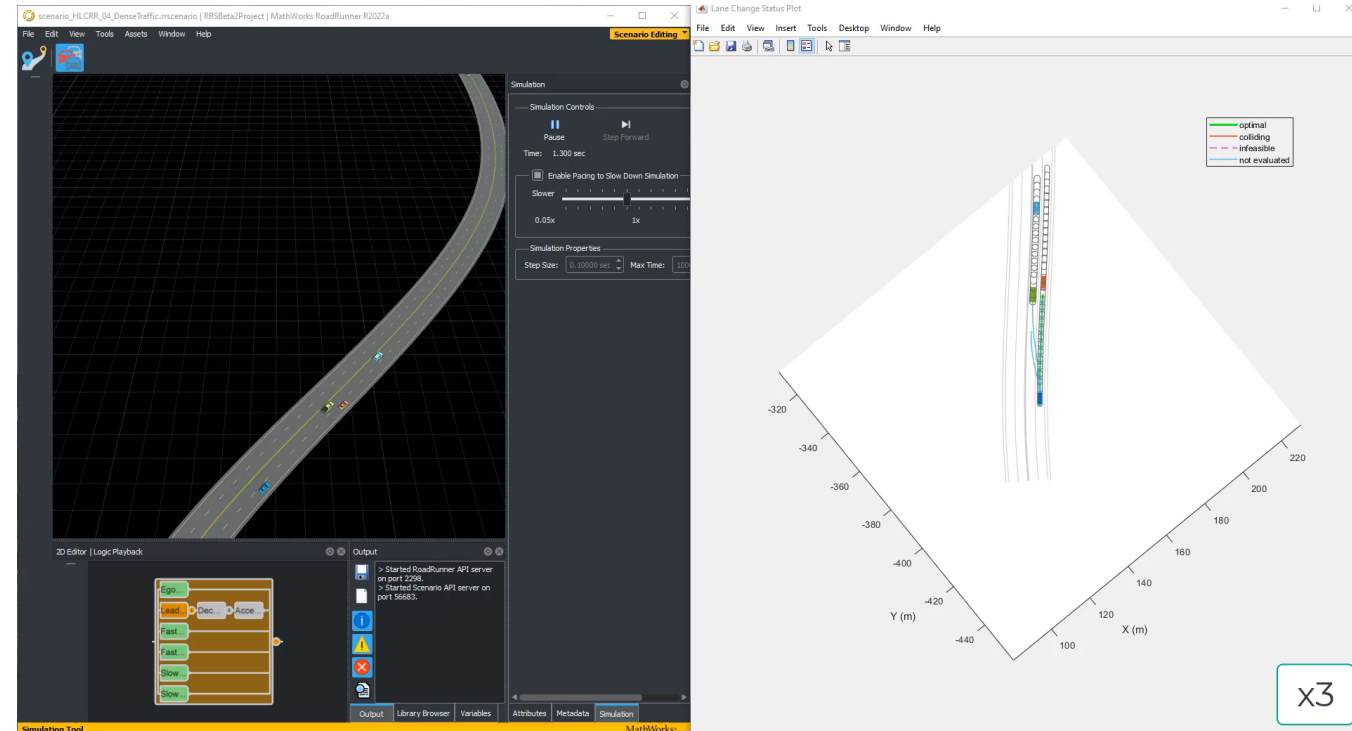
# 实现Simulink与RoadRunner Scenario的接口



# 仿真Simulink中的自动换道规划器



- 设计并实现自车的规划算法
- 定义其他目标车辆的轨迹和逻辑
- 显示可选的和最终选择的自车轨迹



