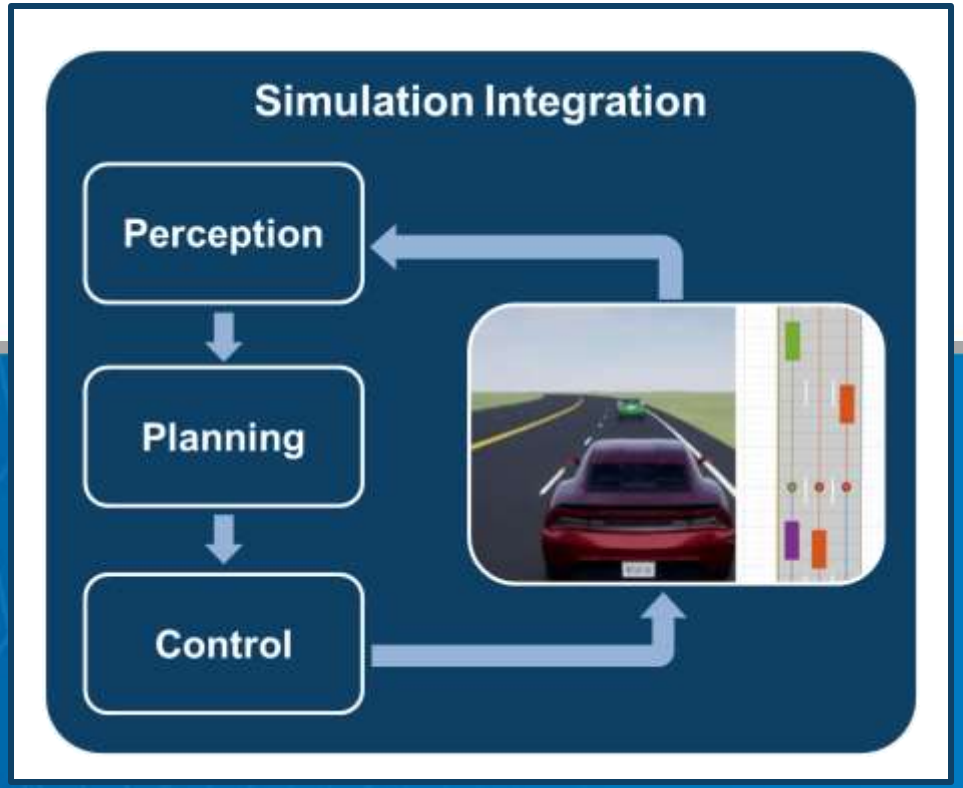
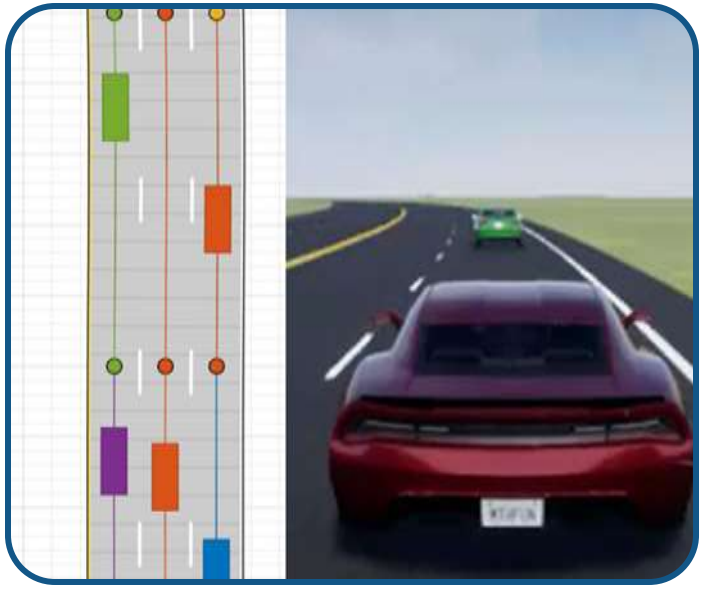
What's New in Automated Driving with MATLAB and Simulink



Mark Corless
Industry Marketing
Automated Driving Segment Manager

Some common questions from automated driving engineers



How can I
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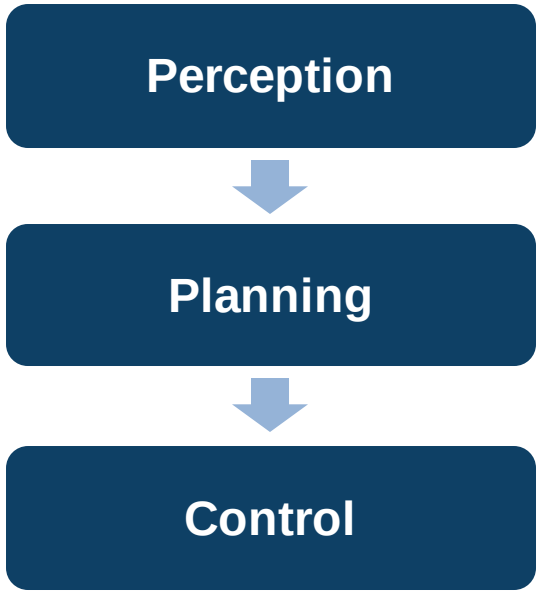
to test my designs?



How can I
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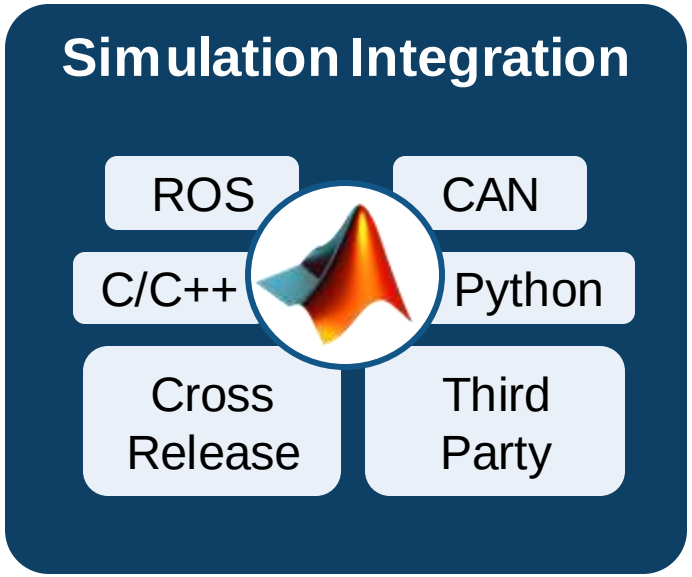

How can I
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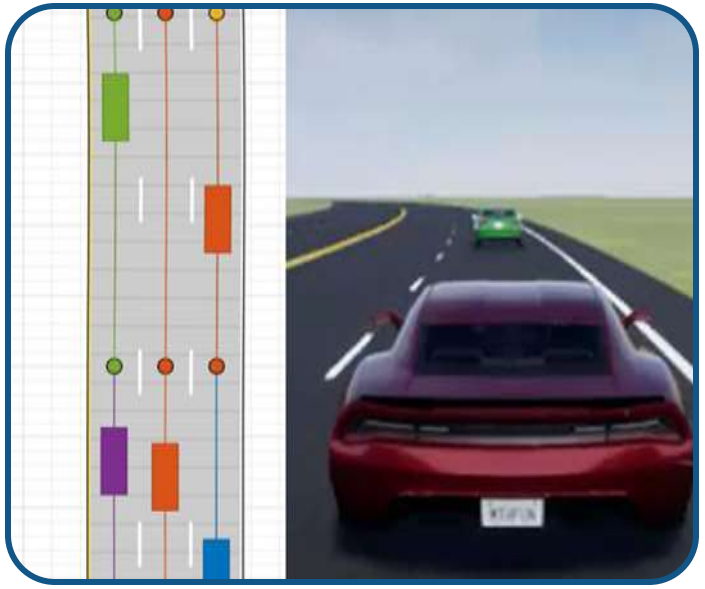
Some common questions from automated driving engineers



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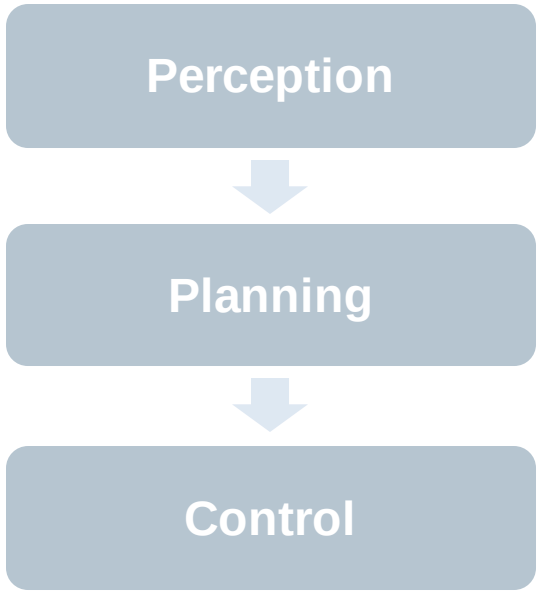

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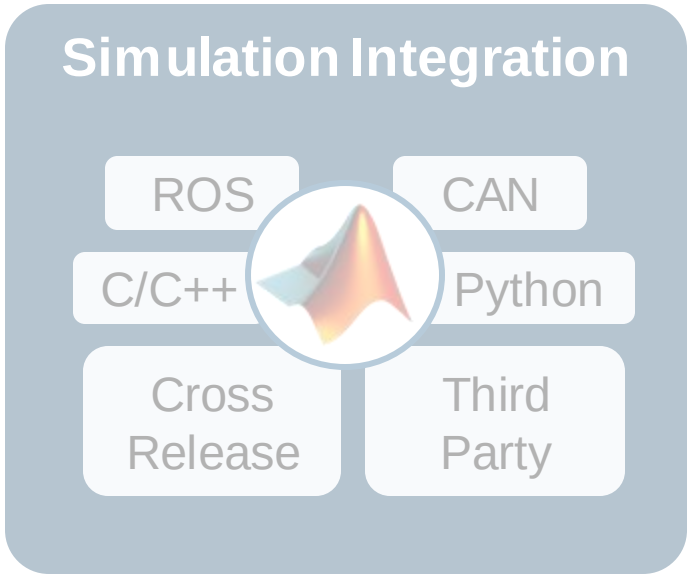


How can I
integrate
with other environments?

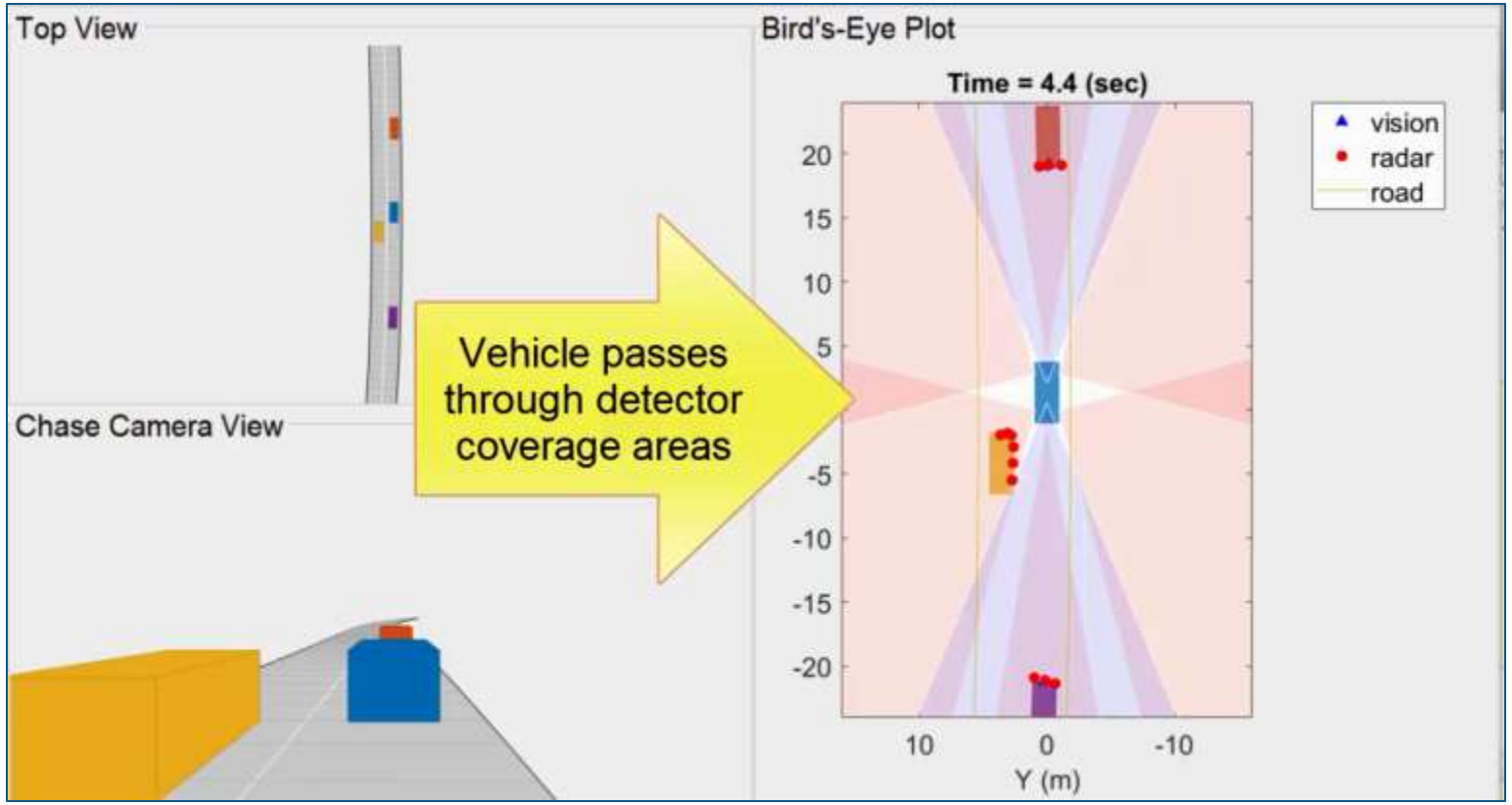
Synthesize scenarios to test sensor fusion algorithms

[Sensor Fusion Using Synthetic Radar and Vision Data]

- Synthesize road and vehicles
- Add probabilistic vision and radar detection sensors
- Fuse and track detections
- Visualize sensor coverage areas, detections, and tracks

Automated Driving Toolbox™

R2017a



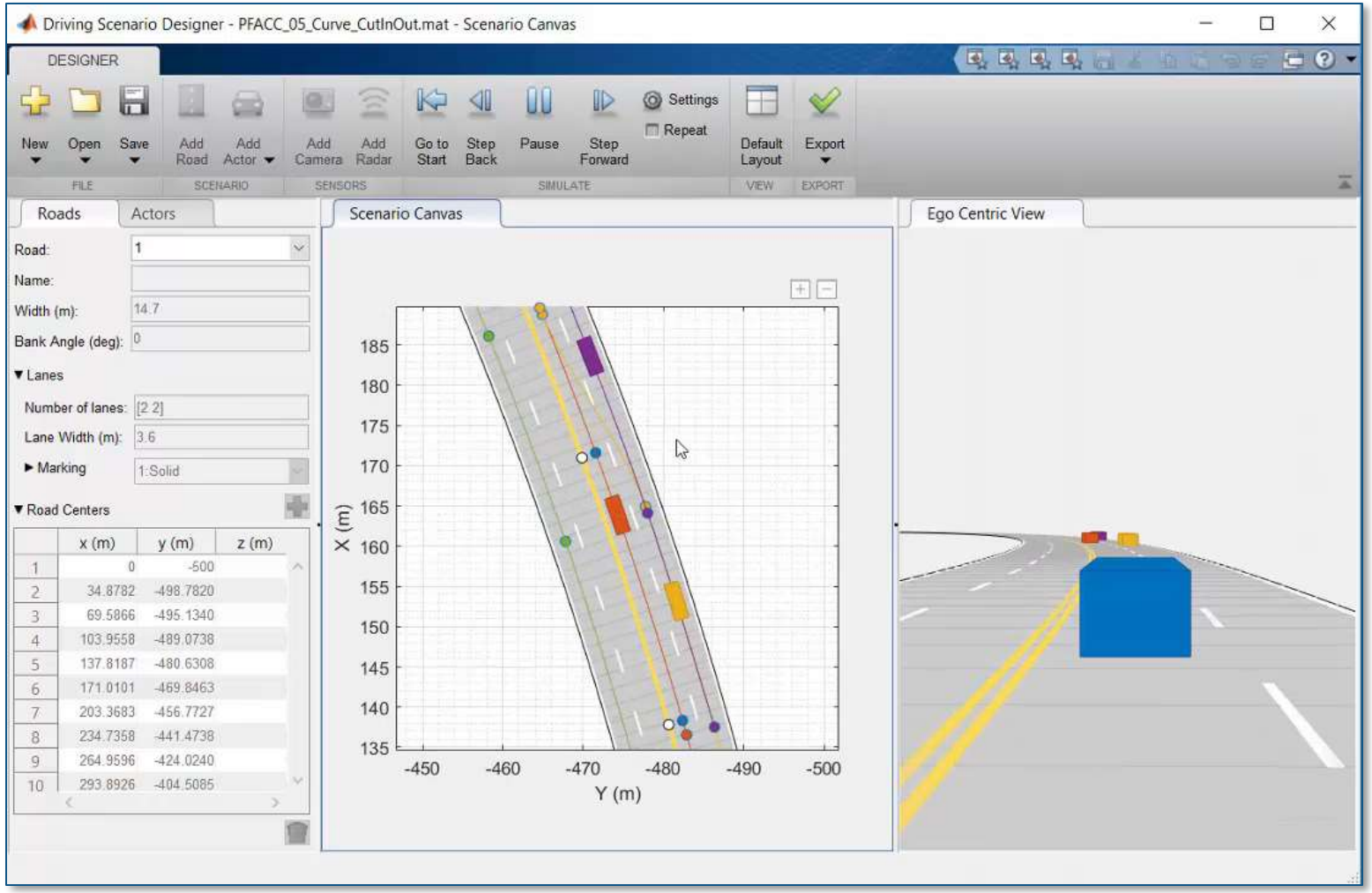
Graphically author driving scenarios

Driving Scenario Designer

- Create roads and lane markings
- Add actors and trajectories
- Specify actor size and radar cross-section (RCS)
- Explore pre-built scenarios
- Import OpenDRIVE roads

Automated Driving Toolbox™

R2018a



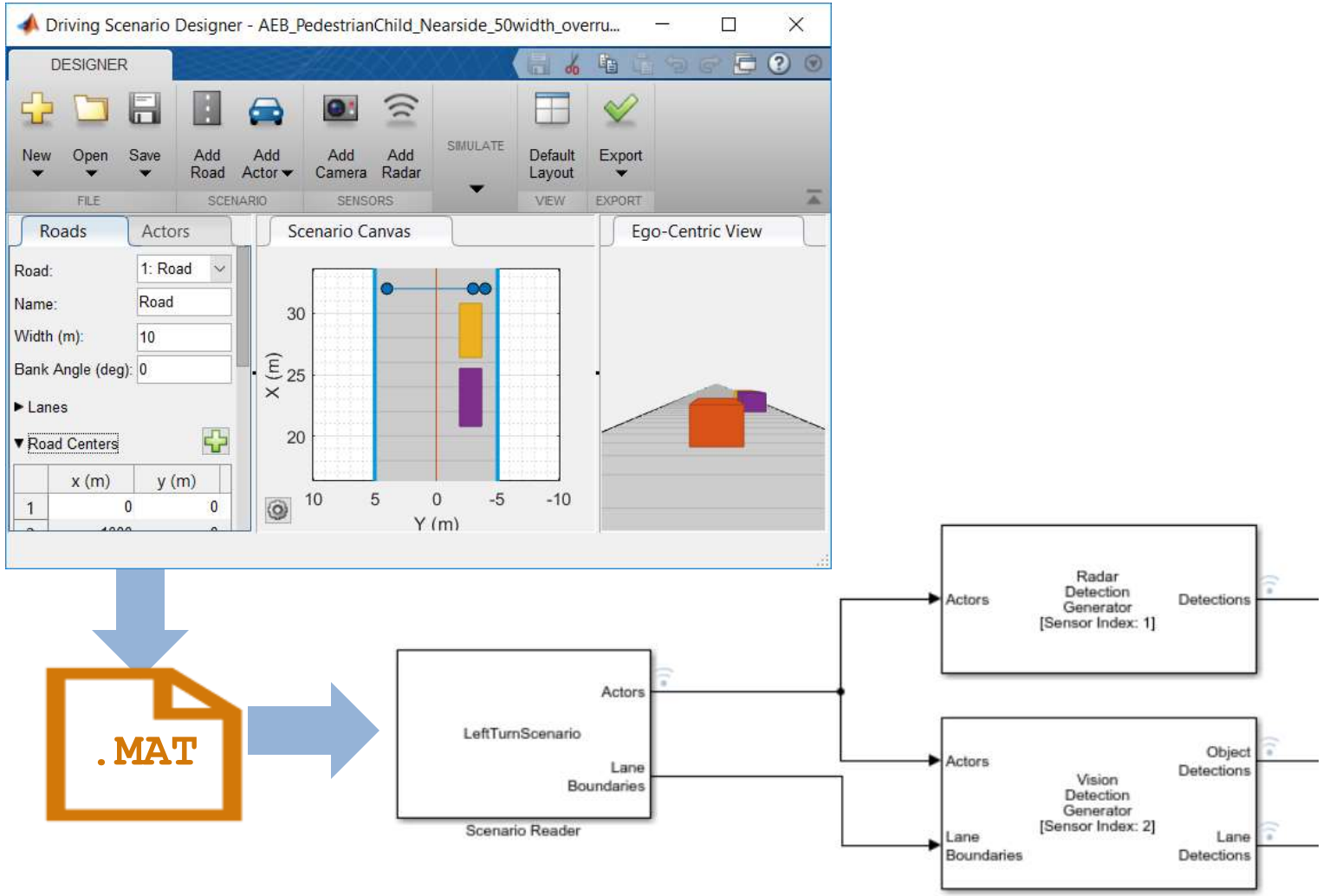
Integrate driving scenarios into Simulink simulations

[Test Open-Loop ADAS Algorithm Using Driving Scenario]

- Edit driving scenario
- Integrate into Simulink
- Add sensor models
- Visualize results
- Pace simulation

Automated Driving Toolbox™

R2019a



Integrate driving scenario into closed loop simulation

[Lane Following Control with Sensor Fusion]

