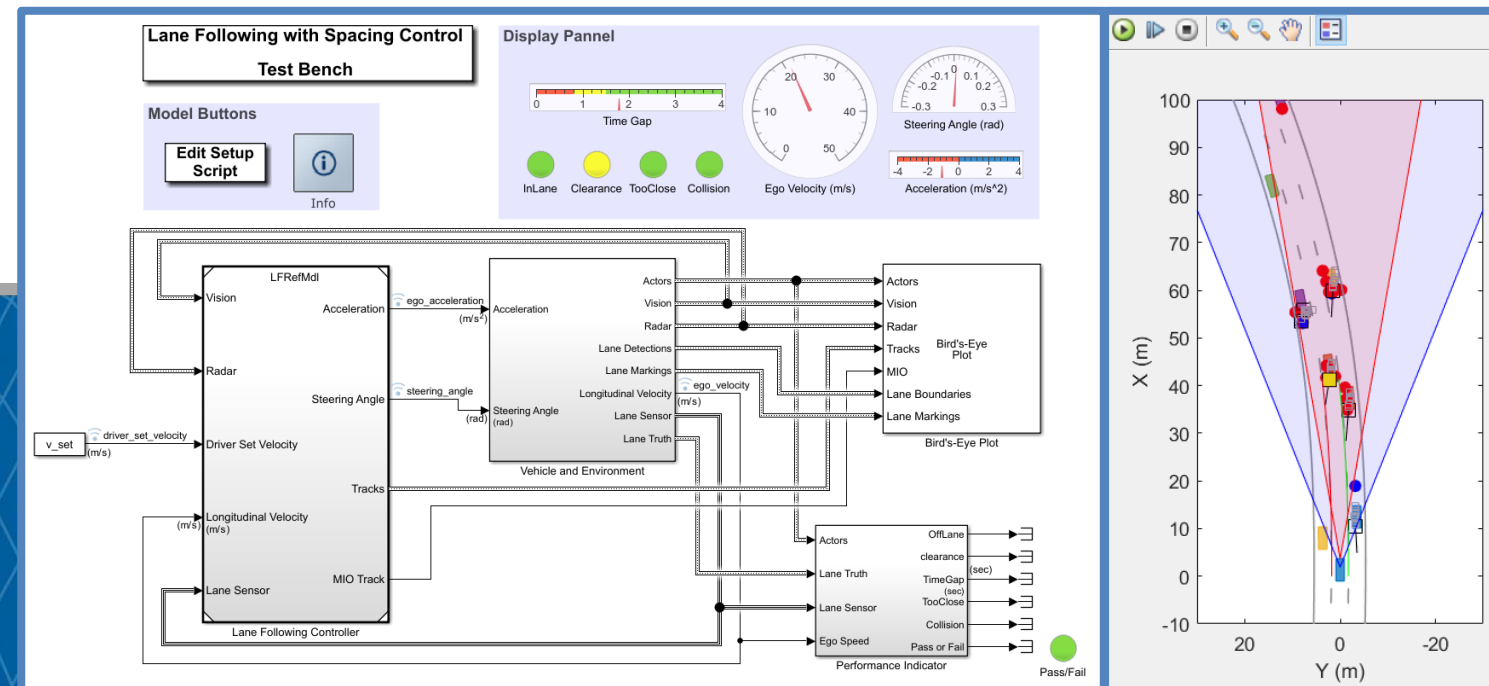


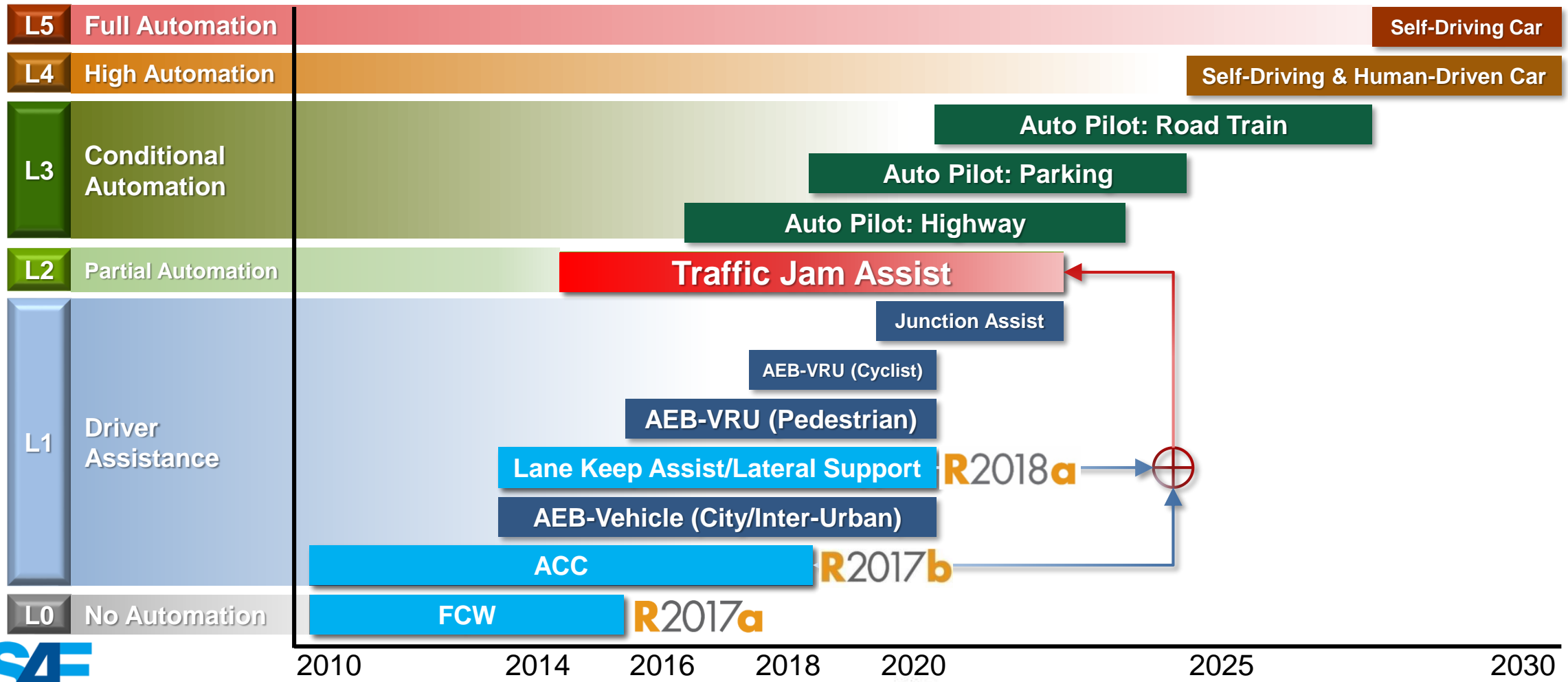
Automated Driving System Toolbox

Design and Test **Traffic Jam Assist**, *A Case Study*



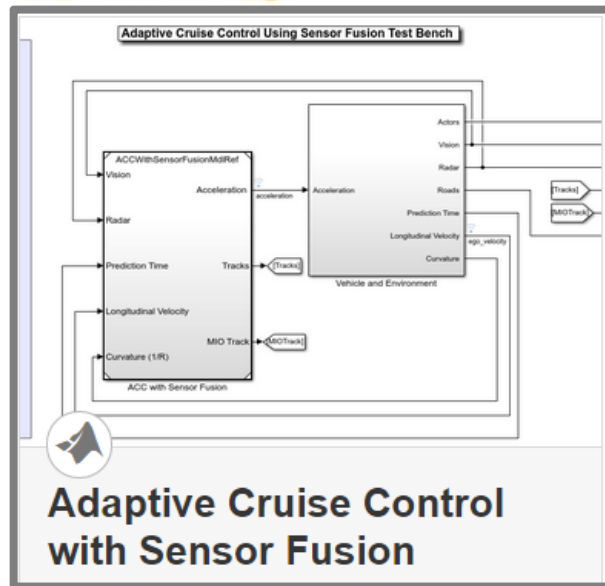
Seo-Wook Park
Principal Application Engineer