x3

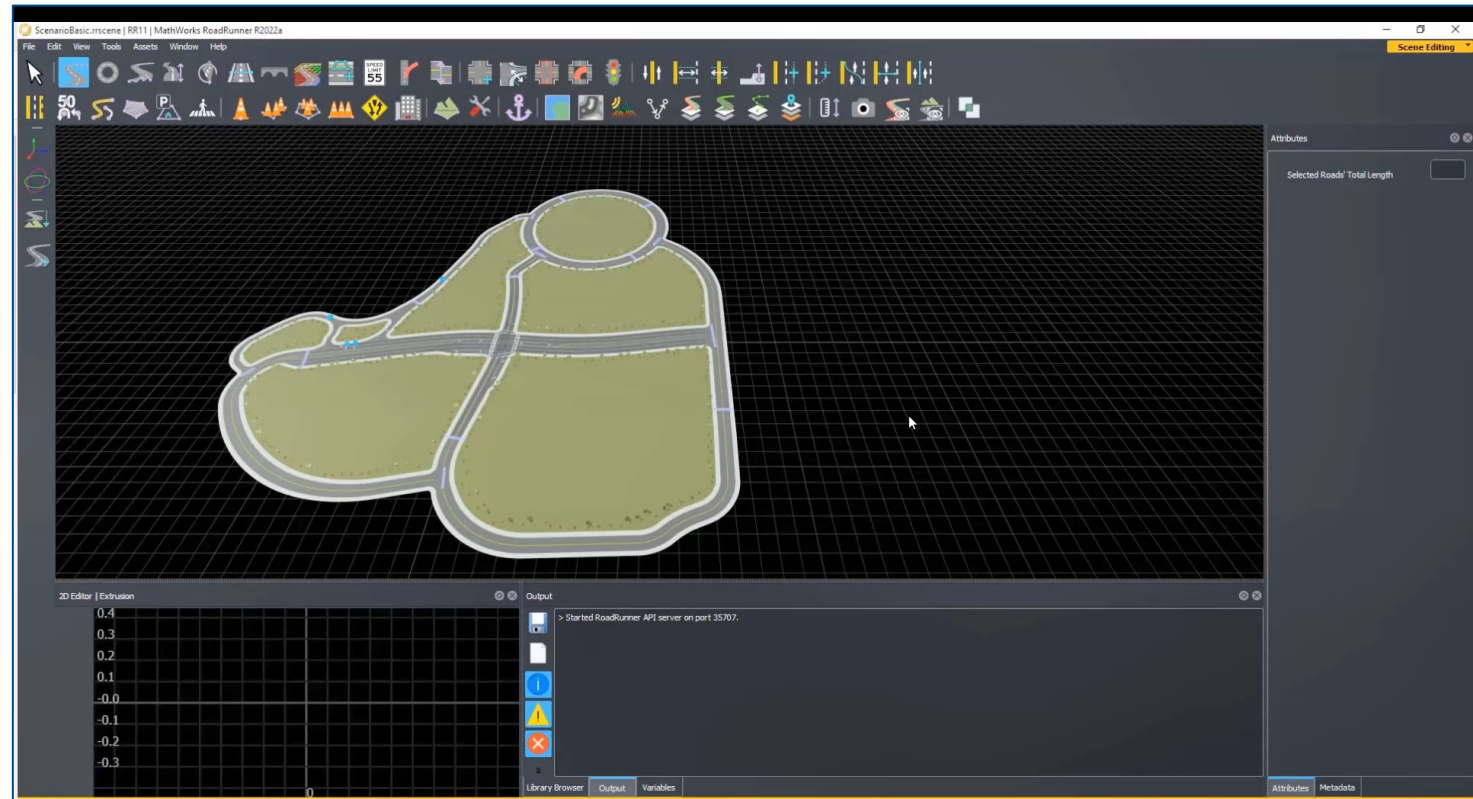
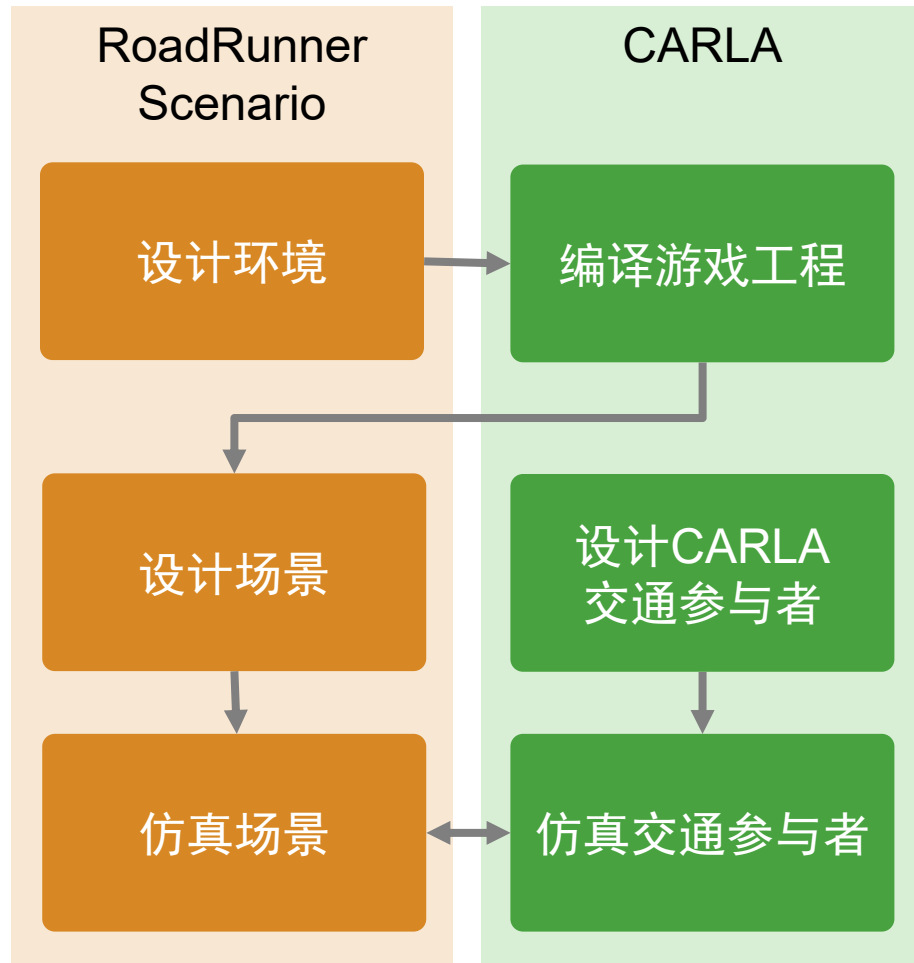
[Highway Lane Change Planner with RoadRunner Scenario](#)