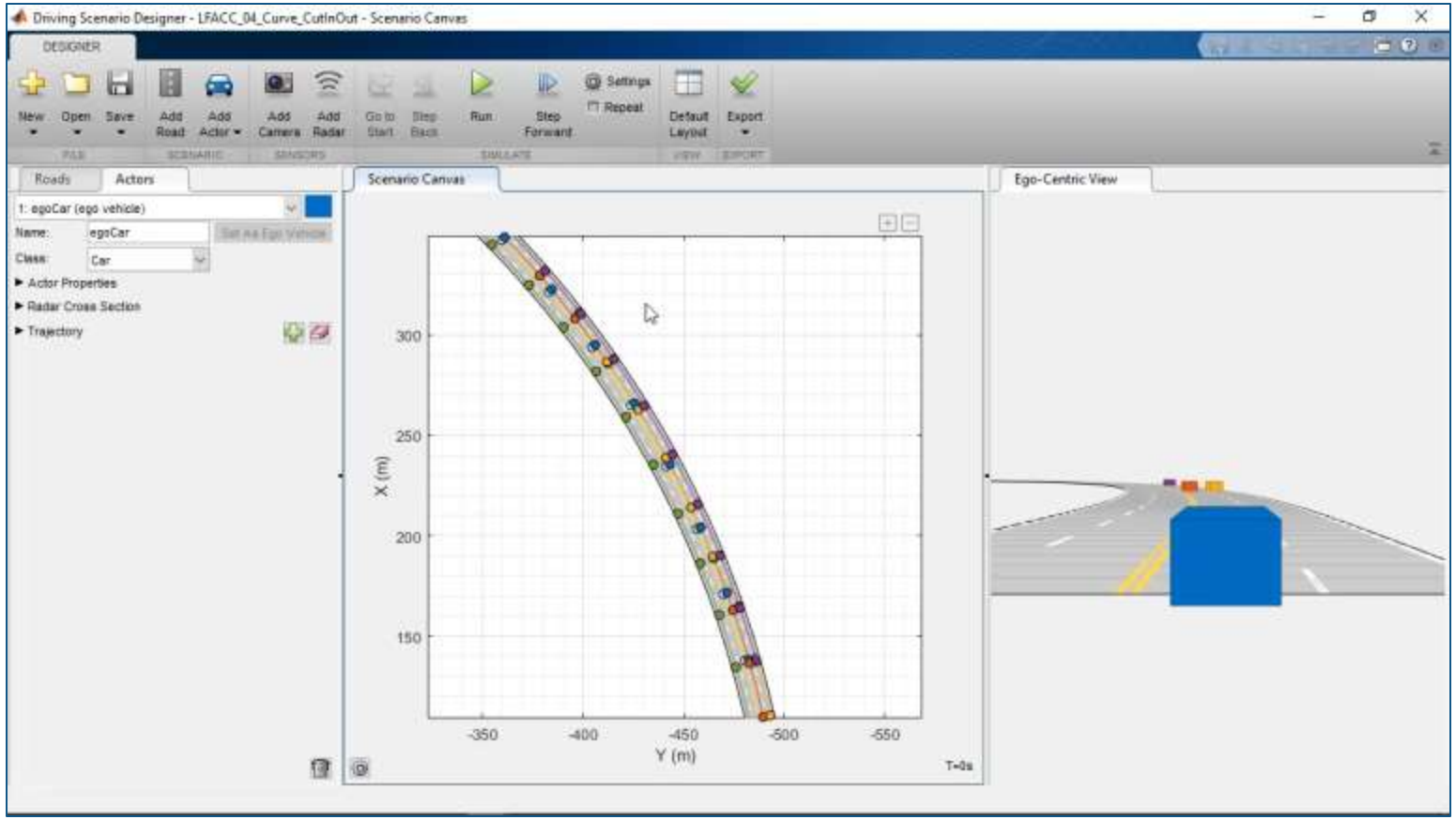
- Integrate scenario into system
- Design lateral (lane keeping) and longitudinal (lane spacing) model predictive controllers
- Visualize sensors and tracks
- Generate C/C++ code
- Test with software in the loop (SIL) simulation

Model Predictive Control Toolbox™

Automated Driving Toolbox™

Embedded Coder®

R2018b



Design lateral and longitudinal controls

[Lane Following Control with Sensor Fusion]

- Integrate scenario into system
- Design lateral (lane keeping) and longitudinal (lane spacing) model predictive controllers
- Visualize sensors and tracks
- Generate C/C++ code
- Test with software in the loop (SIL) simulation

Model Predictive Control Toolbox™

Automated Driving Toolbox™

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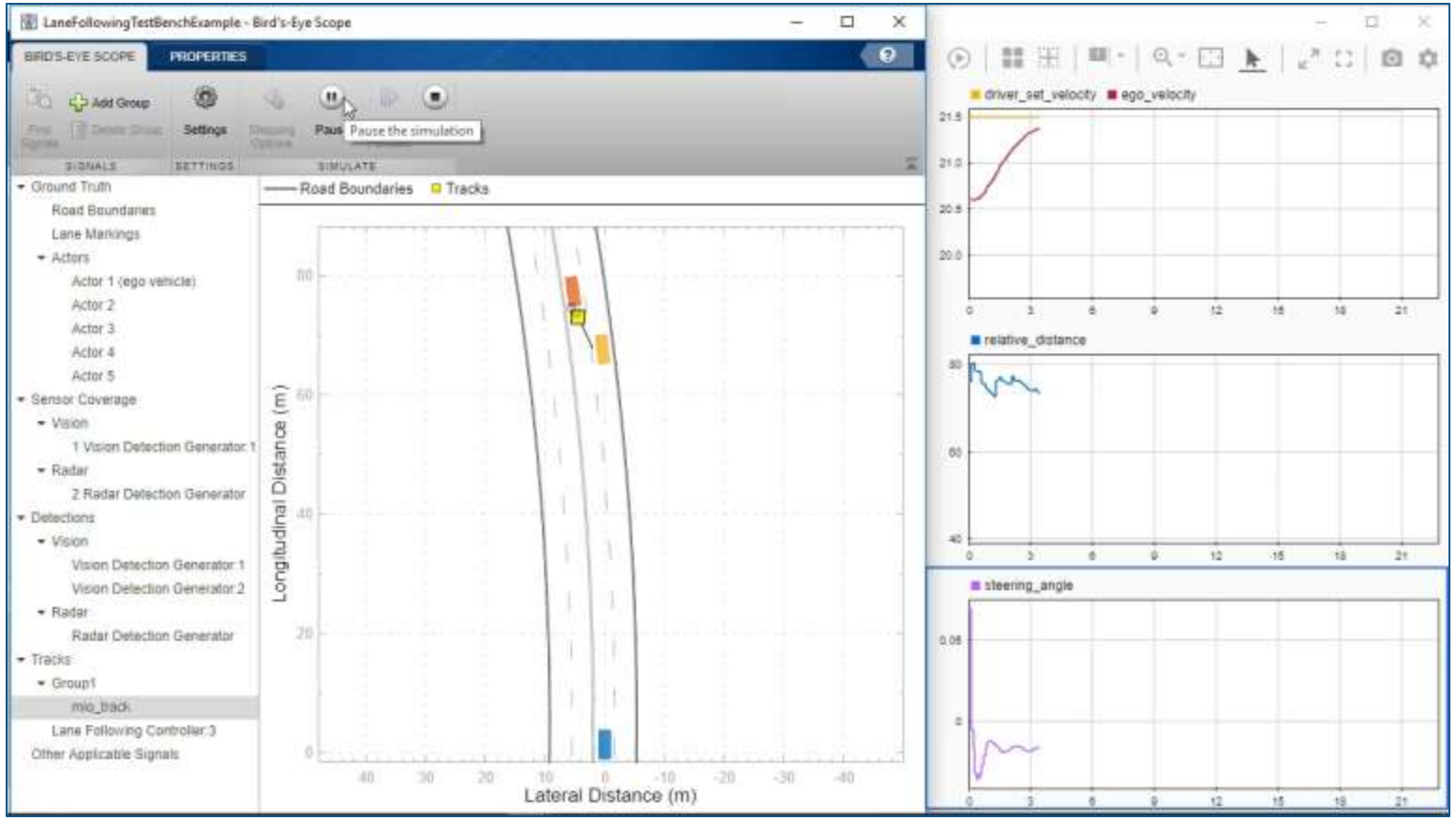

Visualize sensor detections and tracks

[Lane Following Control with Sensor Fusion]

- Integrate scenario into system
- Design lateral (lane keeping) and longitudinal (lane spacing) model predictive controllers
- Visualize sensors and tracks
- Generate C/C++ code
- Test with software in the loop (SIL) simulation

Model Predictive Control Toolbox™

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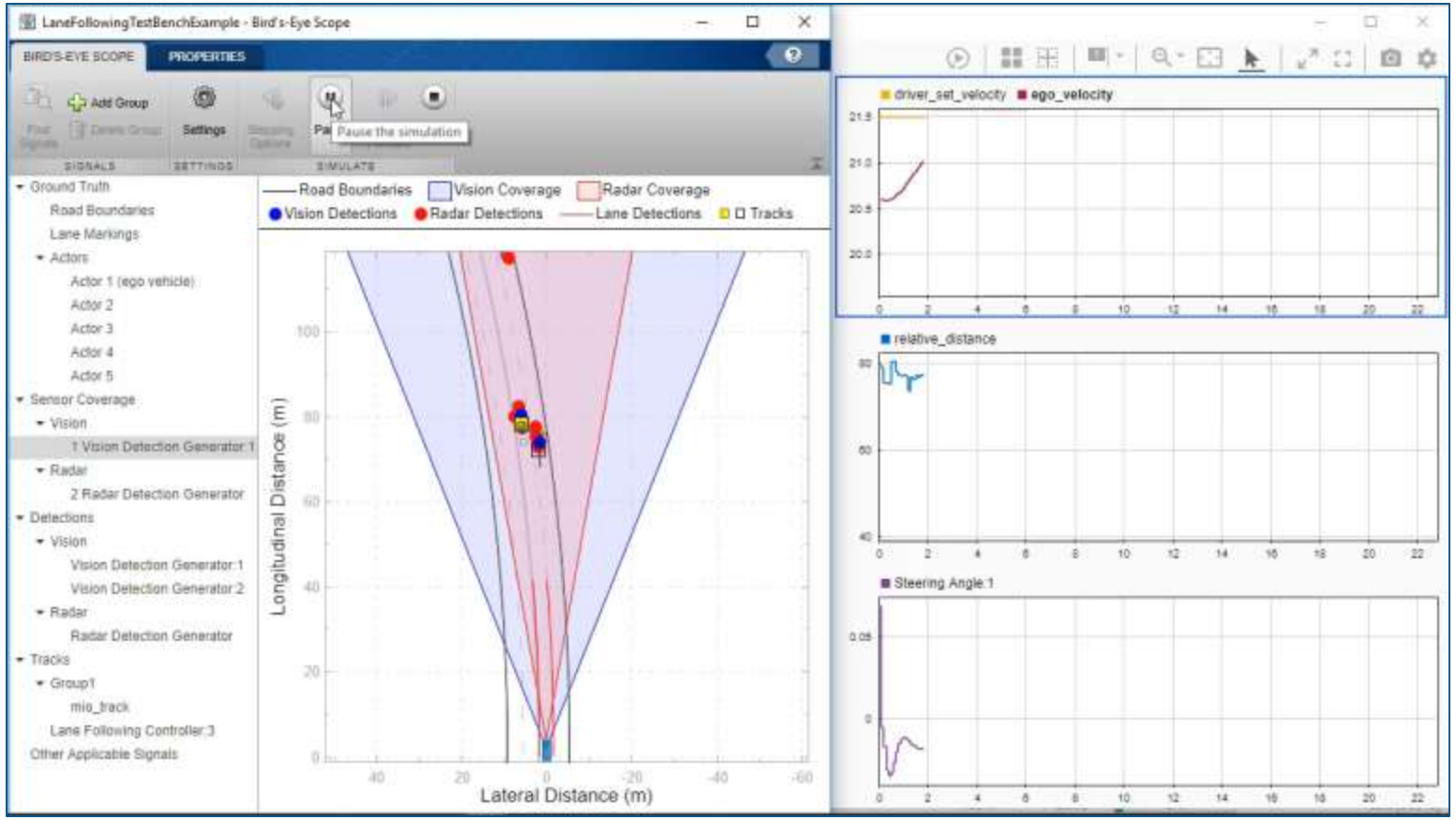


Automate testing against driving scenarios

[Testing a Lane Following Controller with Simulink Test]

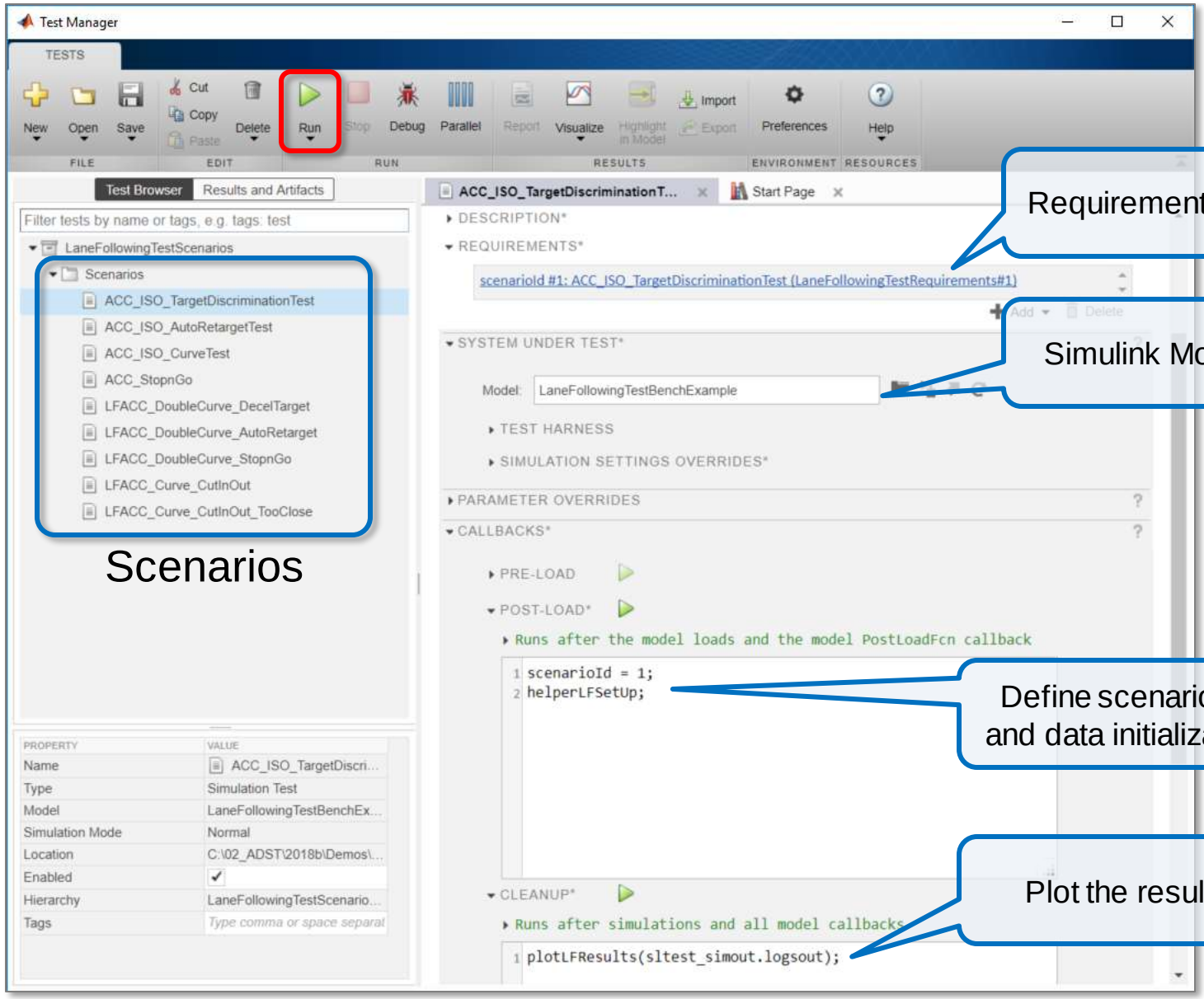
- Author high level requirements
- Synthesize driving scenarios
- Specify assessment criteria
- Run interactive simulation
- Automate regression testing
- Review verification status

Simulink Test™

Automated Driving Toolbox™

Model Predictive Control Toolbox™

R2018b



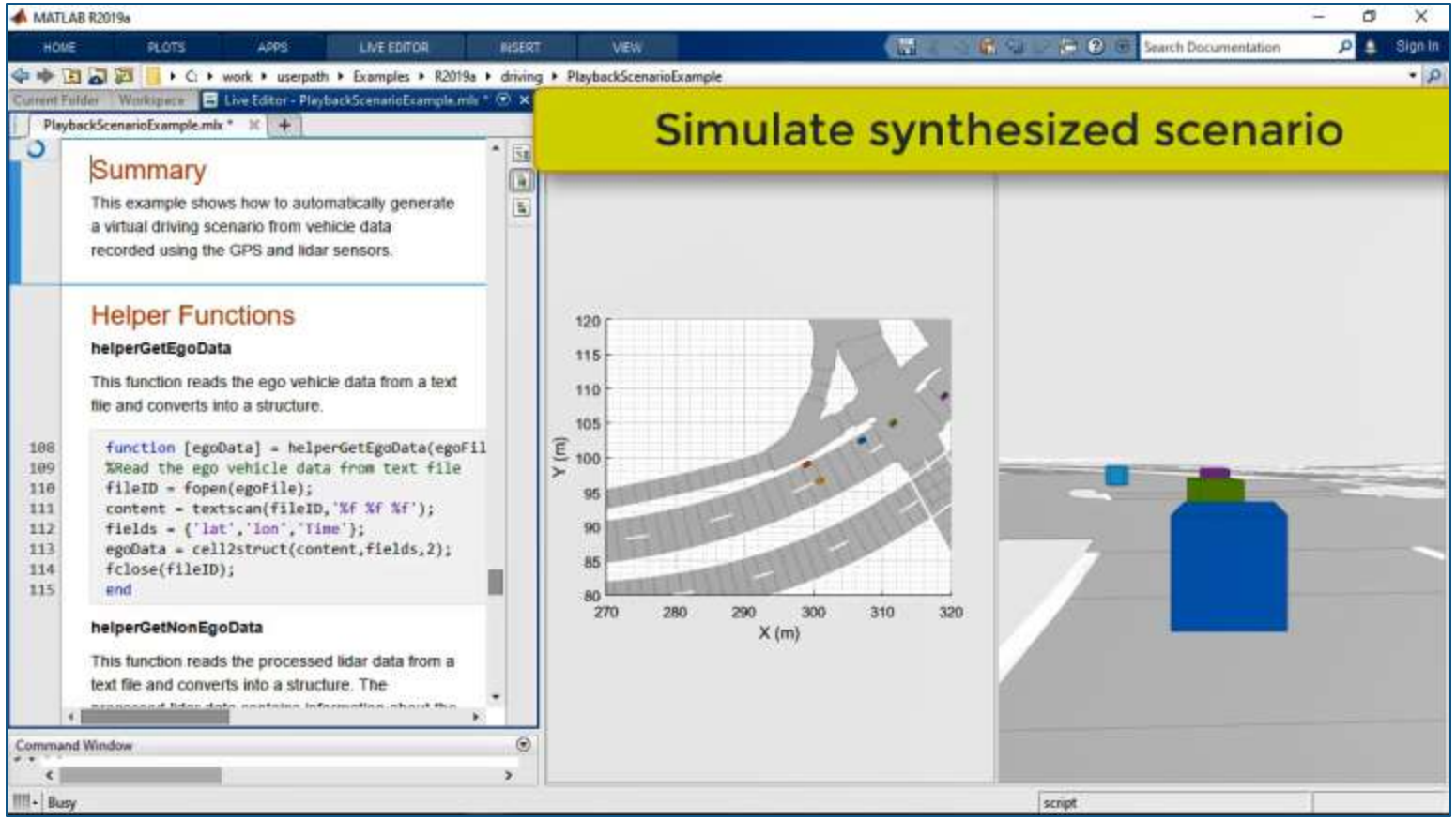
Synthesize driving scenarios from recorded data

[Scenario Generation from Recorded Vehicle Data]

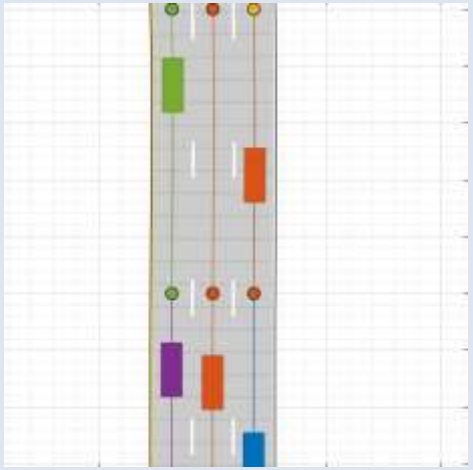
- Visualize video
- Import OpenDRIVE roads
- Import GPS
- Import object lists

Automated Driving Toolbox™

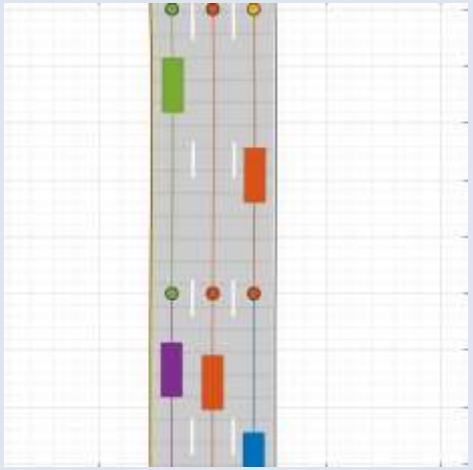
R2019a



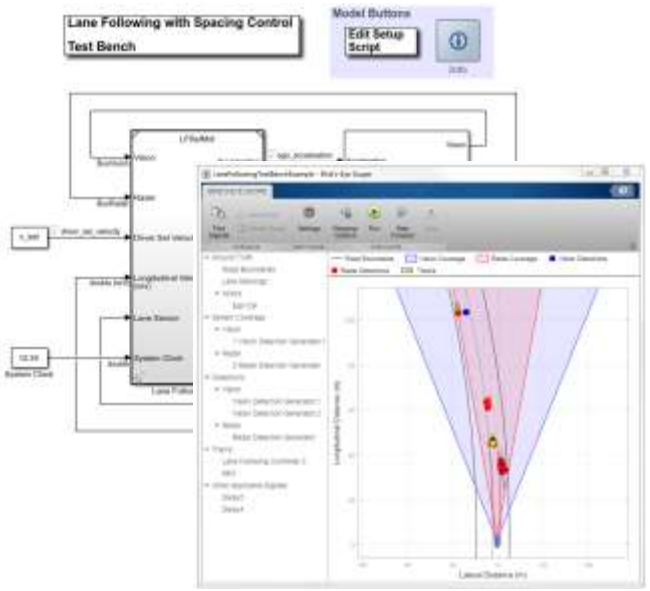
How can I design with virtual scenarios?

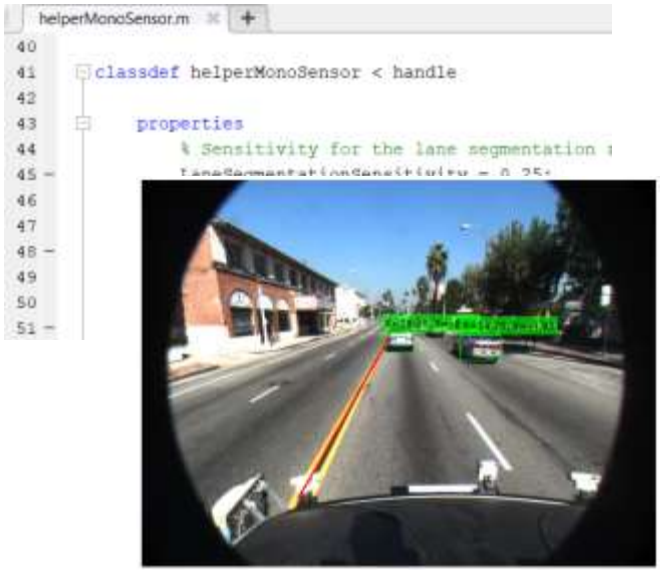
Scenes	**Driving Scenarios (cuboid)** 
Testing	Controls Controls + sensor fusion
Authoring	Driving Scenario Designer App drivingScenario programmatic API
Sensing	Probabilistic radar detections Probabilistic vision detections Probabilistic lane detections

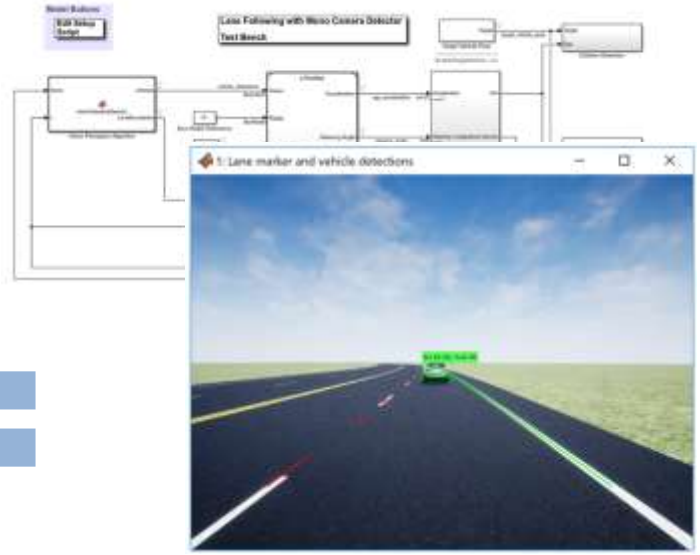
How can I design with virtual scenarios?

Scenes	**Driving Scenarios (cuboid)**	**3D Simulation (Unreal Engine)**
		
Testing	Controls Controls + sensor fusion	Controls Controls + vision
Authoring	Driving Scenario Designer App drivingScenario programmatic API	Unreal Editor
Sensing	Probabilistic radar detections Probabilistic vision detections Probabilistic lane detections	Ideal camera (viewer)

Simulate controls and perception systems







[Lane Following Control with Sensor Fusion]

Model Predictive Control Toolbox™

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[Visual Perception Using Monocular Camera]

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R2017a

[Lane-Following Control with Monocular Camera Perception]

Model Predictive Control Toolbox™

Automated Driving Toolbox™

Vehicle Dynamics Blockset™

R2018b

Simulate lane controls with vision based perception

[Lane-Following Control with Monocular Camera Perception]

- Integrate Simulink controller
  - Lane follower
  - Spacing control
- Integrate MATLAB perception
  - Lane boundary detector
  - Vehicle detector
- Synthesize ideal camera image from Unreal Engine

Model Predictive Control Toolbox™

Automated Driving Toolbox™

Vehicle Dynamics Blockset™

R2018b

Some common questions from automated driving engineers

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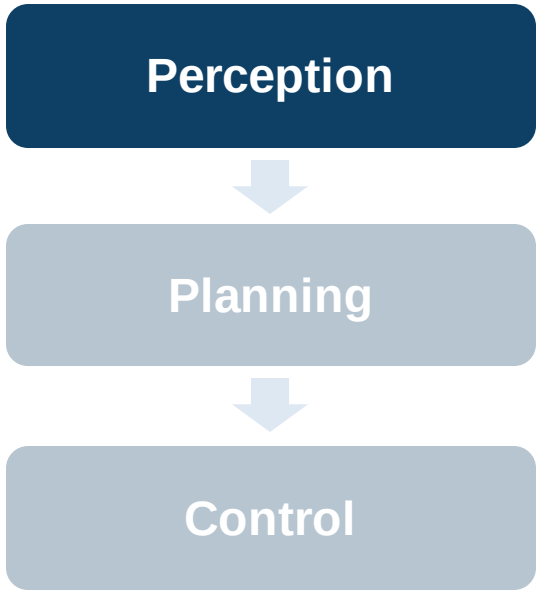

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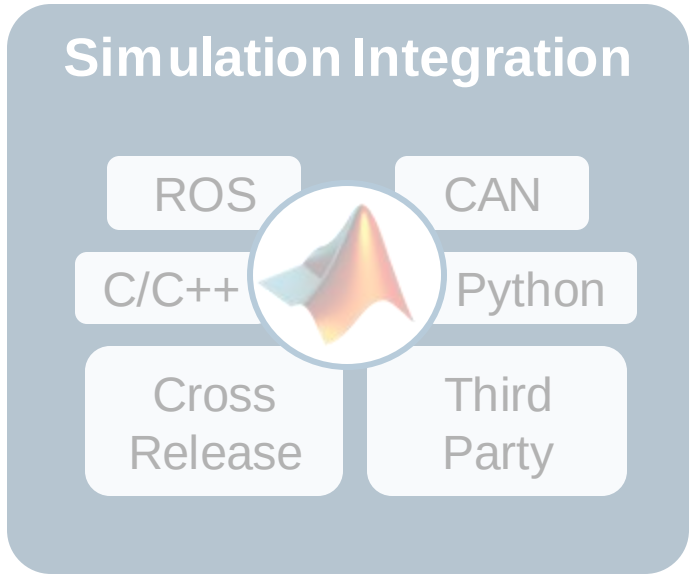
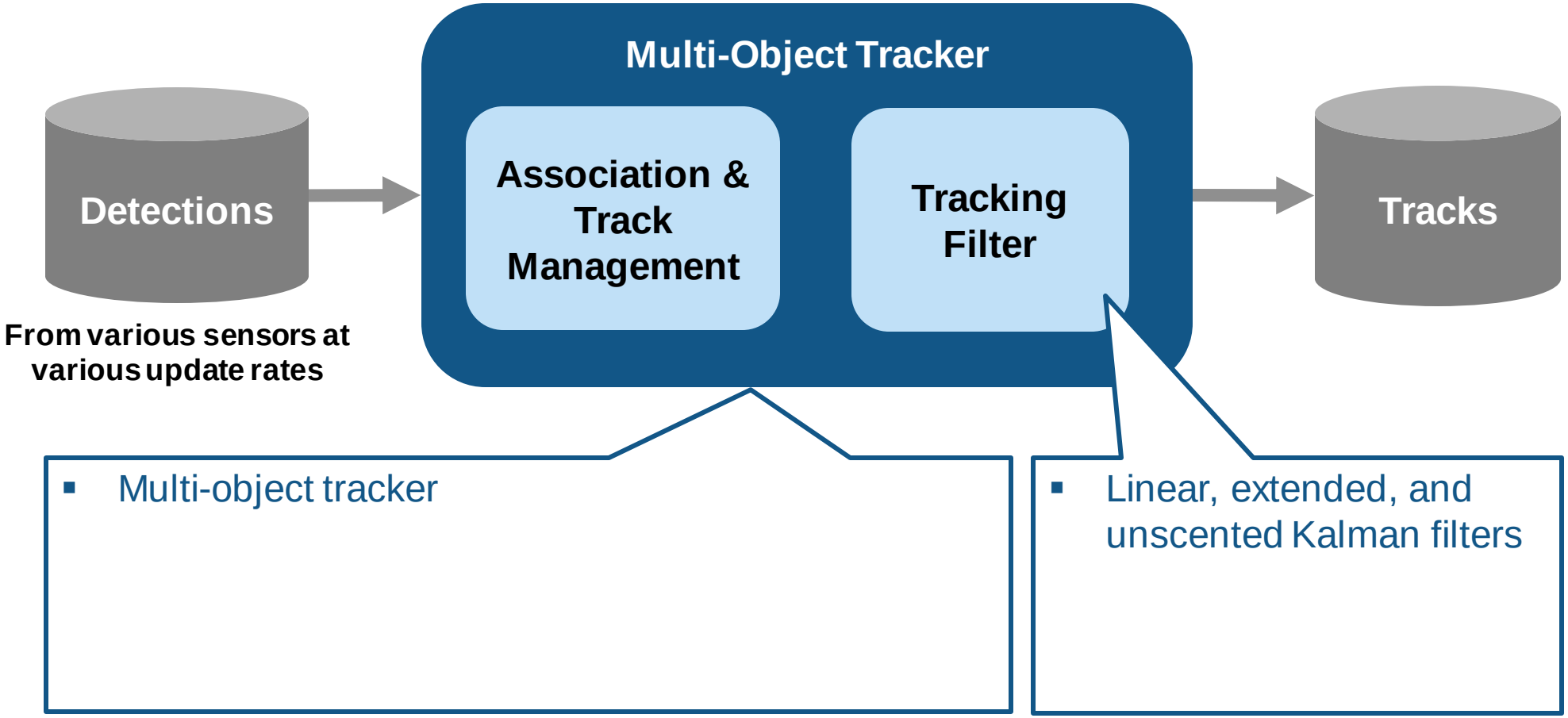


How can I
integrate
with other environments?

Design trackers



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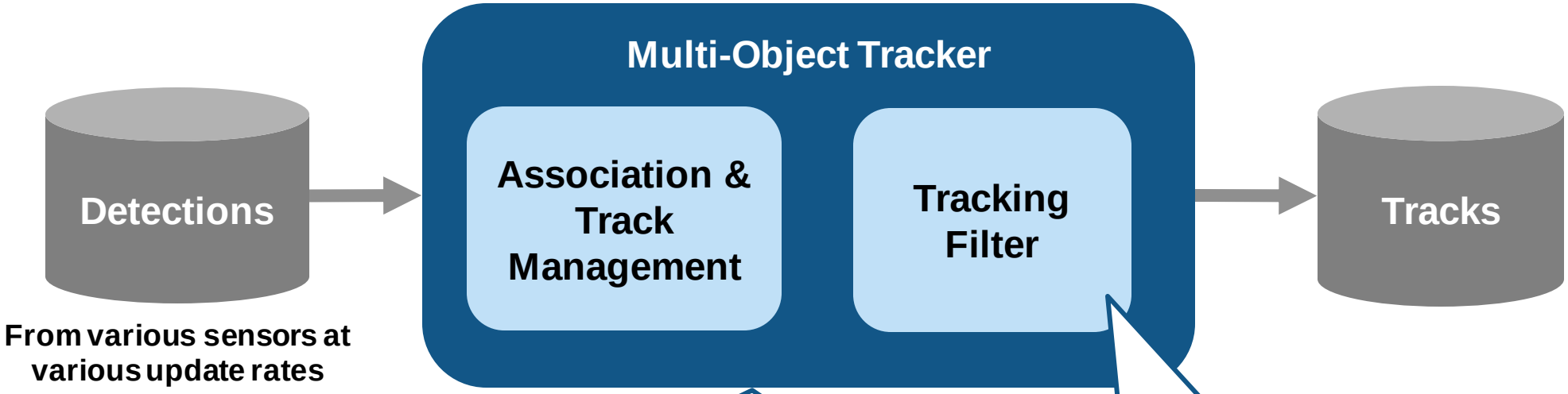
R2017a

Design trackers



- Multi-object tracker
- Global Nearest Neighbor (GNN) tracker
- Joint Probabilistic Data Association (JPDA) tracker
- Track-Oriented Multi-Hypothesis Tracker (TOMHT)
- Probability Hypothesis Density (PHD) tracker

- Linear, extended, and unscented Kalman filters
- Particle, Gaussian-sum, and Interacting Multiple Model (IMM) filters

Automated Driving Toolbox™

Sensor Fusion and Tracking Toolbox™

R2019a

Design multi-object trackers

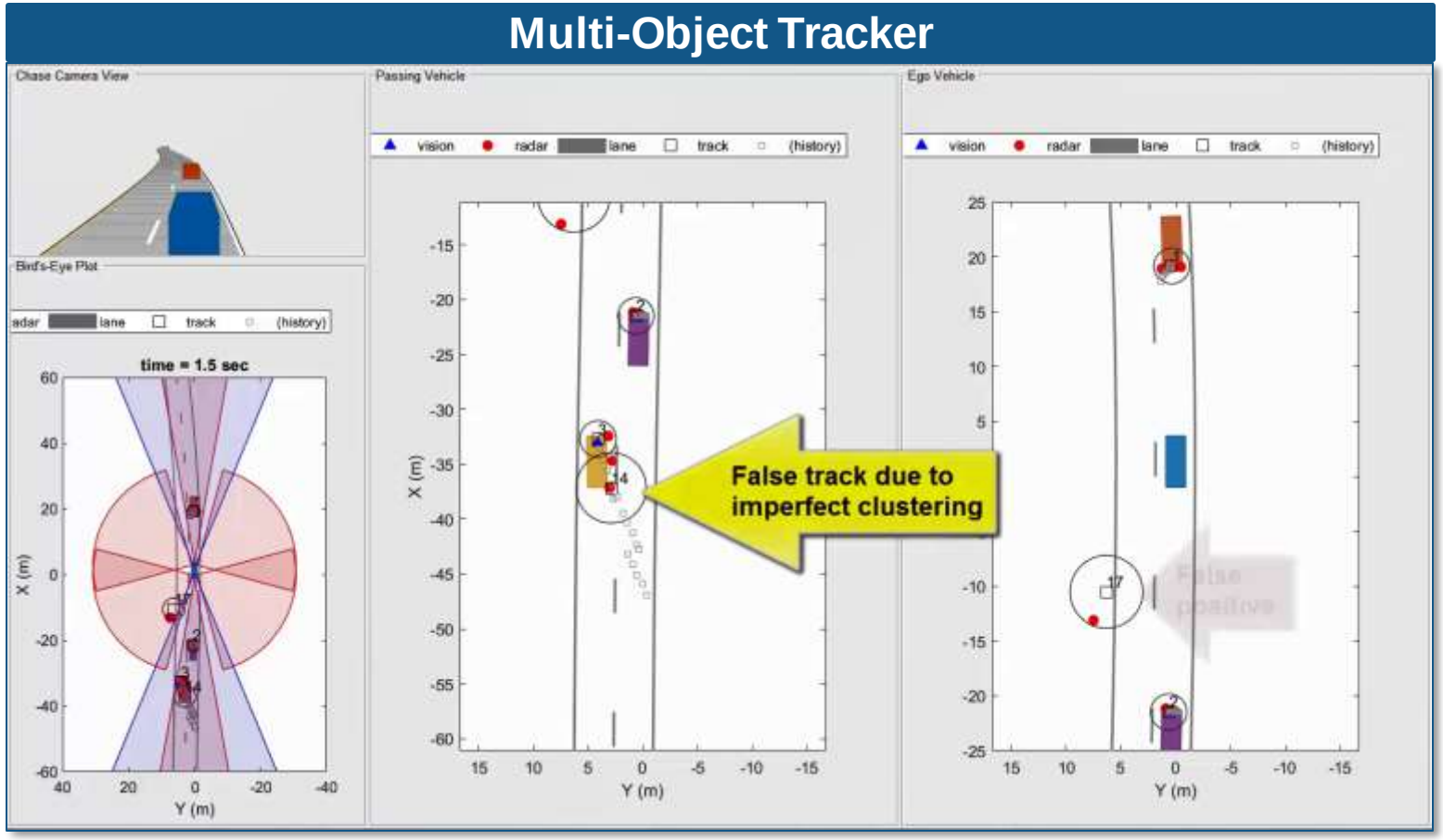
[Extended Object Tracking]

- Design multi-object tracker
- Design extended object trackers
- Evaluate tracking metrics
- Evaluate error metrics
- Evaluate desktop execution time

Sensor Fusion and Tracking Toolbox™

Automated Driving Toolbox™

Updated R2019a



Design extended object trackers

[Extended Object Tracking]

- Design multi-object tracker
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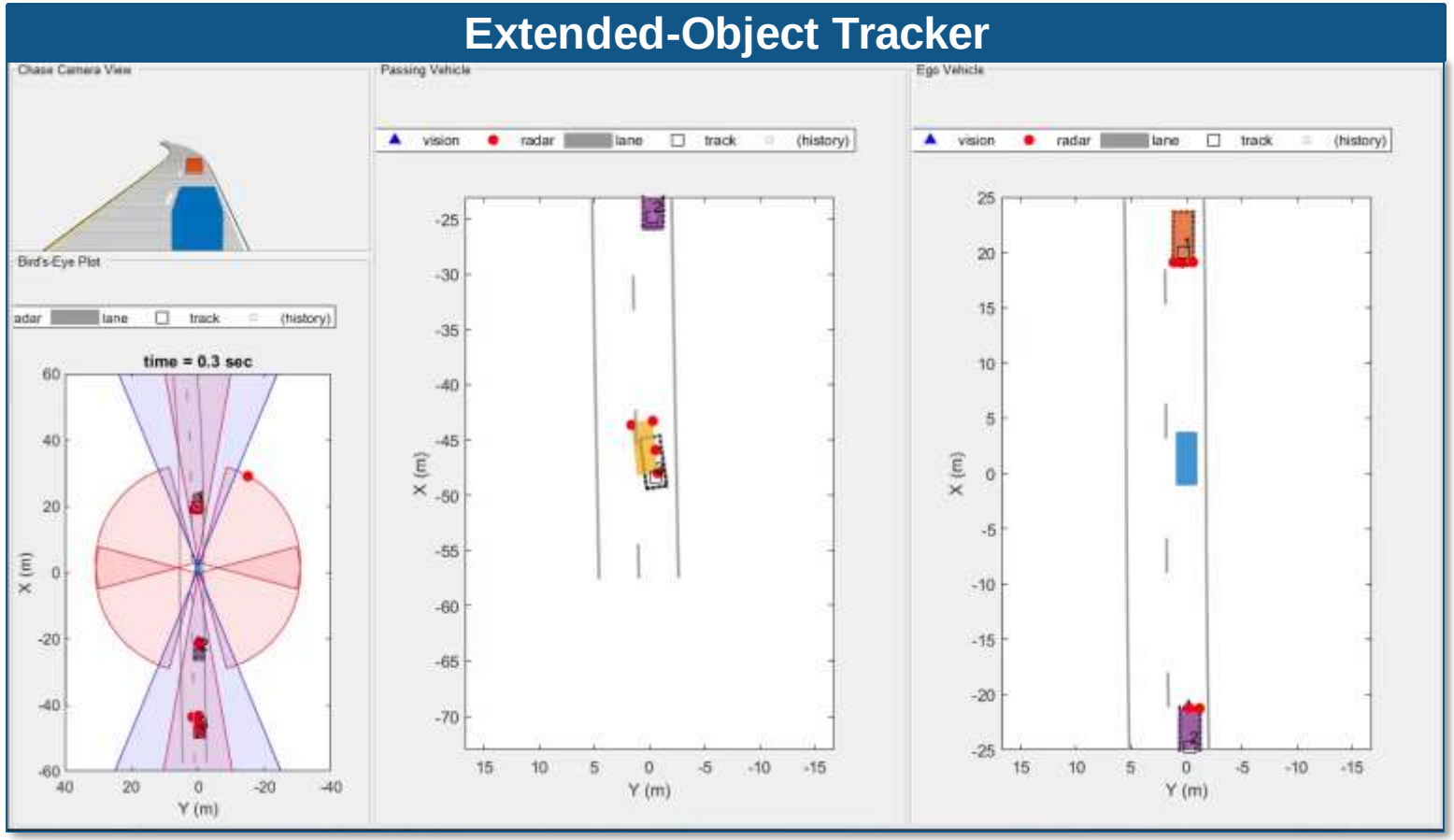
Sensor Fusion and Tracking Toolbox™

Automated Driving Toolbox™

Updated R2019a



Evaluate tracking performance

[Extended Object Tracking]

- Design multi-object tracker
- Design extended object trackers
- Evaluate tracking metrics
- Evaluate error metrics
- Evaluate desktop execution time

Sensor Fusion and Tracking Toolbox™

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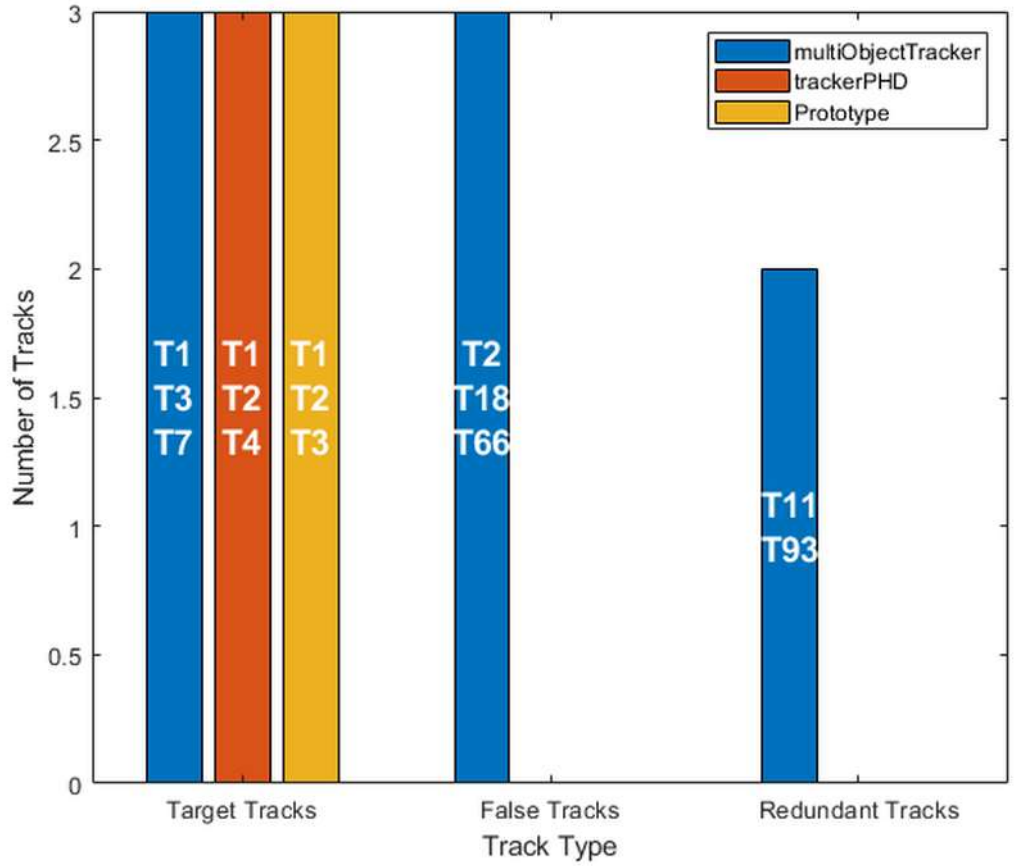
Updated R2019a



Multi-object tracker

Probability Hypothesis Density tracker

Extended object (size and orientation) tracker

Evaluate error metrics

[Extended Object Tracking]

- Design multi-object tracker
- Design extended object trackers
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Sensor Fusion and Tracking Toolbox™