RoadRunner Scenario, Automated Driving Toolbox™, Navigation Toolbox™

R2022a



# 在CARLA中设计交通参与者并仿真场景

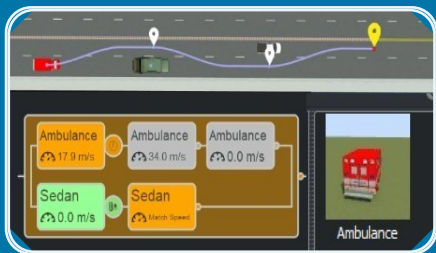


[Cosimulate Actors with CARLA](#)

RoadRunner Scenario

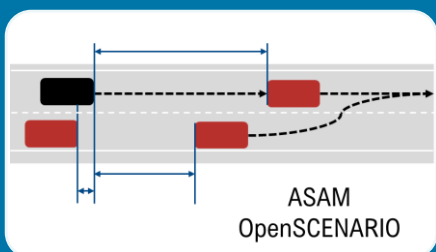
R2022a

# 使用RoadRunner Scenario, 设计和仿真面向自动驾驶应用的场景



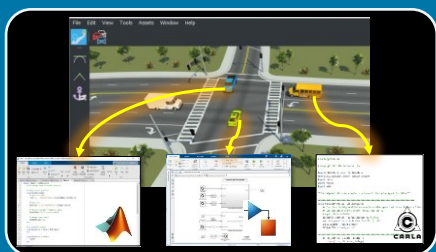
## 设计和仿真交通场景

- 设计车辆路径和场景逻辑
- 在不同的道路中重用场景设计
- 通过编程方式泛化场景参数



## 与OpenSCENARIO的接口

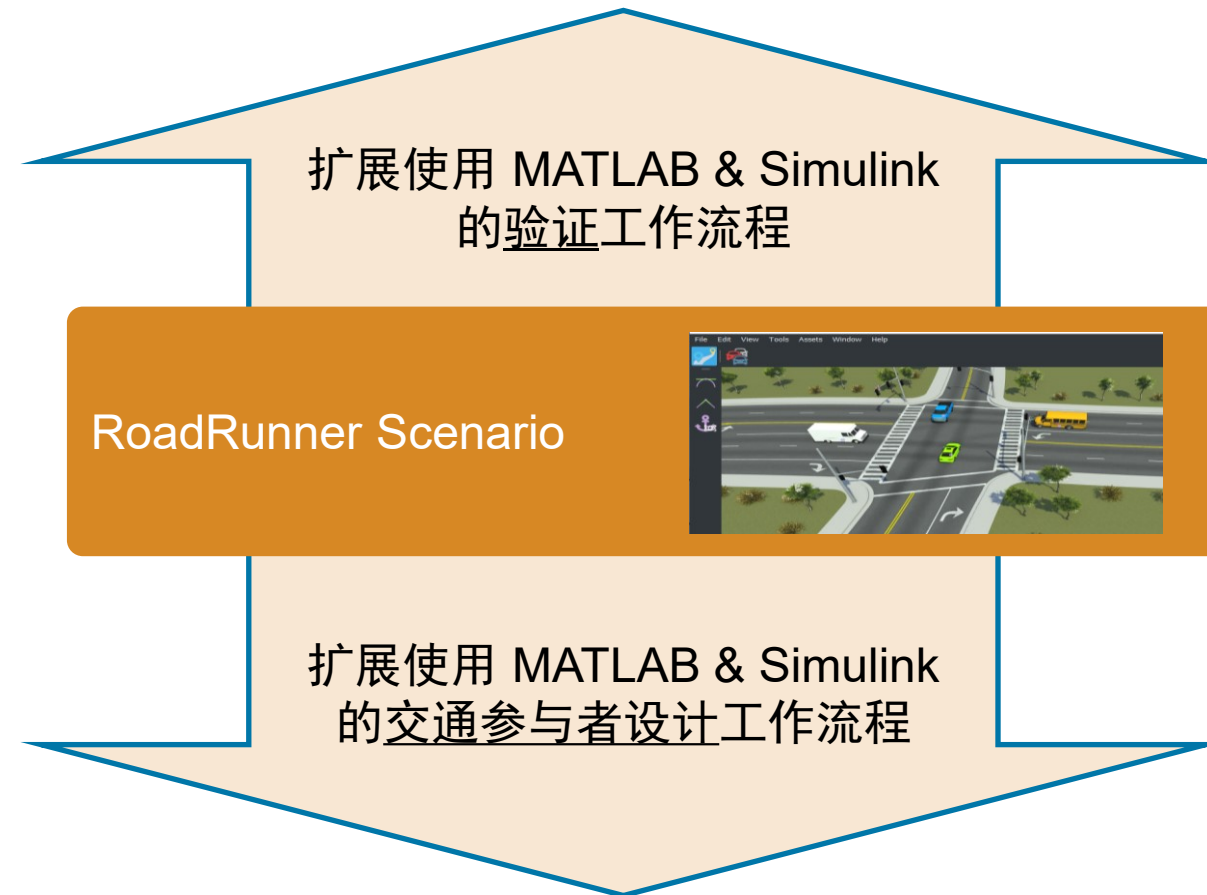
- 导出到 OpenSCENARIO v2.0
- 导出到 OpenSCENARIO v1.x
- 导入来自 OpenSCENARIO v1.x 的轨迹



## 联合MATLAB, Simulink, 以及CARLA仿真

- 在 MATLAB 中设计交通参与者行为
- 在 Simulink 中设计交通参与者行为
- 在 CARLA 中设计交通参与者行为