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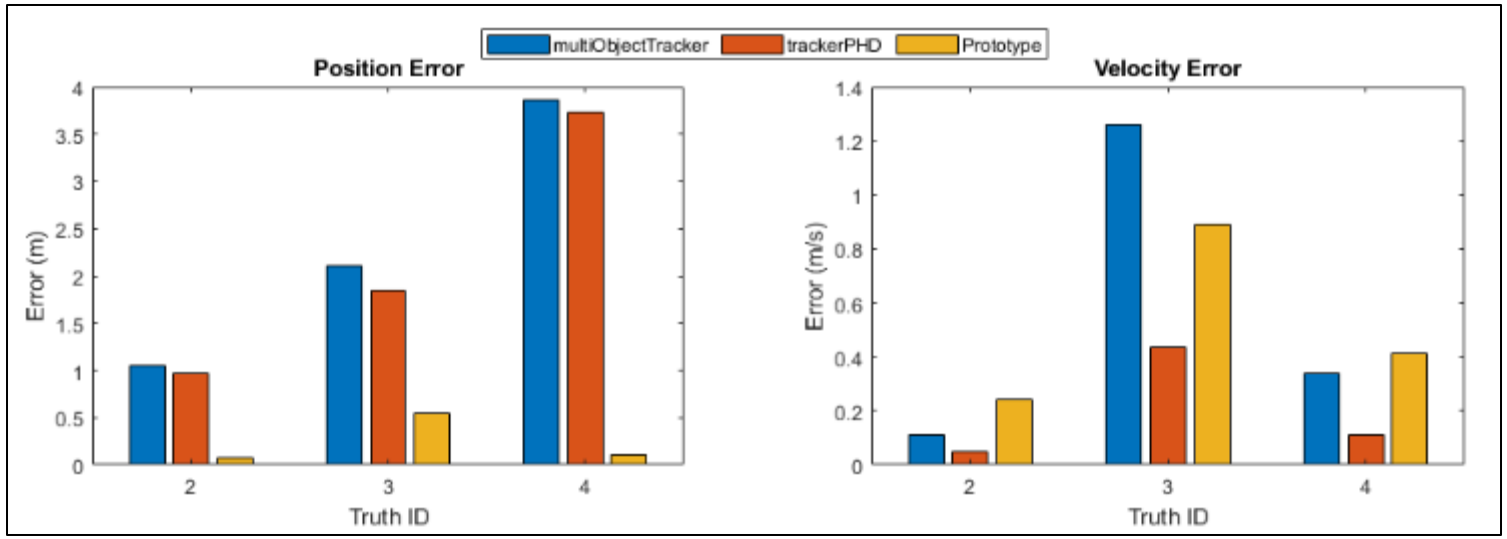
Updated R2019a



Multi-object tracker

Probability Hypothesis Density tracker

Extended object (size and orientation) tracker

Compare relative execution times of object trackers

Extended Object Tracking

- Design multi-object tracker
- Design extended object trackers
- Evaluate tracking performance
- Evaluate error metrics
- Evaluate desktop execution time

Sensor Fusion and Tracking Toolbox™

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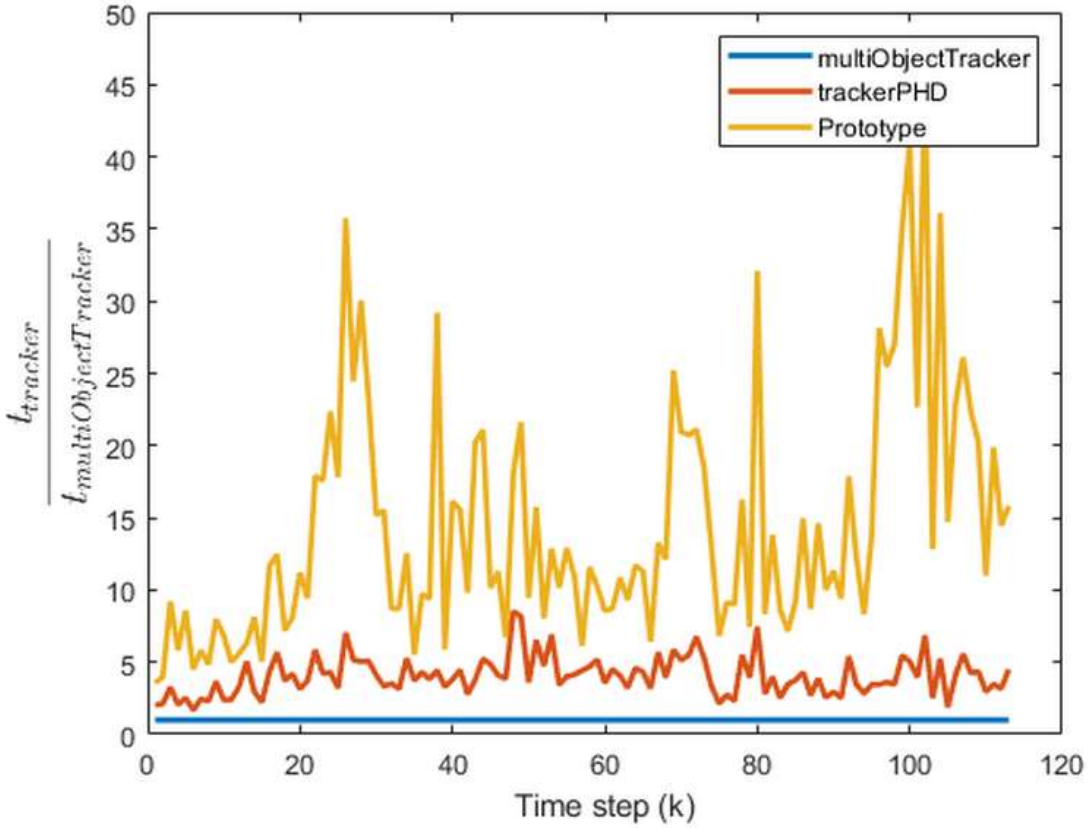
Updated R2019a



Multi-object tracker

Probability Hypothesis Density tracker

Extended object (size and orientation) tracker

Design detector for lidar point cloud data

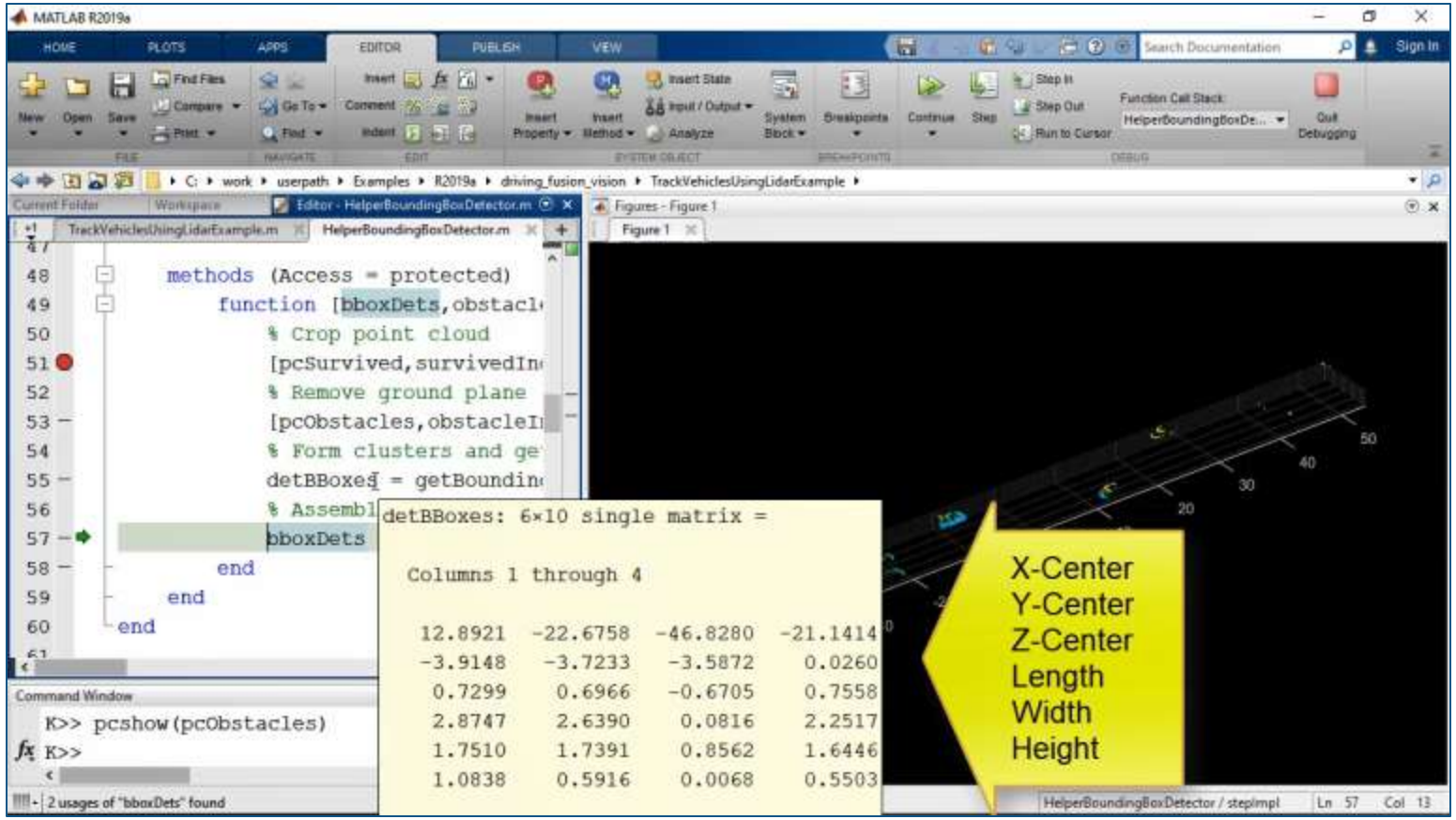
[Track Vehicles Using Lidar: From Point Cloud to Track List]

- Design 3-D bounding box detector
- Design tracker (target state and measurement models)
- Generate C/C++ code for detector and tracker

Sensor Fusion and Tracking Toolbox™

Computer Vision Toolbox™

R2019a



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Sensor Fusion and Tracking Toolbox™

Computer Vision Toolbox™

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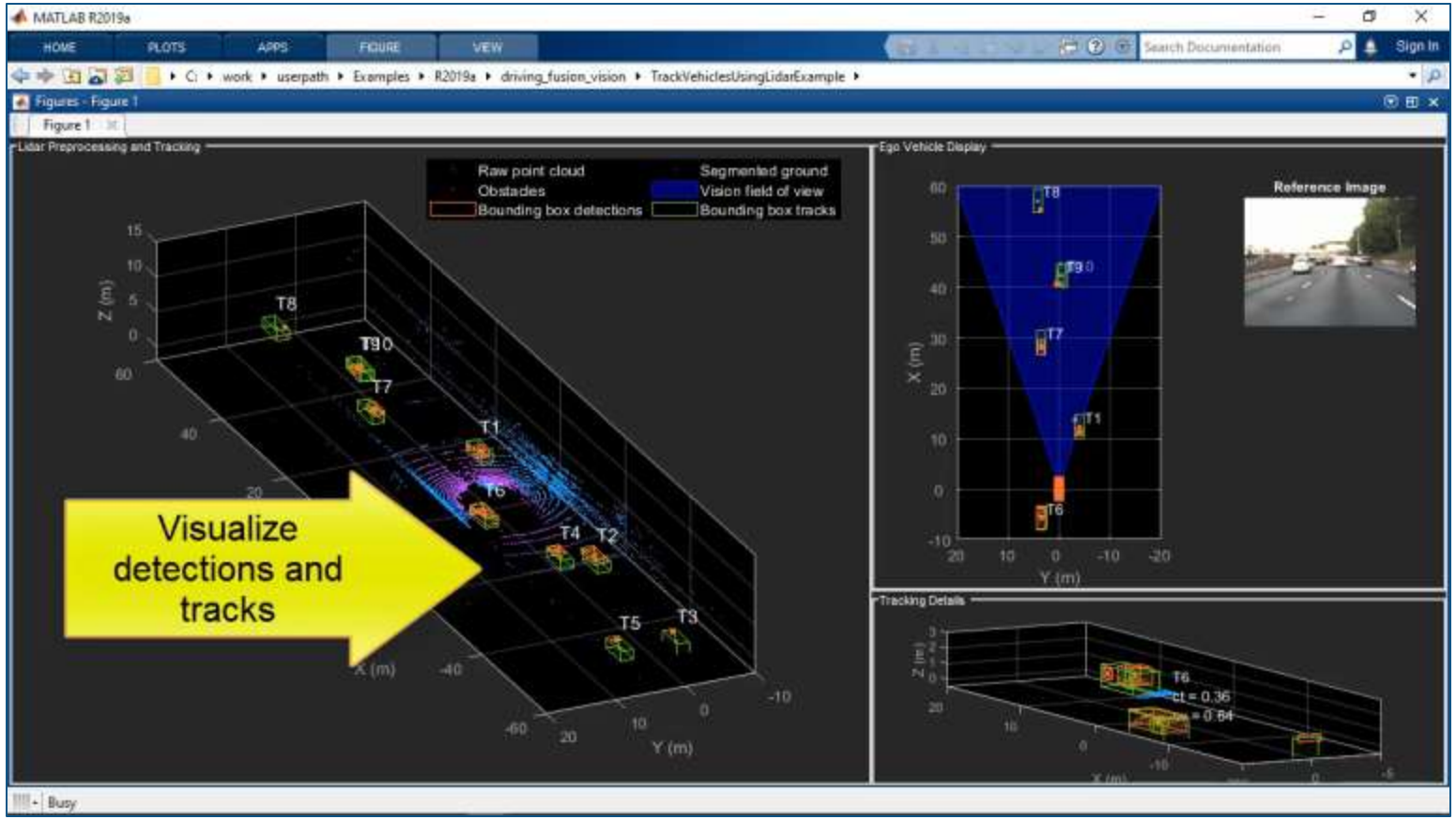

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Sensor Fusion and Tracking Toolbox™

Computer Vision Toolbox™

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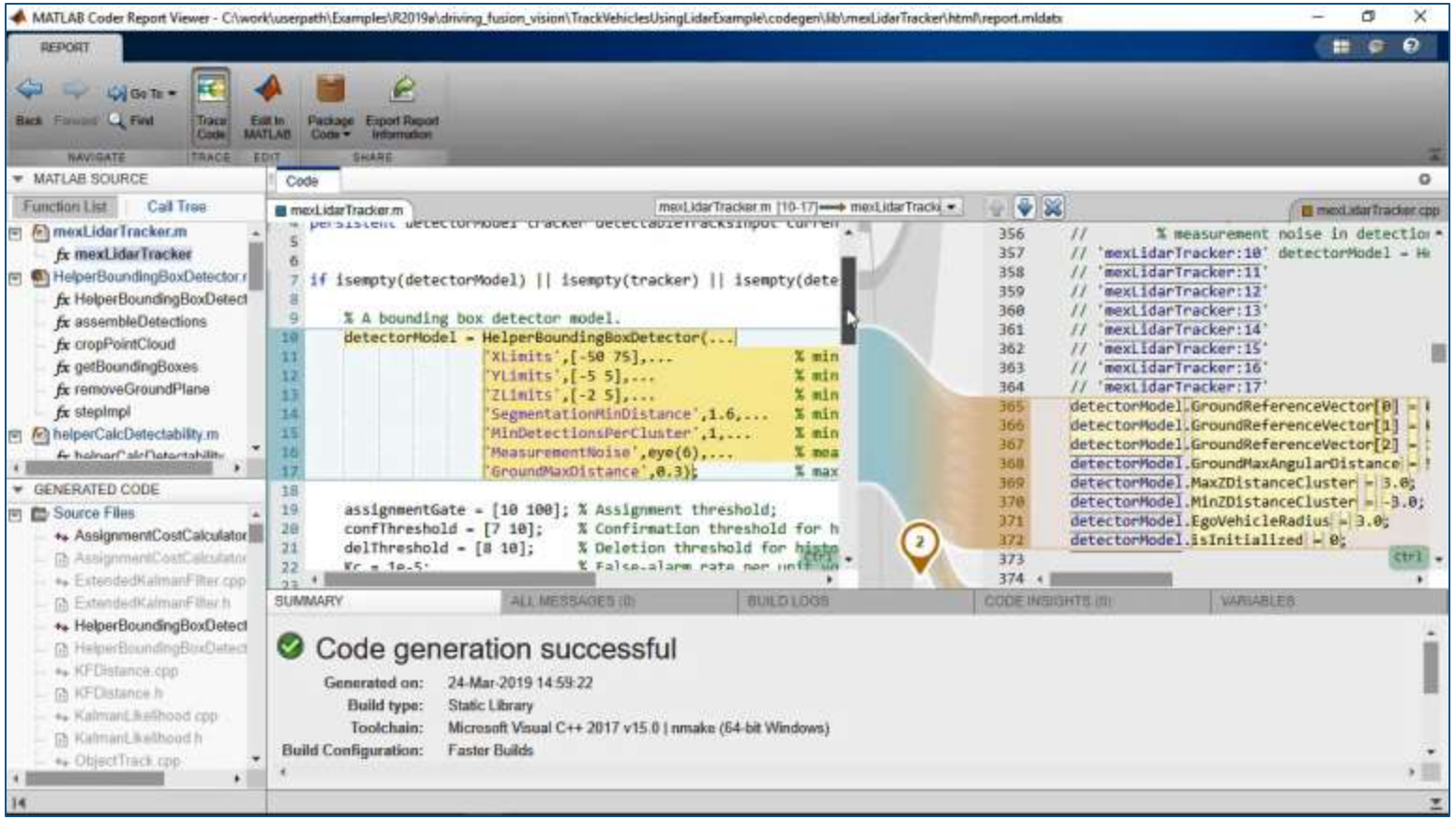


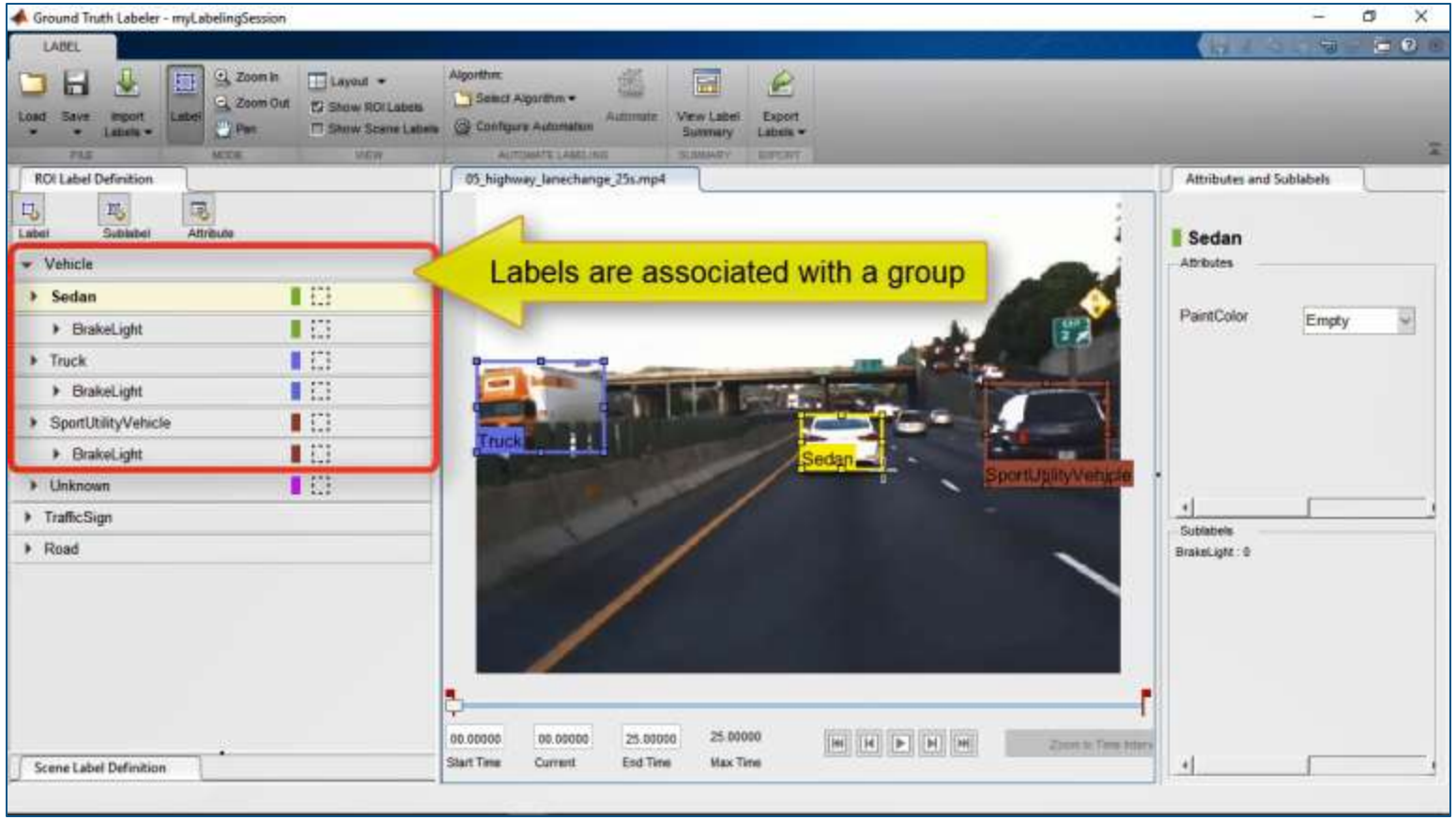
Create region of interest labels and groups

[Get Started with the Ground Truth Labeler]

- Label rectangles
- Label lane markings
- Label pixels
- Label scenes
- Create label groups
- Create sublabels
- Add label attributes

Automated Driving Toolbox™

Updated R2019a



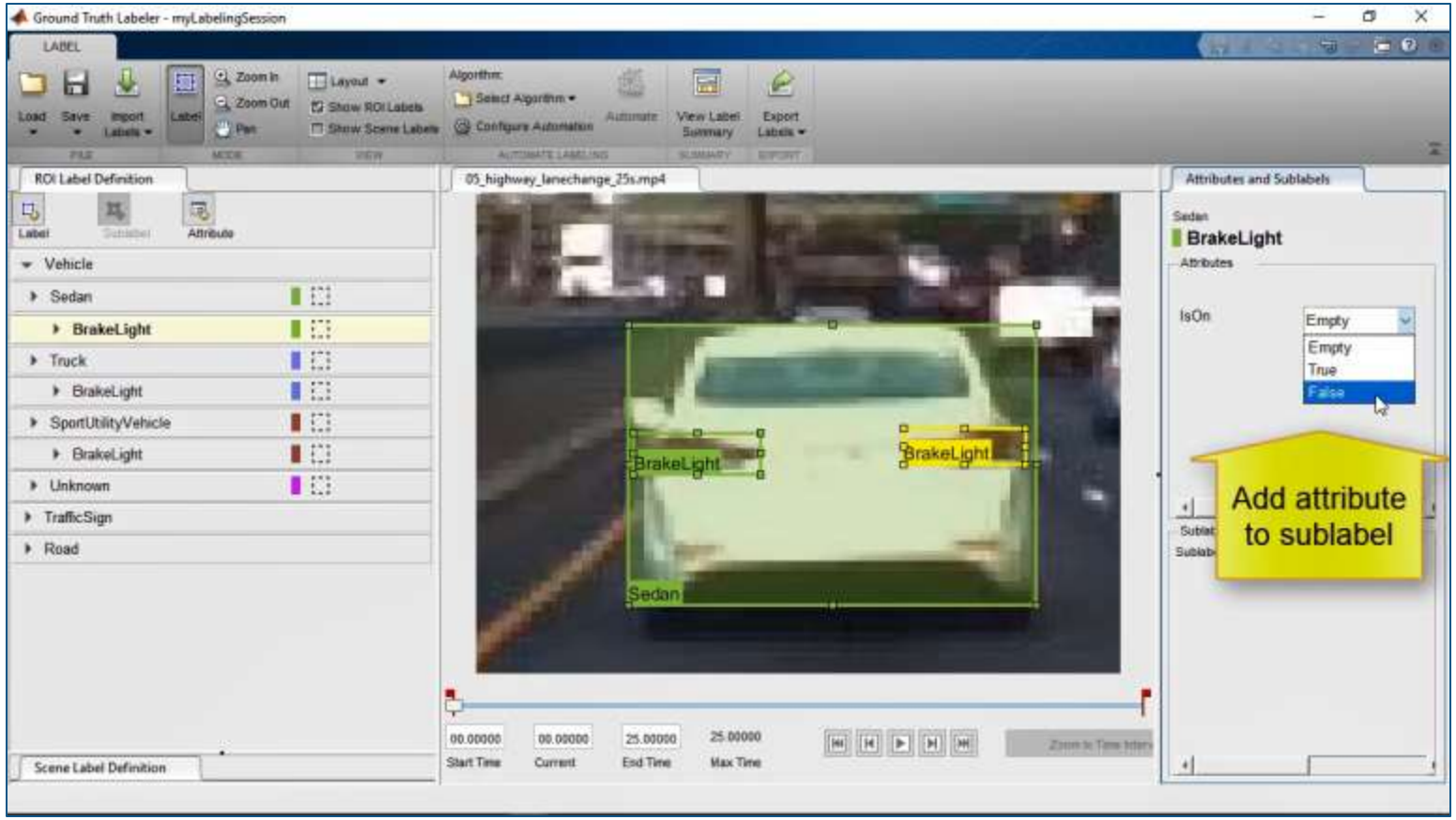
Create sublabels and add attributes

[Get Started with the Ground Truth Labeler]

- Label rectangles
- Label lane markings
- Label pixels
- Label scenes
- Create label groups
- Create sublabels
- Add label attributes

Automated Driving Toolbox™

Updated R2019a



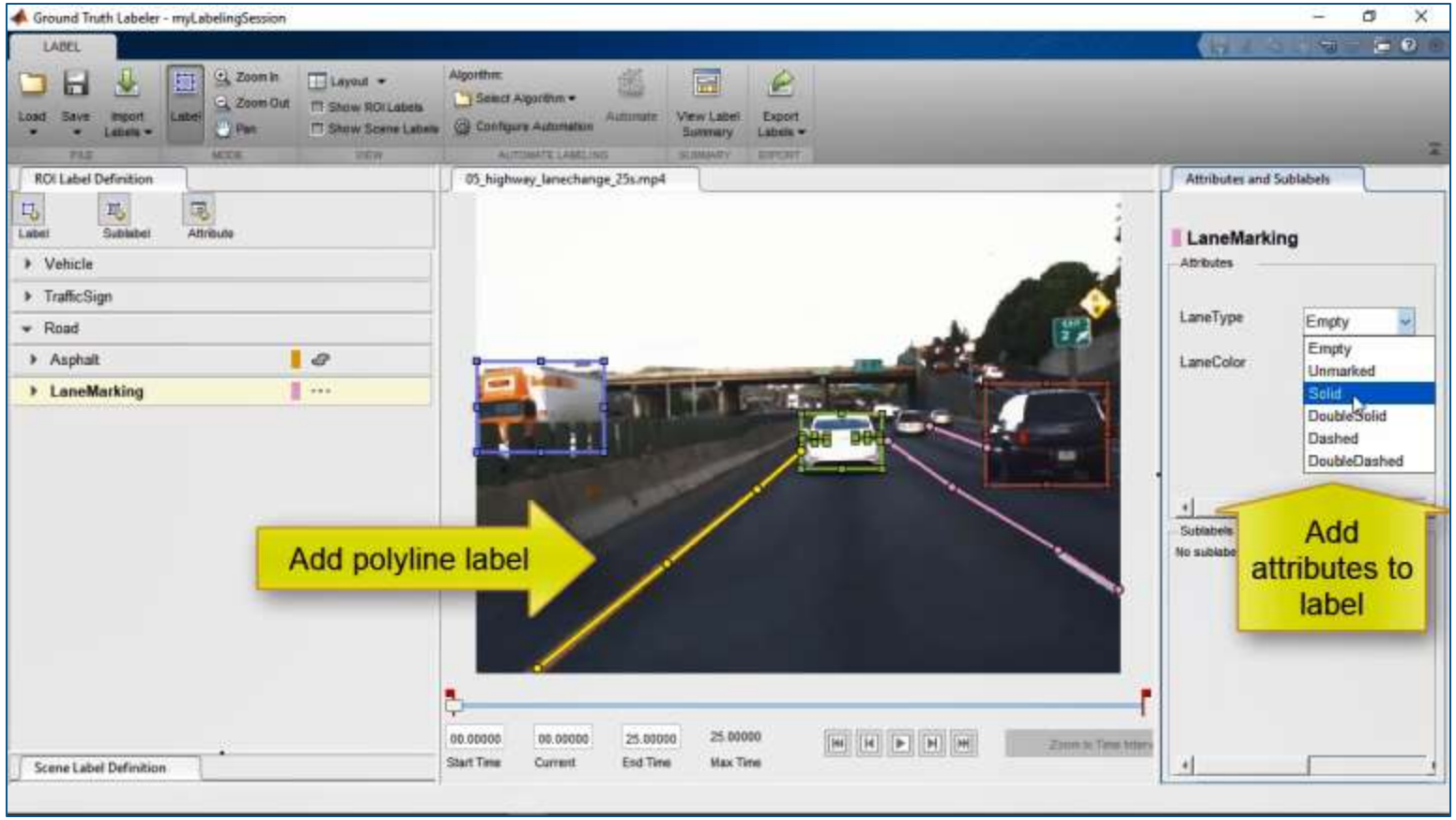
Create polyline labels and add attributes

[Get Started with the Ground Truth Labeler]

- Label rectangles
- Label lane markings
- Label pixels
- Label scenes
- Create label groups
- Create sublabels
- Add label attributes

Automated Driving Toolbox™

Updated R2019a



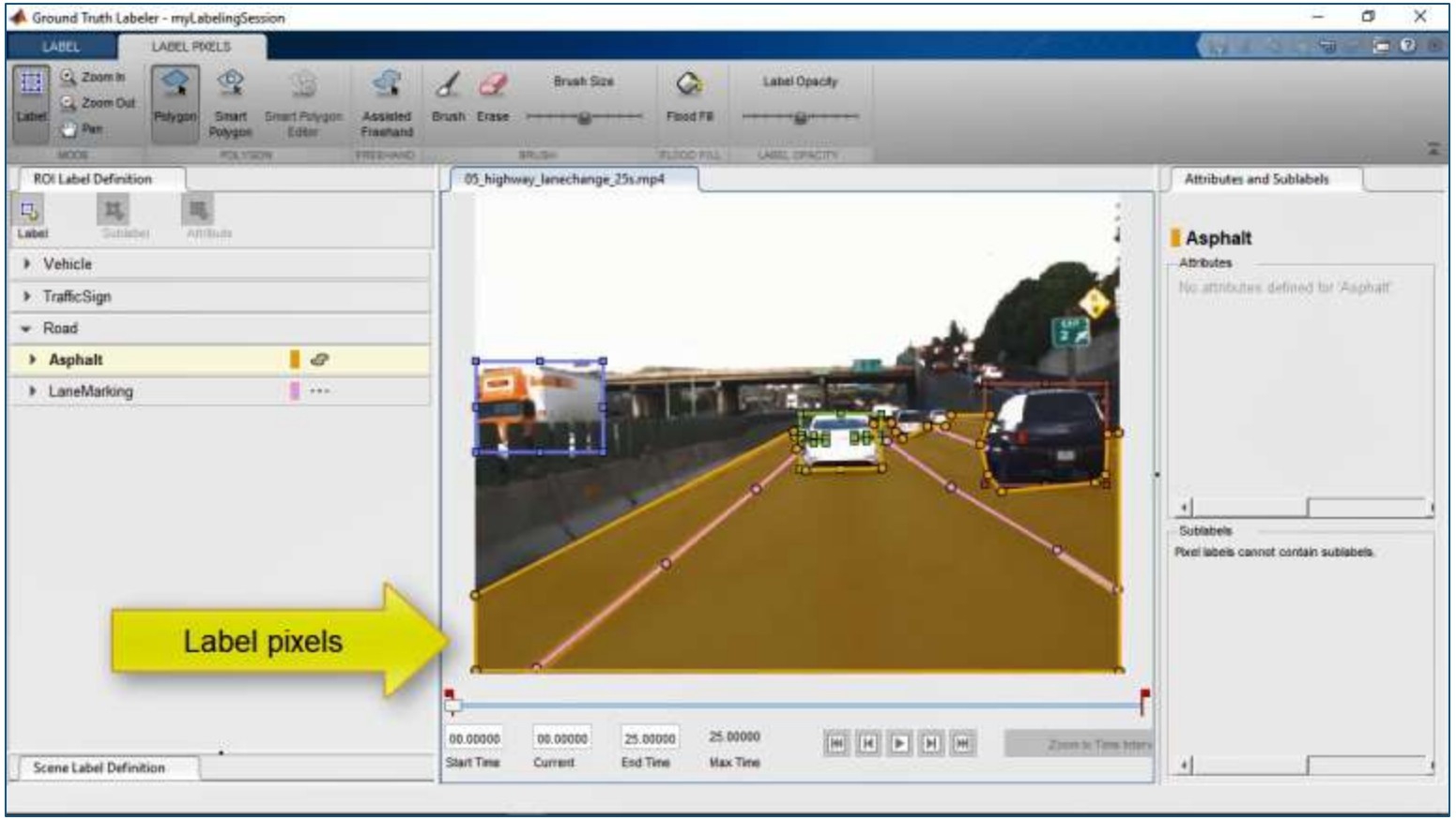
Create pixel labels

[Get Started with the Ground Truth Labeler]

- Label rectangles
- Label lane markings
- Label pixels
- Label scenes
- Create label groups
- Create sublabels
- Add label attributes

Automated Driving Toolbox™

Updated R2019a



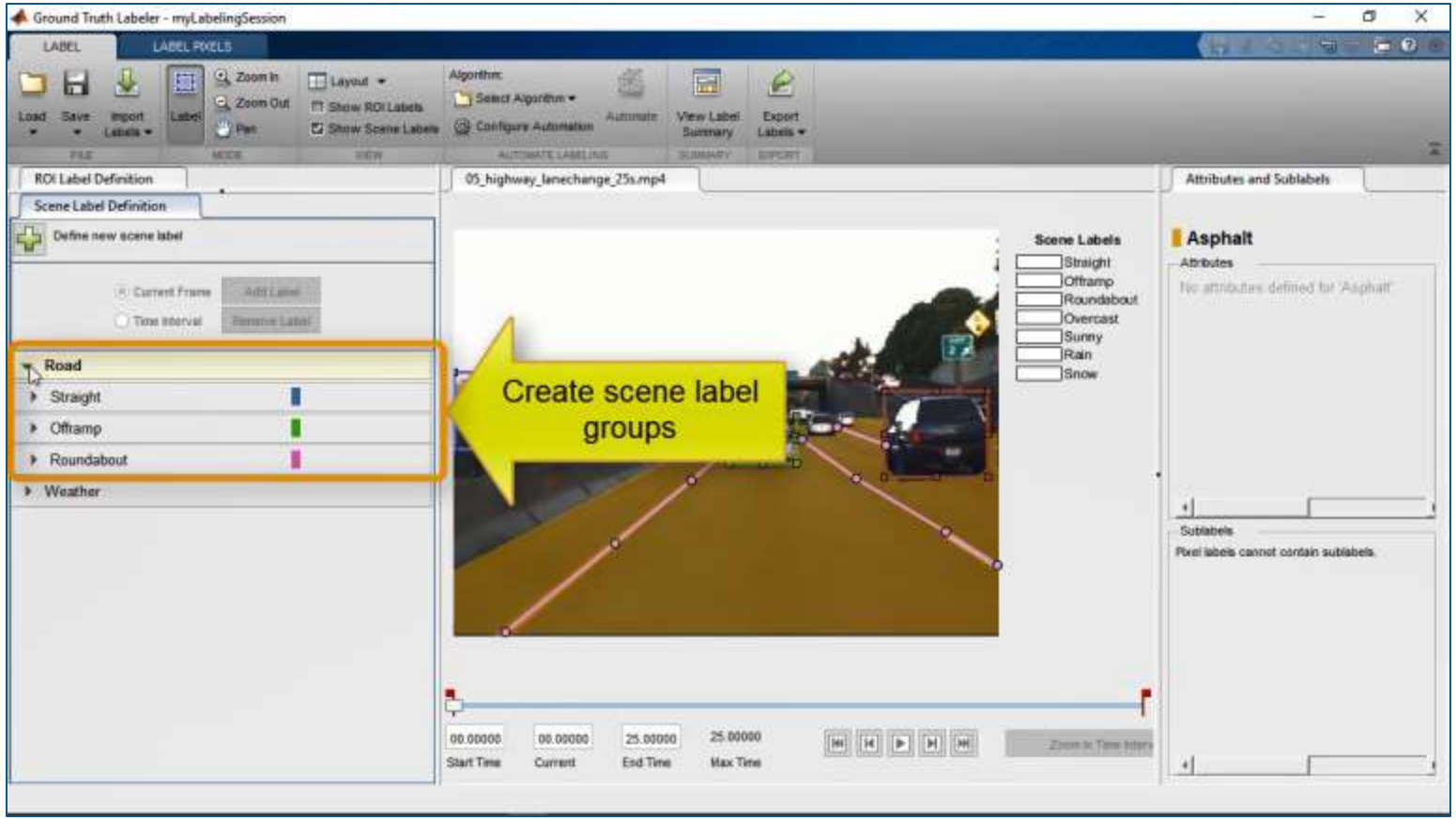
Create scene labels and groups

[Get Started with the Ground Truth Labeler]

- Label rectangles
- Label lane markings
- Label pixels
- Label scenes
- Create label groups
- Create sublabels
- Add label attributes

Automated Driving Toolbox™

Updated R2019a



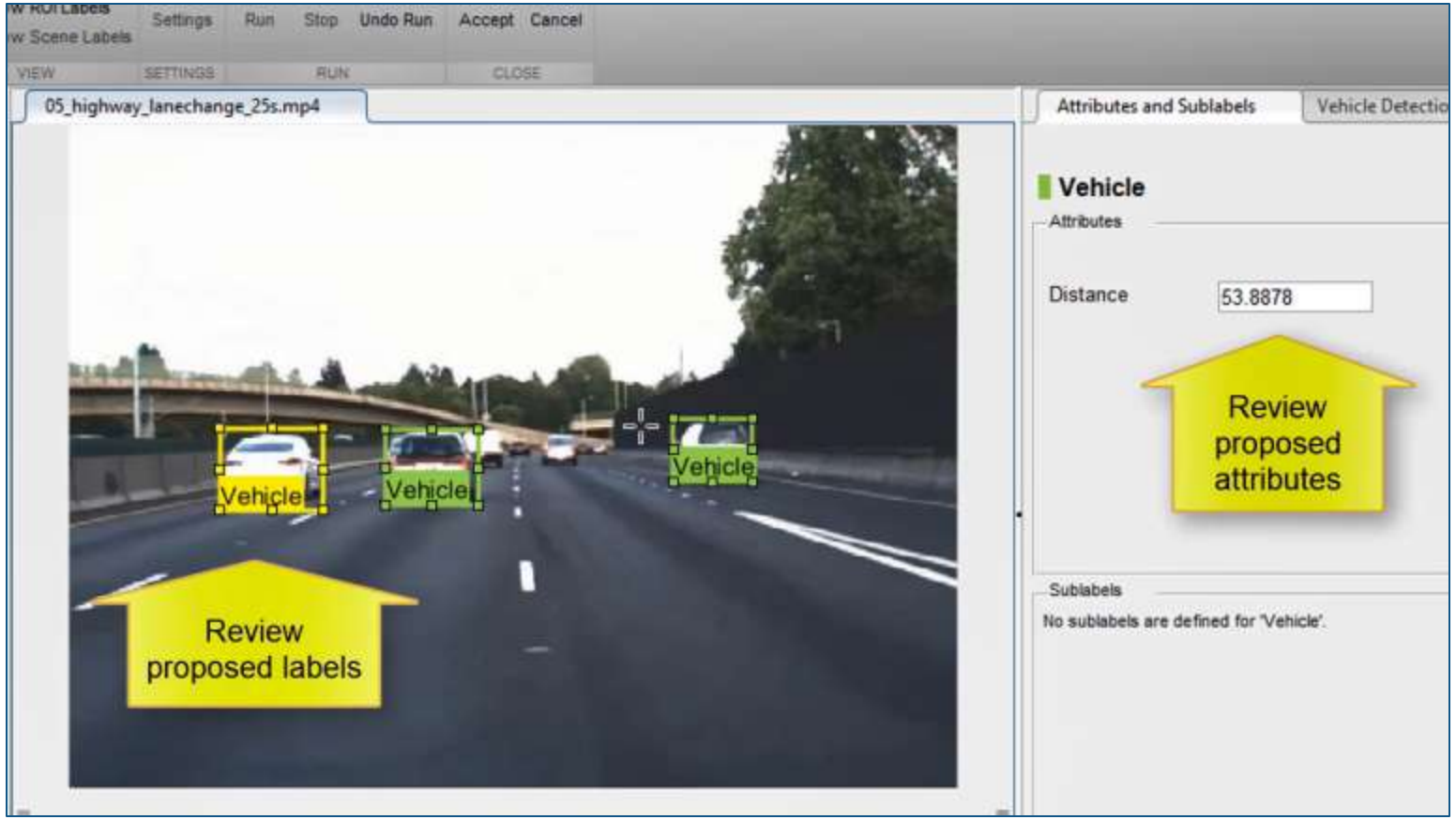
Import custom automation algorithms

[Automate Attributes of Labeled Objects]

- Import automation algorithm into Ground Truth Labeling app
- Detect vehicles from monocular camera
- Estimate distance to detected vehicles
- Run automation algorithm and interactively validate labels

Automated Driving Toolbox™

R2018b



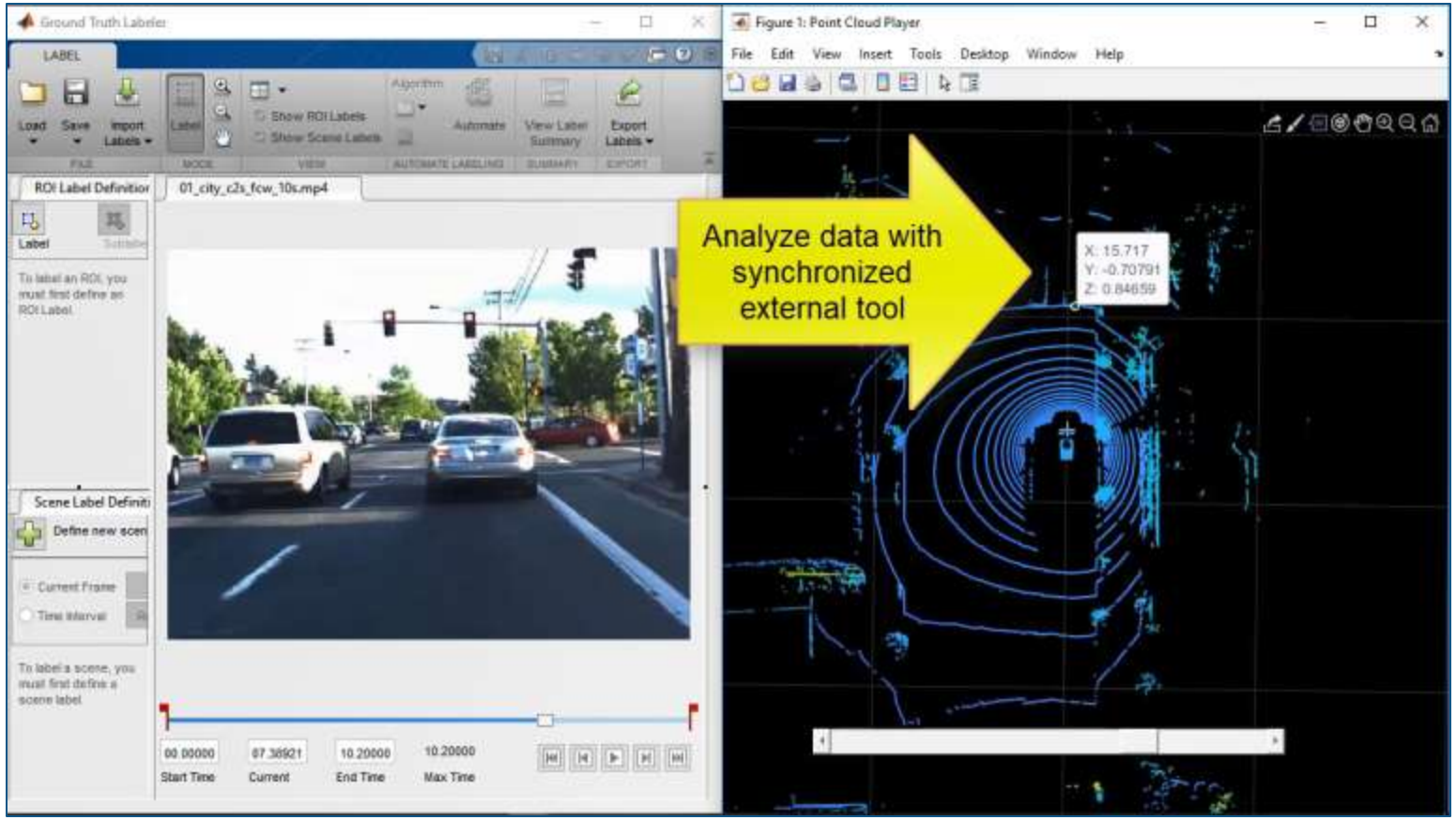
Add custom visualizations for multi-sensor data