## 与MathWorks合作，扩展工作流程



联系MathWorks工程师，获取PoC原型或咨询服务，扩展RoadRunner Scenario工作流程。

# 与MathWorks合作，扩展工作流程



联系MathWorks工程师，获取PoC原型或咨询服务，扩展RoadRunner Scenario工作流程。

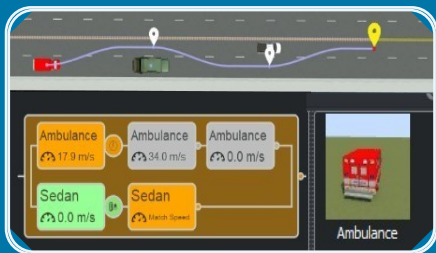
R2022a

# 基于场景的测试方案总览



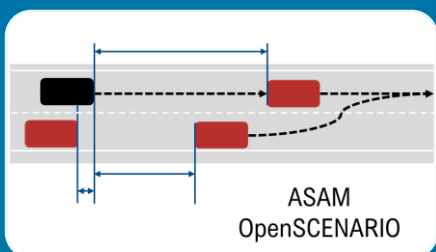


# 使用RoadRunner Scenario, 设计和仿真面向自动驾驶应用的场景



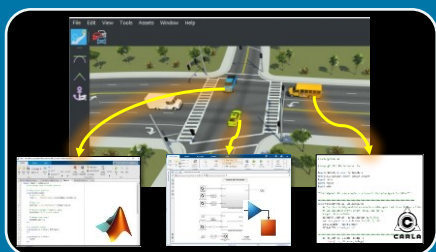
## 设计和仿真交通场景

- 设计车辆路径和场景逻辑
- 在不同的道路中重用场景设计
- 通过编程方式泛化场景参数



## 与OpenSCENARIO的接口

- 导出到 OpenSCENARIO v2.0
- 导出到 OpenSCENARIO v1.x
- 导入来自 OpenSCENARIO v1.x 的轨迹



## 联合MATLAB, Simulink, 以及CARLA仿真

- 在 MATLAB 中设计交通参与者行为
- 在 Simulink 中设计交通参与者行为
- 在 CARLA 中设计交通参与者行为



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Thank you