Connect Lidar Display to Ground Truth Labeler

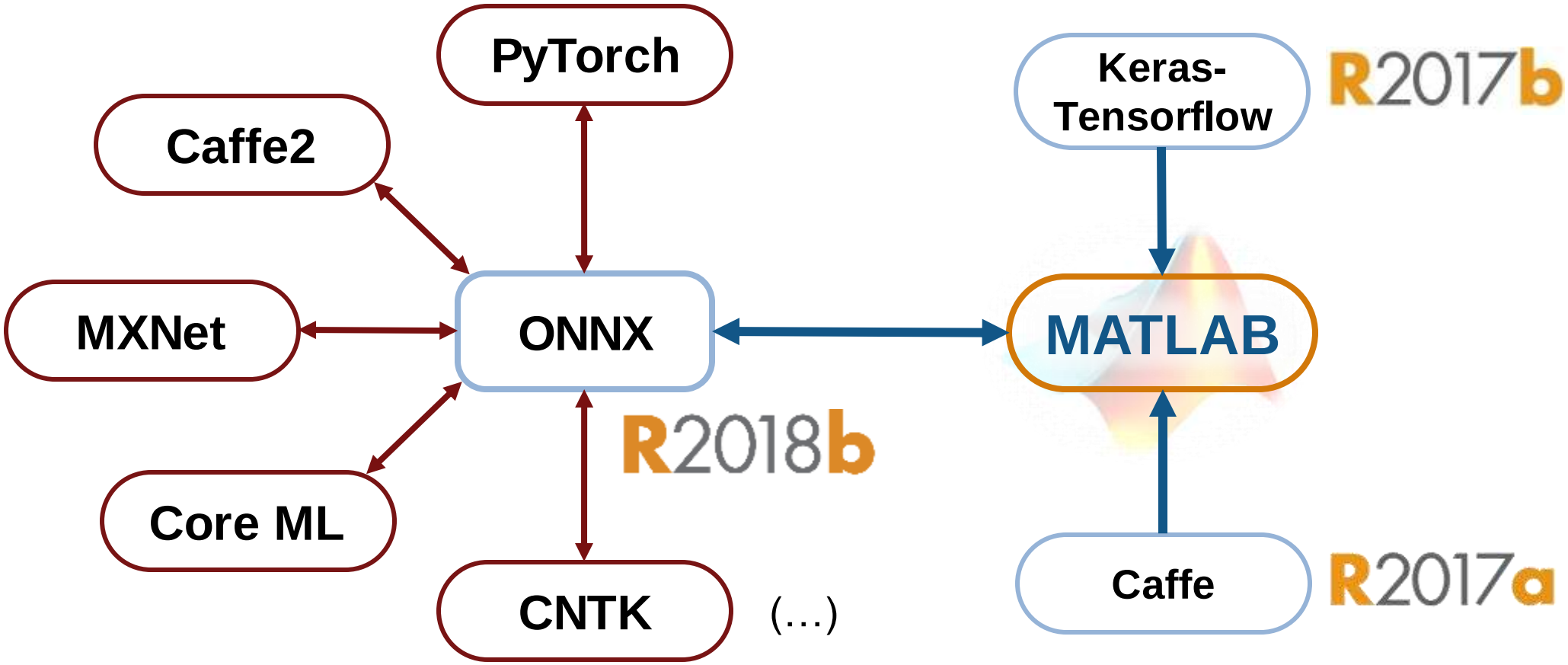
- Sync external tool to each frame change
- Control external tool through playback controls

Automated Driving Toolbox™

R2017a



Interoperate with neural network frameworks



Open Neural Network Exchange

Design camera, lidar, and radar perception algorithms

Detect vehicle with camera

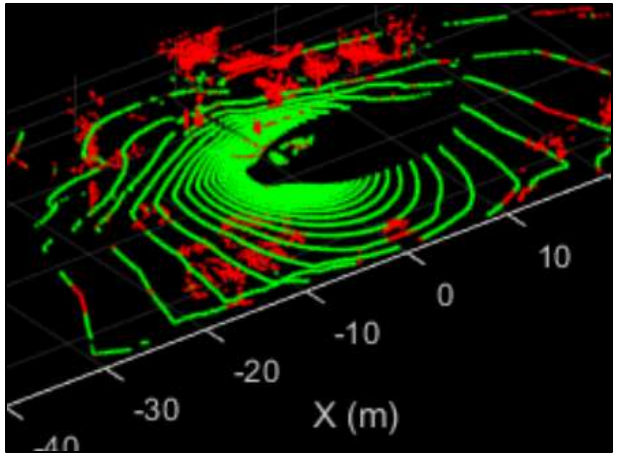
[Object Detection Using YOLO v2 Deep Learning]

Computer Vision Toolbox™

Deep Learning Toolbox™

R2019a

Detect ground with lidar

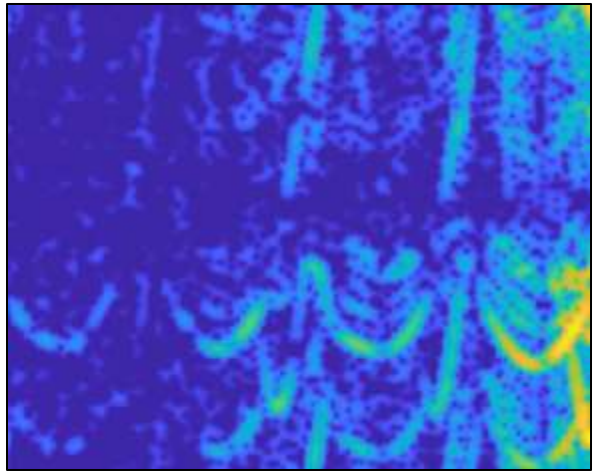


[Segment Ground Points from Organized Lidar Data]

Computer Vision Toolbox™

R2018b

Detect pedestrian with radar



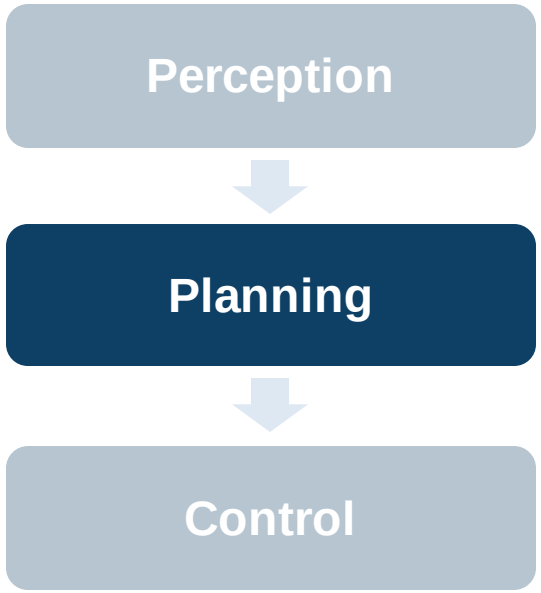
[Introduction to Micro-Doppler Effects]

Phased Array System Toolbox™

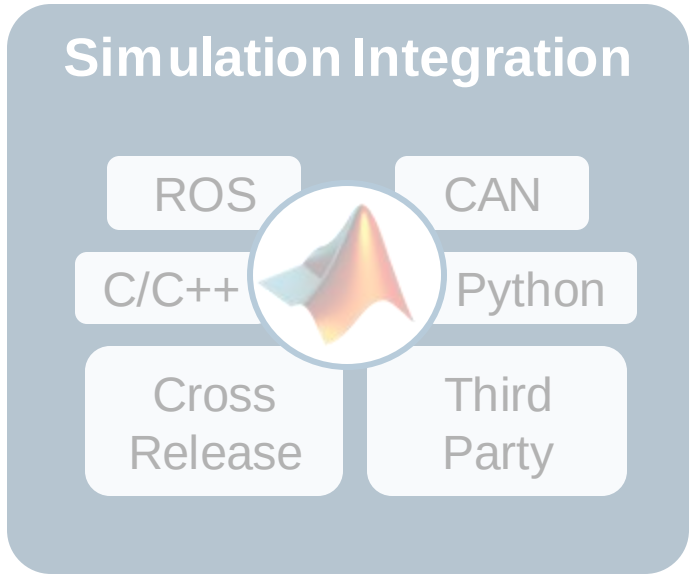
R2019a

Some common questions from automated driving engineers

How can I
synthesize scenarios
to test my designs?



How can I
discover and design
in multiple domains?



How can I
integrate
with other environments?

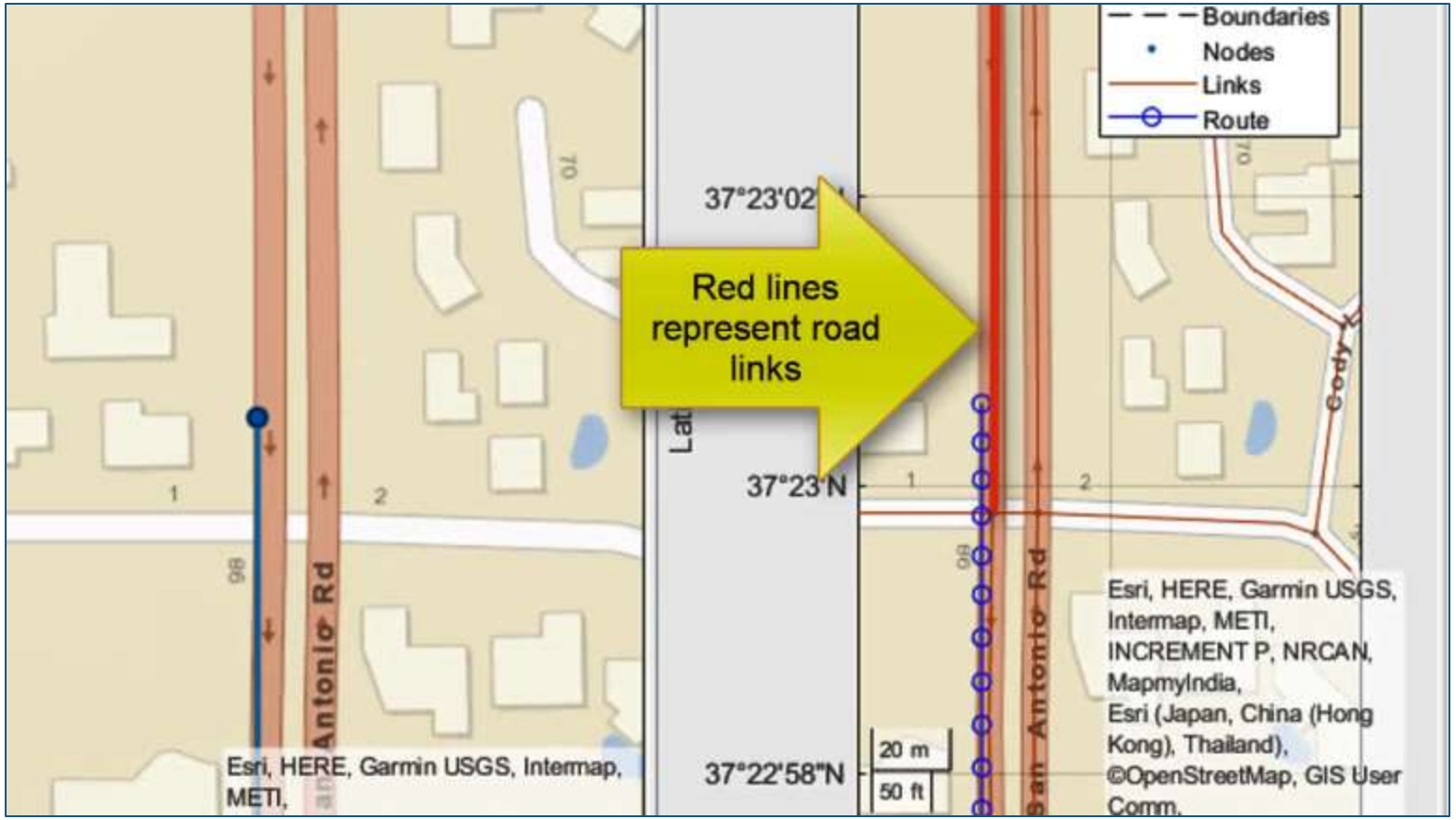
Read road and speed attributes from HERE HD Live Map data

[Use HERE HD Live Map Data to Verify Lane Configurations]

- Load camera and GPS data
- Retrieve speed limit
- Retrieve lane configurations
- Visualize composite data

Automated Driving Toolbox™

R2019a



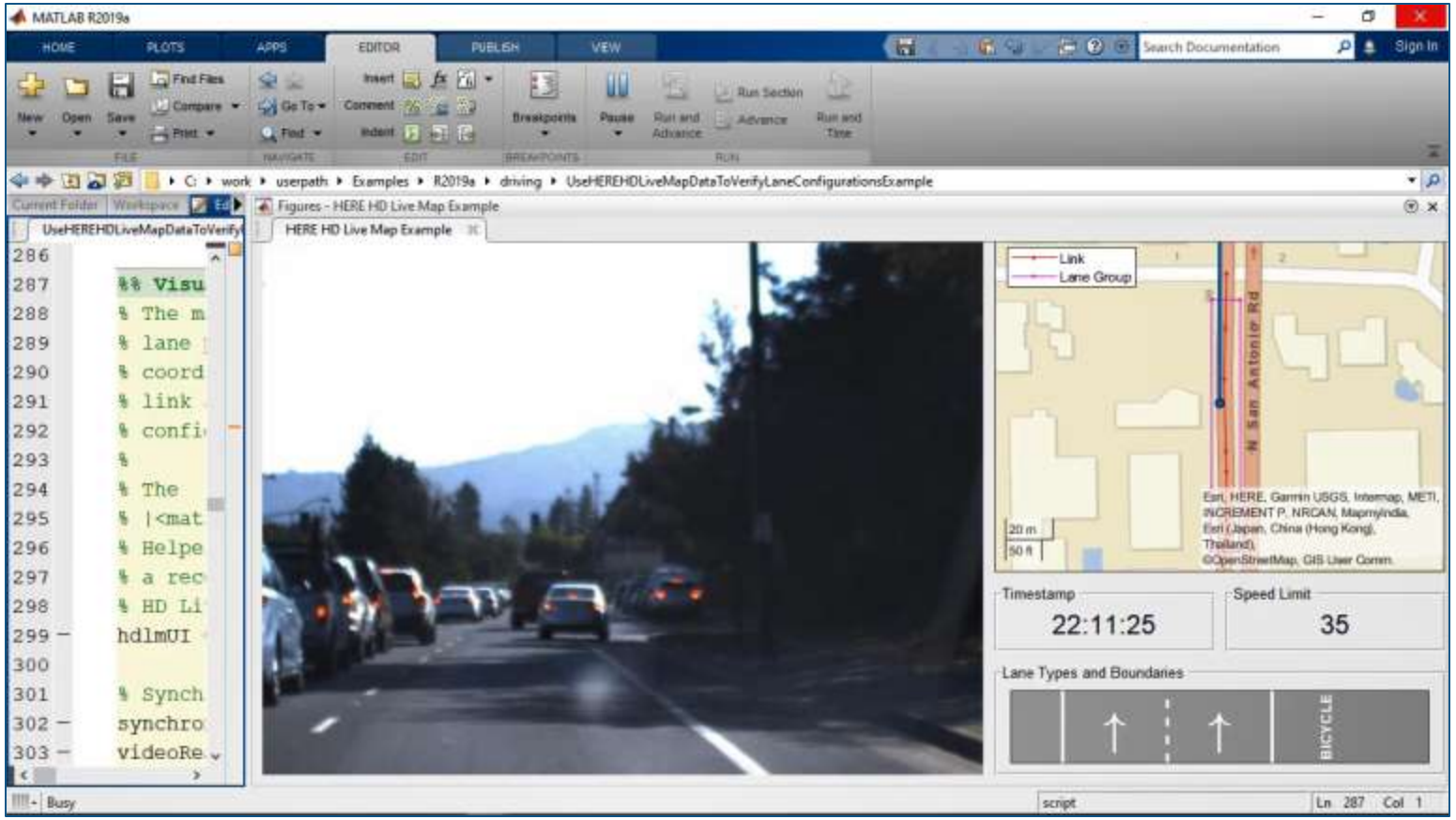
Visualize HERE HD Live Map recorded data

[Use HERE HD Live Map Data to Verify Lane Configurations]

- Load camera and GPS data
- Retrieve speed limit
- Retrieve lane configurations
- Visualize composite data

Automated Driving Toolbox™

R2019a



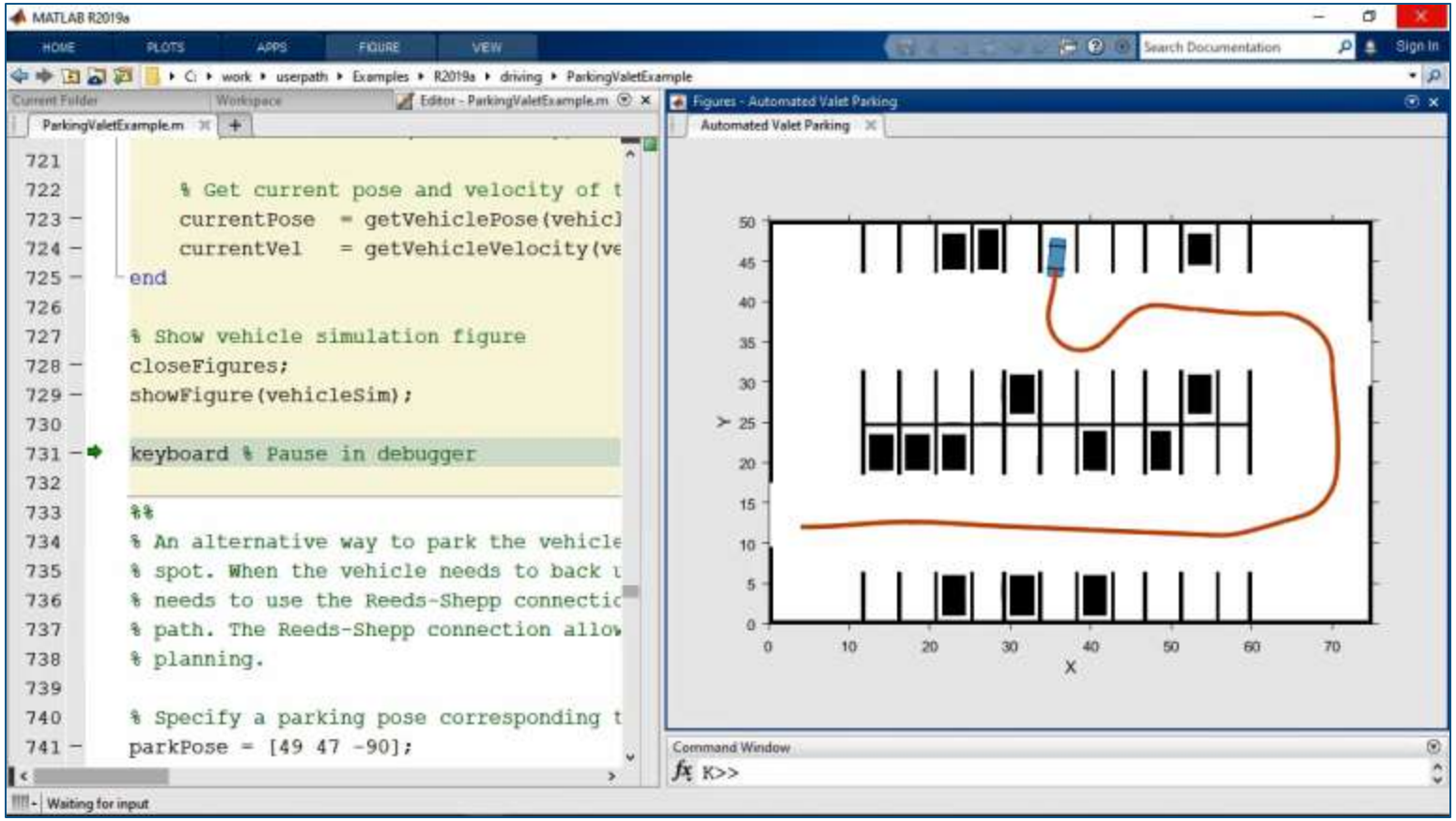
Design path planner

[Automated Parking Valet]

- Create cost map of environment
- Inflate cost map for collision checking
- Specify goal poses
- Plan path using rapidly exploring random tree (RRT*)

Automated Driving Toolbox™

R2018a



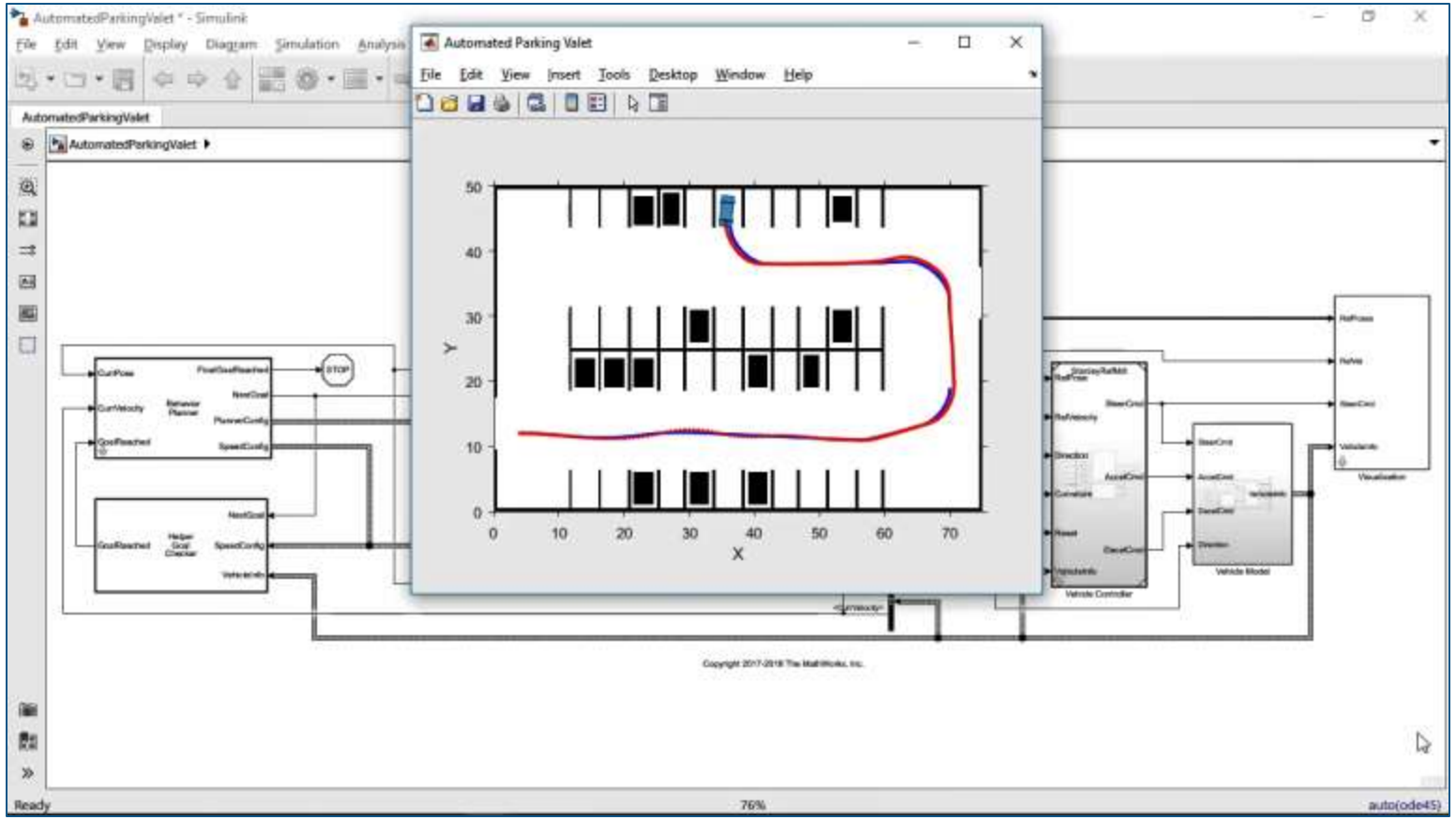
Design path planner and controller

[Automated Parking Valet with Simulink]

- Integrate path planner
- Design lateral controller (based on vehicle kinematics)
- Design longitudinal controller (PID)
- Simulate closed loop with vehicle dynamics

Automated Driving Toolbox™

R2018b



Generate C/C++ code for path planner and controller

[Code Generation for Path Planning and Vehicle Control]

- Simulate system
- Configure for code generation
- Generate C/C++ code
- Test using Software-In-the-Loop
- Measure execution time of generated code

Automated Driving Toolbox™

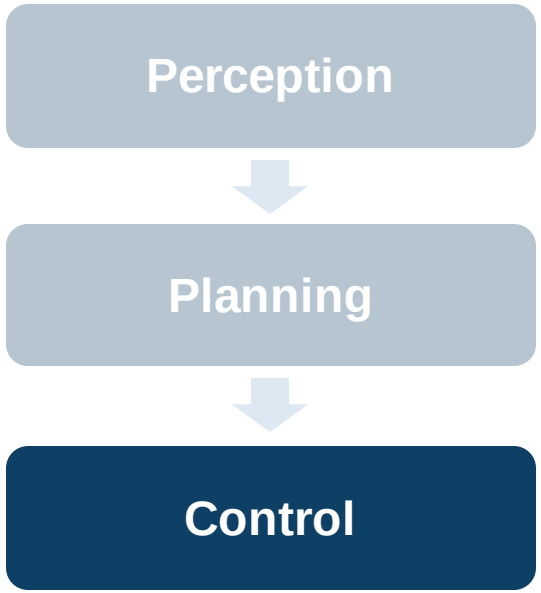
Embedded Coder

R2019a

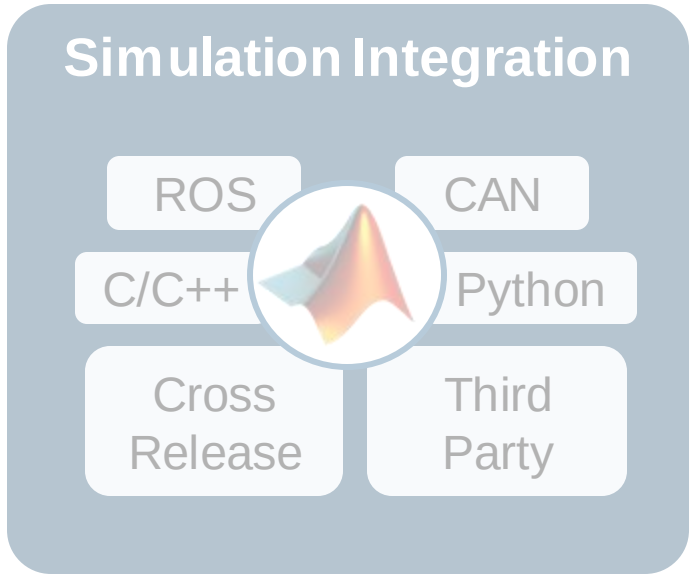
```
186
187   // model step function
188   void step0();
189
190   // model step function
191   void step1();
192
193   // model terminate function
194   void terminate();
195
196   // Constructor
197   AutomatedParkingValetModelClass();
198
199   // Destructor
200   ~AutomatedParkingValetModelClass();
201
202   // Root inport: '<Root>/Costmap' set method
203   void setCostmap(costmapBus localArgInput);
204
205   // Root inport: '<Root>/GoalPose' set method
206   void setGoalPose(real_T localArgInput[3]);
207
```

Some common questions from automated driving engineers

How can I
synthesize scenarios
to test my designs?



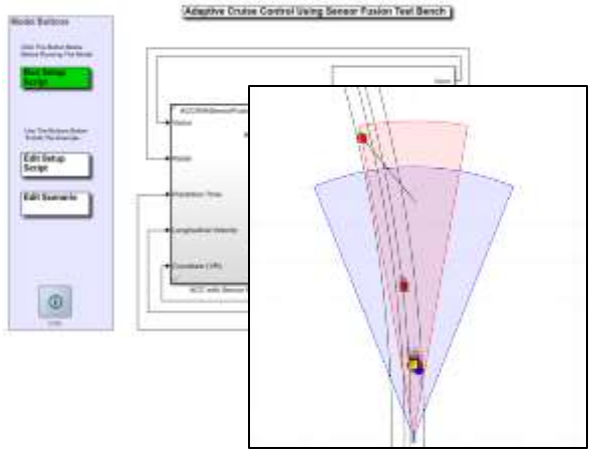
How can I
discover and design
in multiple domains?



How can I
integrate
with other environments?

Design lateral and longitudinal Model Predictive Controllers

Longitudinal Control



[Adaptive Cruise Control with Sensor Fusion]

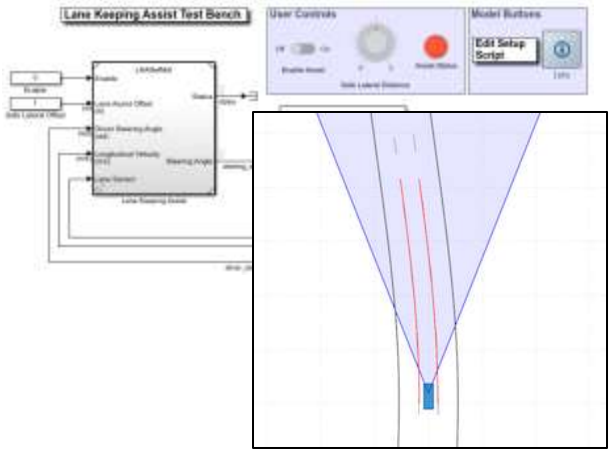
Automated Driving Toolbox™

Model Predictive Control Toolbox™

Embedded Coder®

R2017b

Lateral Control



[Lane Keeping Assist with Lane Detection]

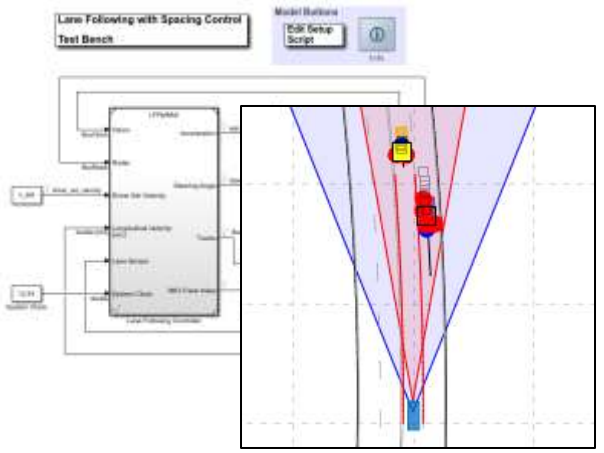
Automated Driving Toolbox™

Model Predictive Control Toolbox™

Embedded Coder®

R2018a

Longitudinal + Lateral



[Lane Following Control with Sensor Fusion and Lane Detection]

Automated Driving Toolbox™

Model Predictive Control Toolbox™

Embedded Coder®

R2018b

Develop automatic emergency braking application

[Automatic Emergency Braking (AEB) with Sensor Fusion]

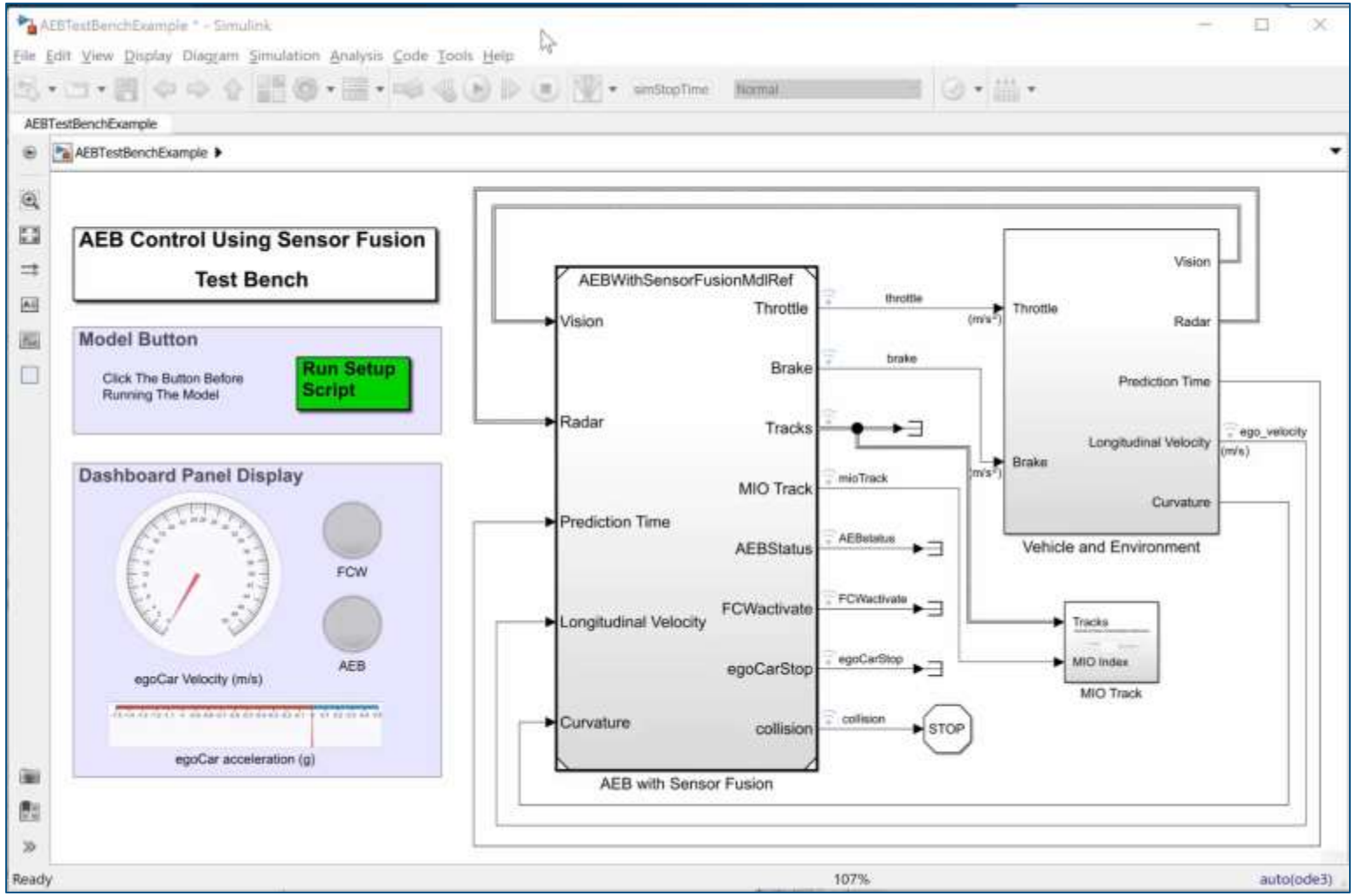
- Specify driving scenario
- Design AEB logic
- Integrate sensor fusion
- Visualize sensors and tracks
- Generate C/C++ code
- Test with software in the loop (SIL) simulation

Automated Driving Toolbox™

Stateflow®

Embedded Coder®

R2018b



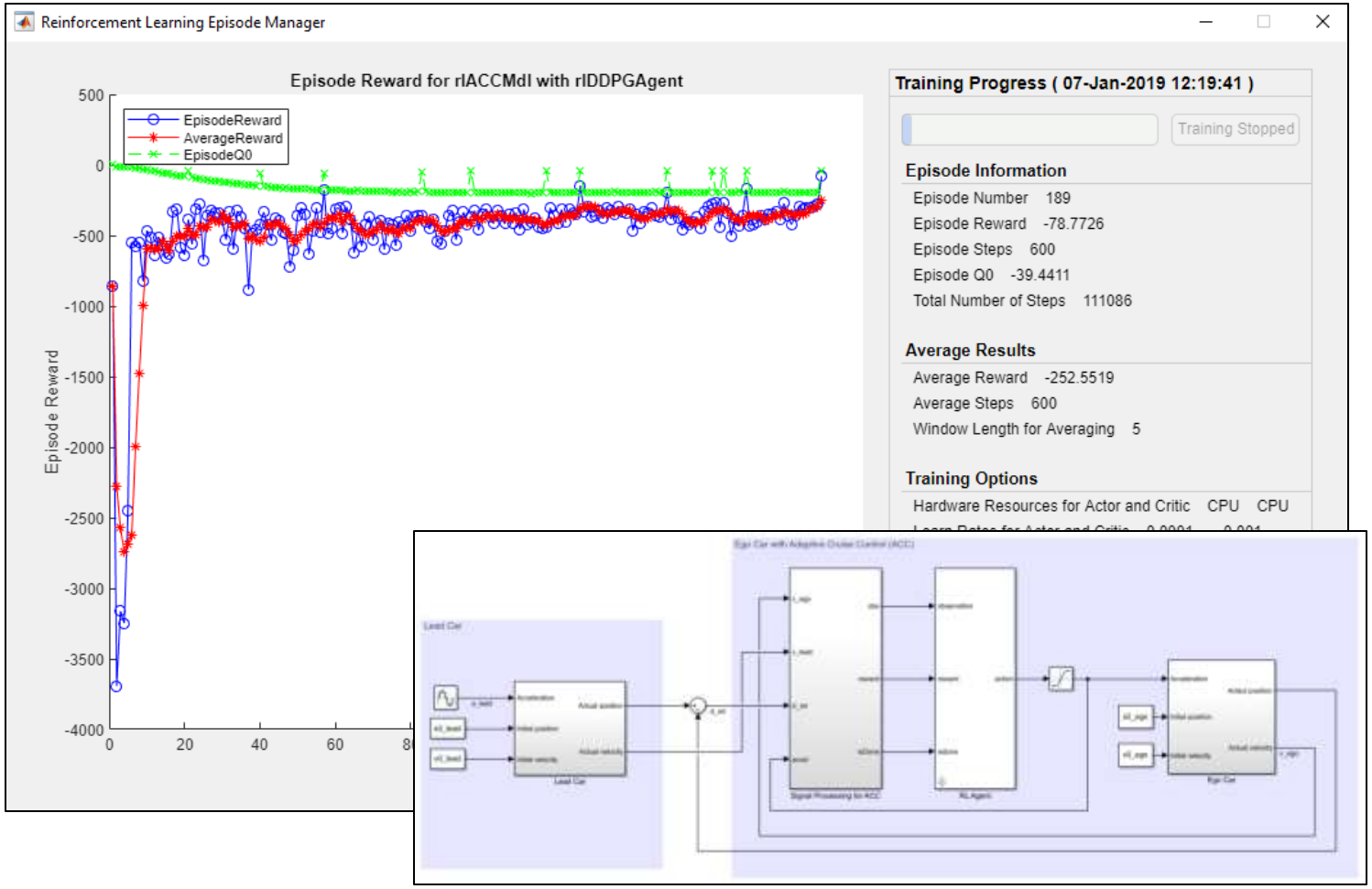
Train reinforcement learning networks for ADAS controllers

[Train Deep Deterministic Policy Gradient (DDPG) Agent for Adaptive Cruise Control]

- Create environment interface
- Create agent
- Train agent
- Simulate trained agent

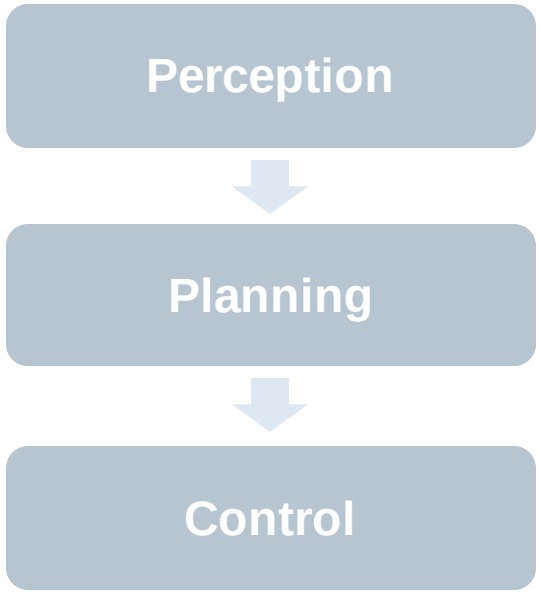
Reinforcement Learning Toolbox™

R2019a

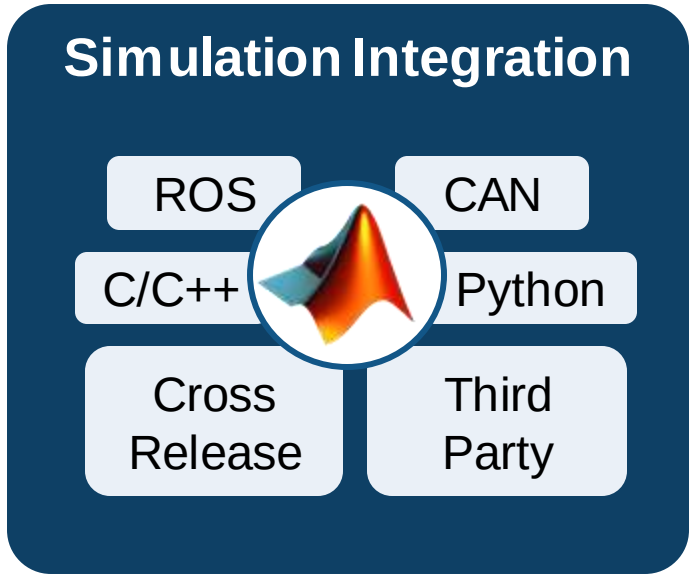


Some common questions from automated driving engineers

How can I
synthesize scenarios
to test my designs?



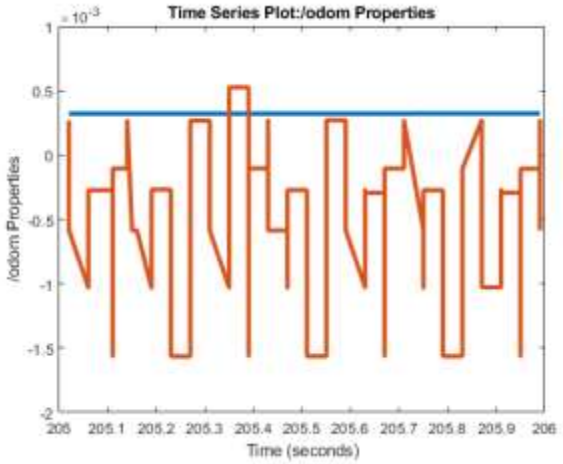
How can I
discover and design
in new domains?



How can I
integrate
with other environments?

Integrate with ROS

Replay logged ROS data

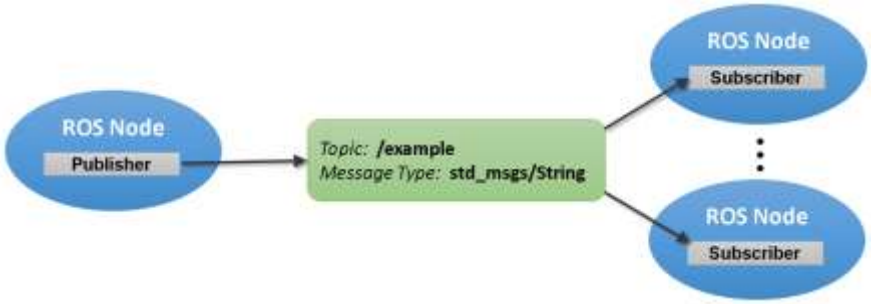


[Work with rosbag Logfiles](#)

Robotic System Toolbox™

Updated **R2018a**

Connect to live ROS data

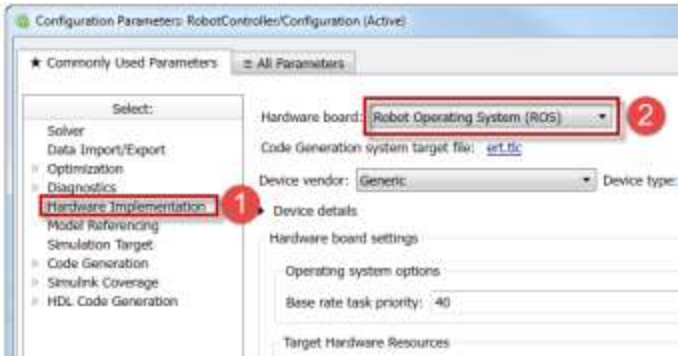


[Exchange Data with ROS Publishers and Subscribers](#)

Robotic System Toolbox™

R2016b

Generate standalone ROS node



[Generate a Standalone ROS Node from Simulink](#)

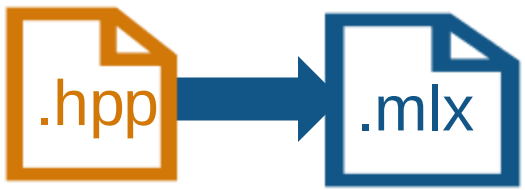
Robotic System Toolbox™

Simulink Coder™

R2016b

Call C++, Python, and OpenCV from MATLAB

Call C++



[Import C++ Library Functionality into MATLAB]

MATLAB®

R2019a

Call Python

```
tw = ...
py.textwrap.TextWrapper(...
  pyargs(...
   'initial_indent',    '% ',...
   'subsequent_indent','% ',...
   'width', int32(30)))
```

[Call Python from MATLAB]

MATLAB®

R2014a

Call OpenCV & OpenCV GPU

```
cv::Rect
cv::KeyPoint
cv::Size
cv::Mat
cv::Ptr
...
```

[Install and Use Computer Vision Toolbox OpenCV Interface]

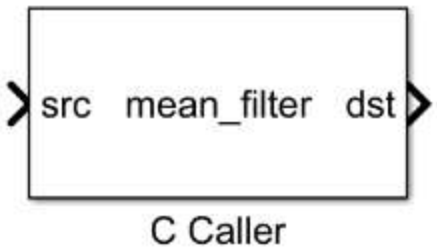
Computer Vision System Toolbox™

OpenCV Interface Support Package

Updated R2018b

Call C code from Simulink

Call C code

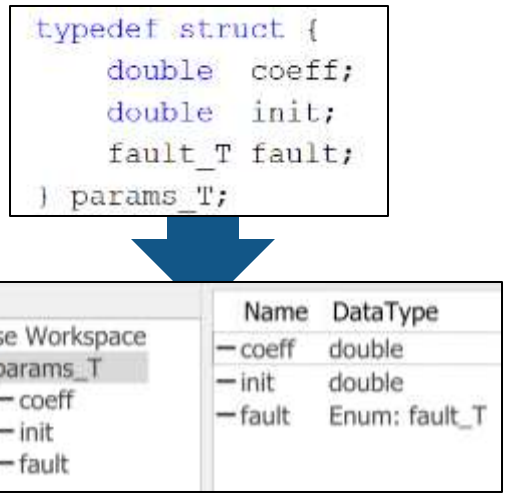


[Bring Custom Image Filter Algorithms as Reusable Blocks in Simulink]

Simulink®

R2017b

Create buses from C structs

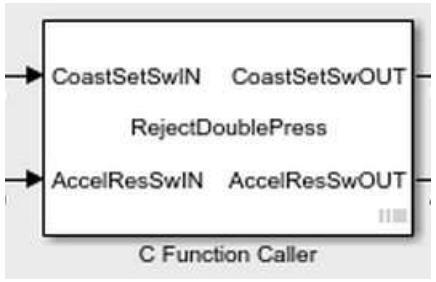


[Import Structure and Enumerated Types]

Simulink®

R2017a

Test and verify C code



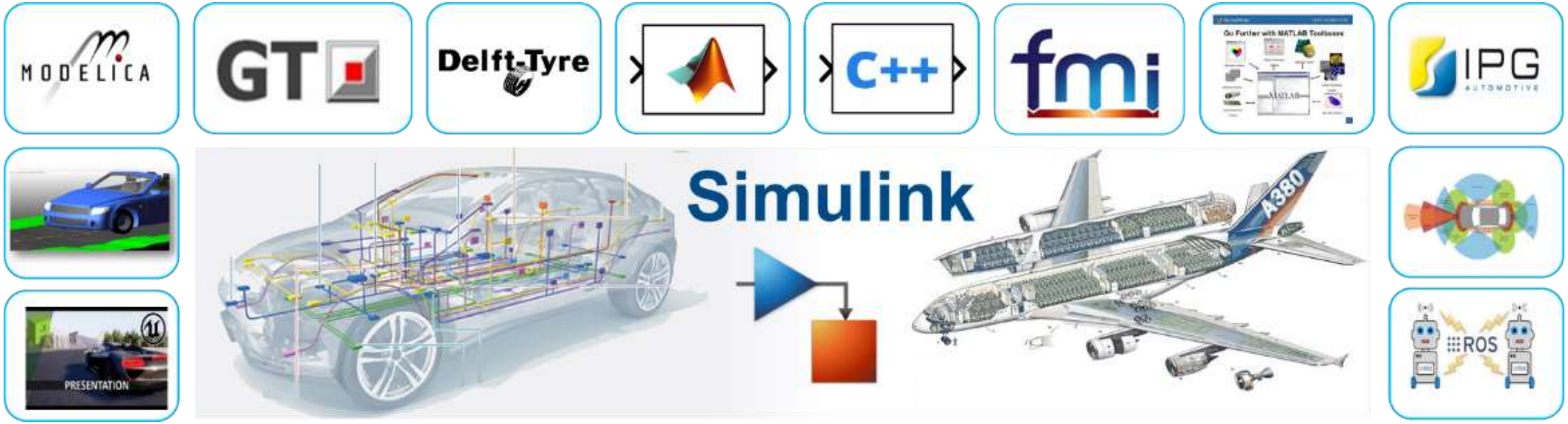
[Custom C Code Verification with Simulink Test]

Simulink Test™

Simulink Coverage™

R2019a

Connect to third party tools



152 Interfaces to 3rd Party Modeling and Simulation Tools

(as of March 2019)

MathWorks Partner

Cross-release simulation through code generation

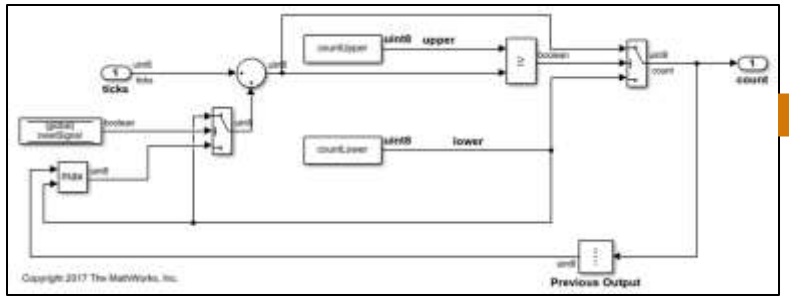
[Integrate Generated Code by Using Cross-Release Workflow]

- Generate code from previous release (R2010a or later)
- Import generated code as a block in current release
- Tune parameters
- Access internal signals

Embedded Coder

R2016a

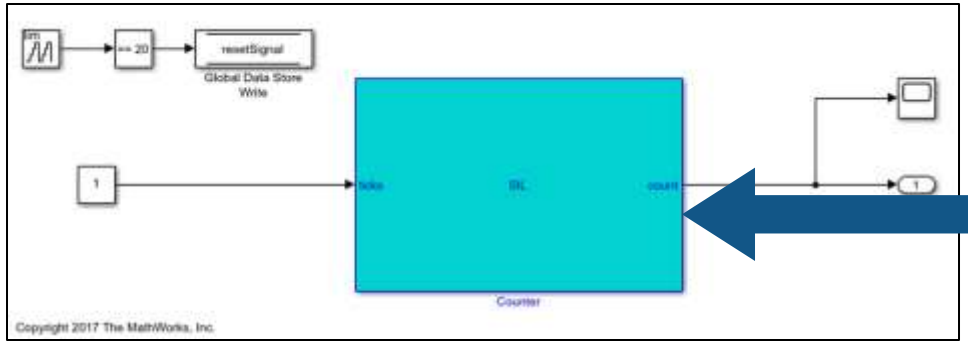
Previous Release



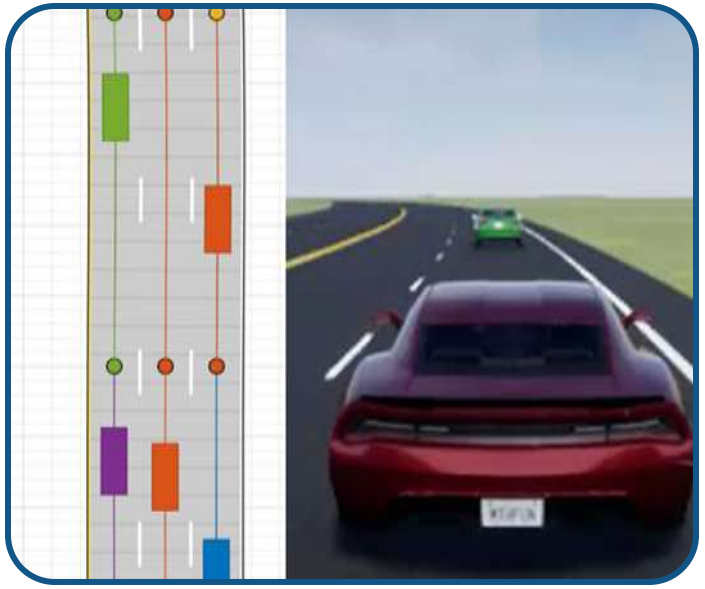
C

`crossReleaseImport`

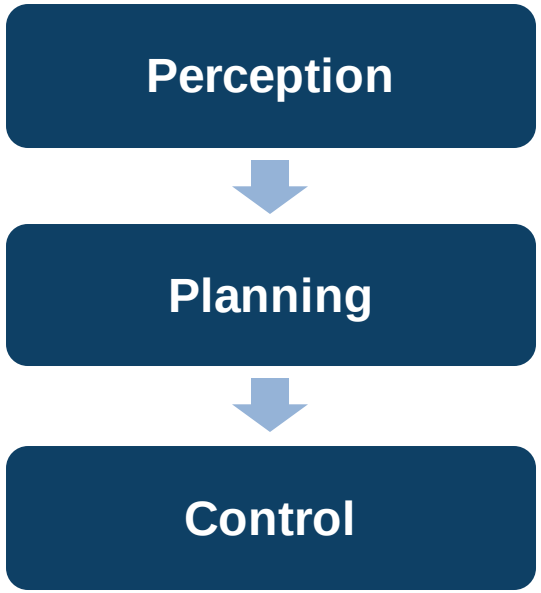
Current Release



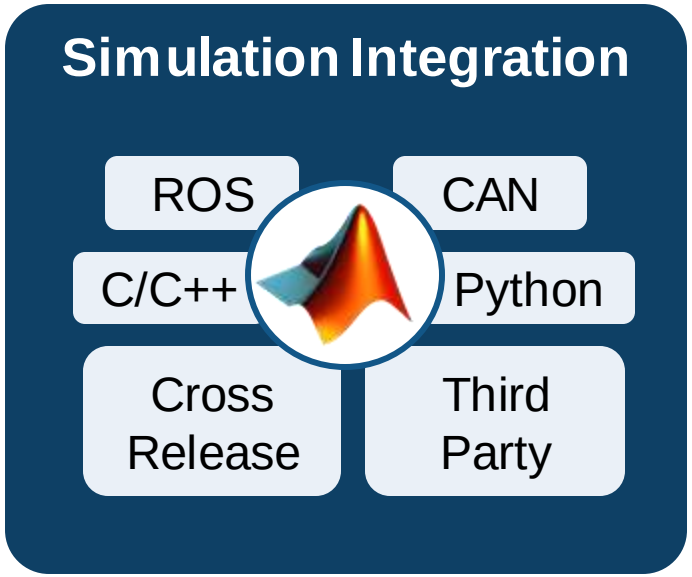
Some common questions from automated driving engineers



Synthesize scenarios
to test my designs

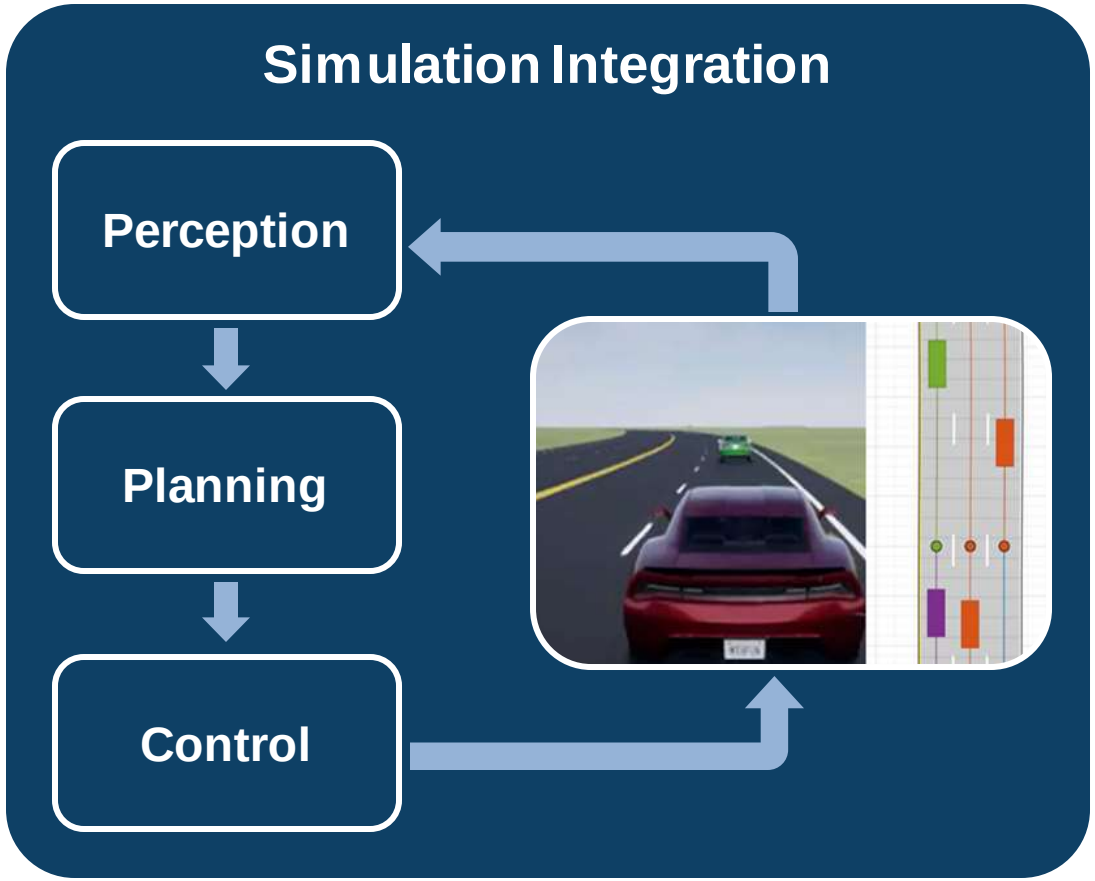


Discover and design
in multiple domains



Integrate
with other environments

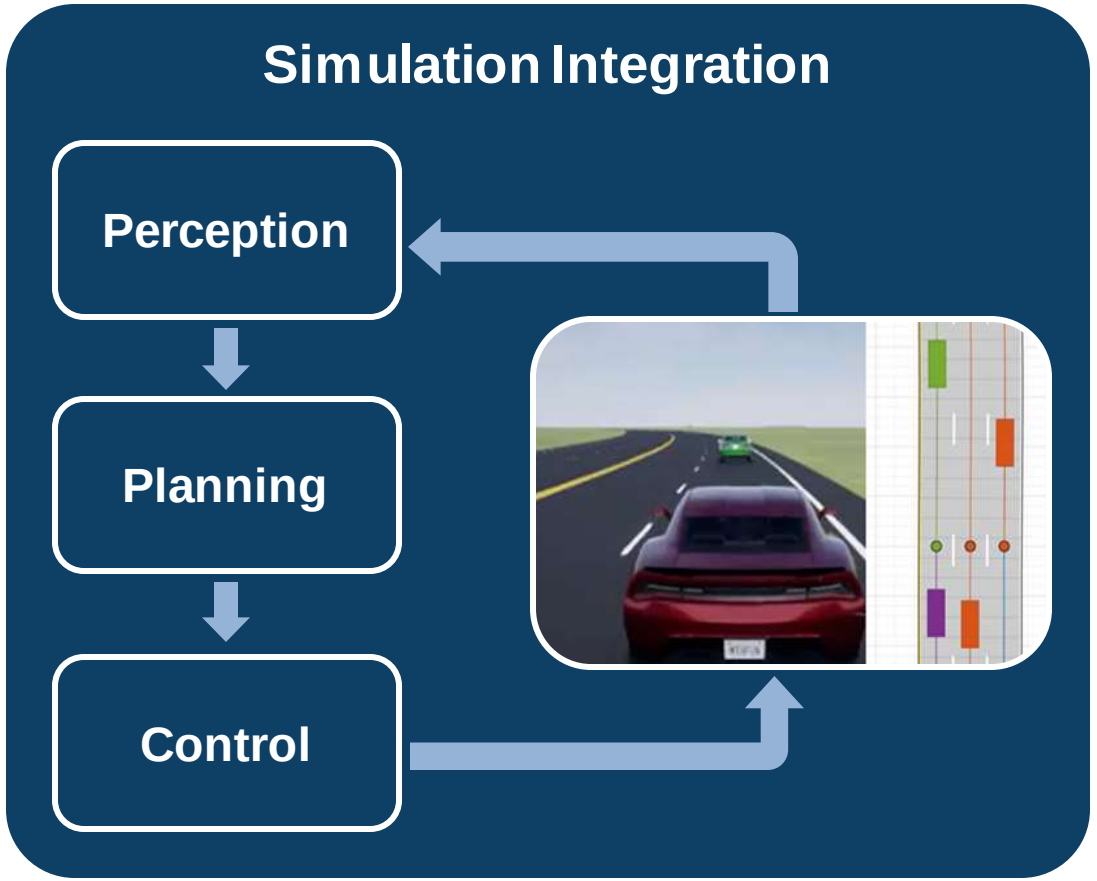
Get started on your own with documented examples



Documentation All Examples

- Automated Driving Toolbox
  - Labeling, perception, sensor fusion, path planning, synthetic sensor data
- Model Predictive Control Toolbox
  (Section: Automated Driving Applications)
  - Adaptive cruise control, lane keeping, lane following with spacing control
- Simulink Test
  (Section: Systematic Testing and Reporting)
  - Test lane following controller with sensor fusion

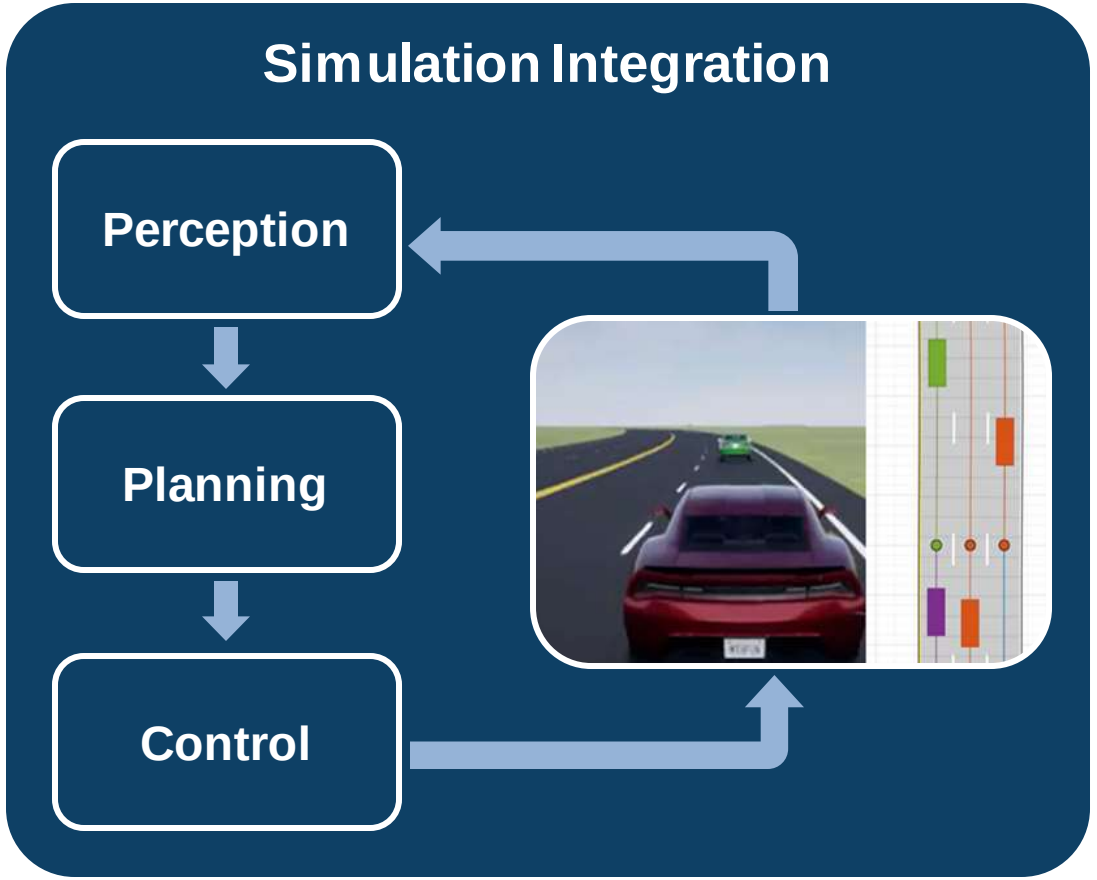
Gain tool experience with Training Services



MATLAB and Simulink Training

- Automated Driving with MATLAB
- Deep Learning with MATLAB
- Computer Vision with MATLAB
- Simulink for System and Algorithm Modeling
- Integrating Code with Simulink
- Code Generation for AUTOSAR Software
- Verification and Validation of Simulink Models
- Polyspace Bug Finder for C/C++ Code Analysis
- Ask about customizing training courses for your needs (contact training)

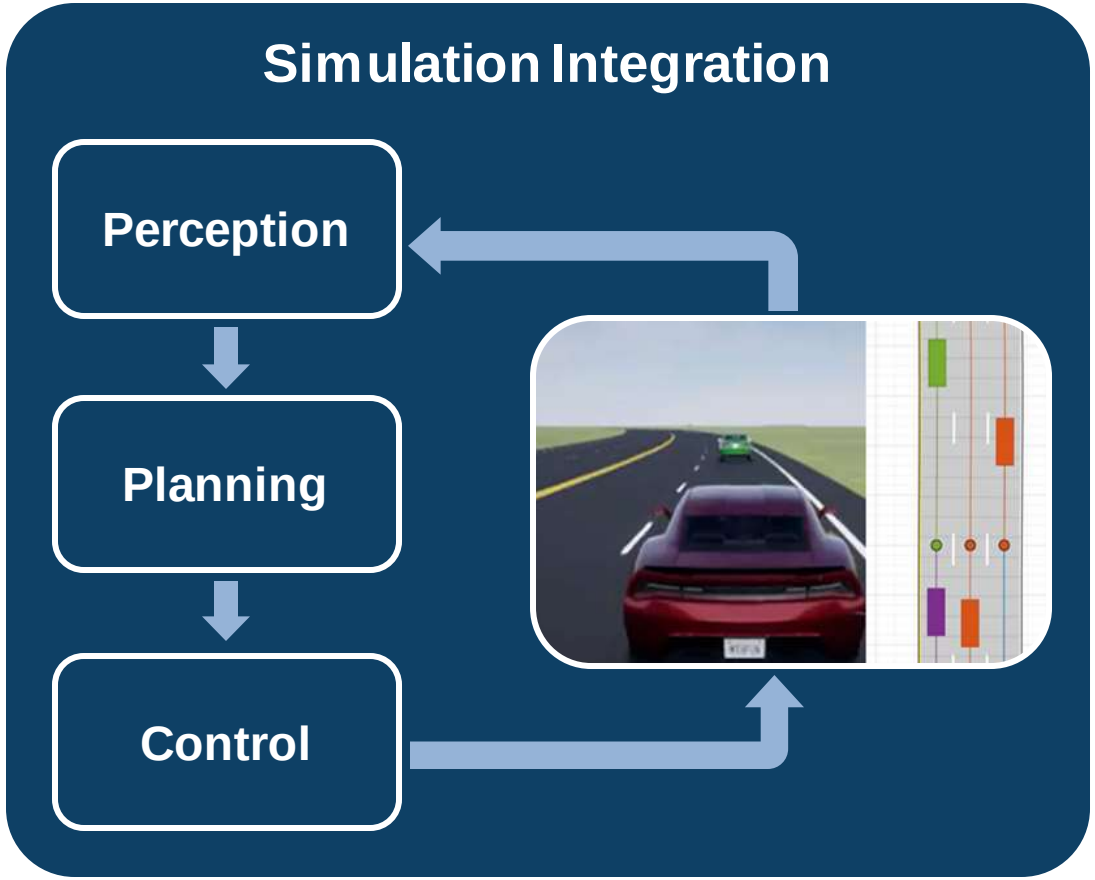
Partner on your projects with Consulting Services



MATLAB and Simulink Consulting Services

- Image Processing and Computer Vision
- MATLAB with Hadoop and Spark
- Tools Integration
- ISO 26262 Process Deployment Advisory Service
- Model-Based Design Process Establishment
- Model-Based Design Process Assessment and Maturity Framework
- Ask about extending tools for labeling or synthesizing sensor data (contact consulting)

Get started developing automated driving systems with MATLAB and Simulink



Discuss your application with me (mark.corless@mathworks.com) or a MathWorks field engineer to help you structure an evaluation

- Understand your goals
- Recommend tasks
- Answer questions