Evolution of ADAS/Autonomous Driving Car



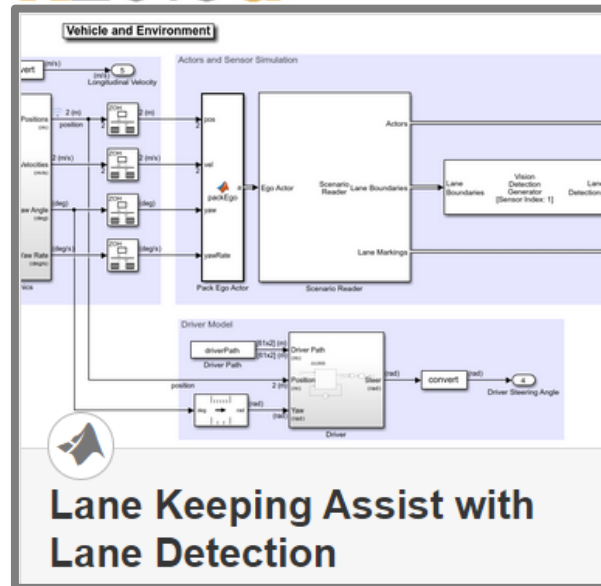
ACC and Lane Following Control for Traffic Jam Assist

R2017b

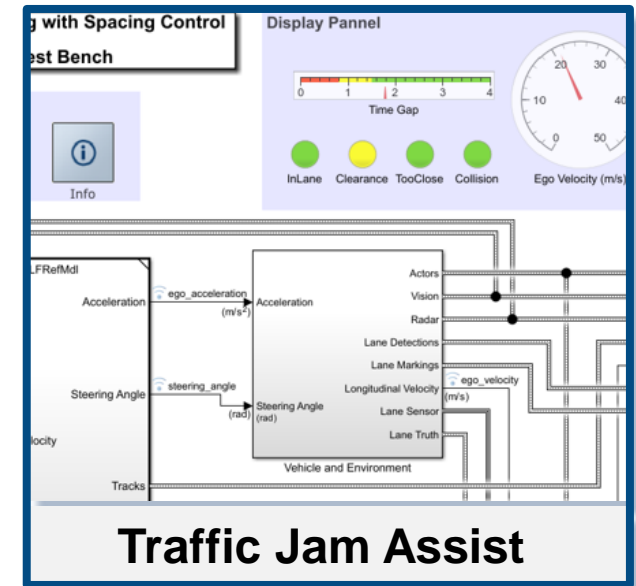


ACC

R2018a



Lane Following Control



Traffic Jam Assist

Traffic Jam Assist

- It helps drivers to follow the preceding vehicle automatically with a predefined time interval in a dense traffic condition

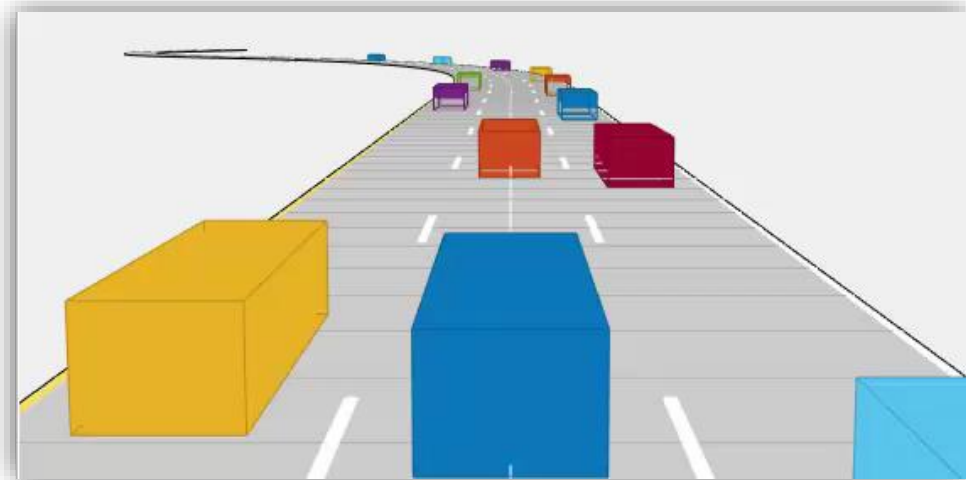


Longitudinal control with ACC with stop & go

... while controlling steering for keeping current lane.



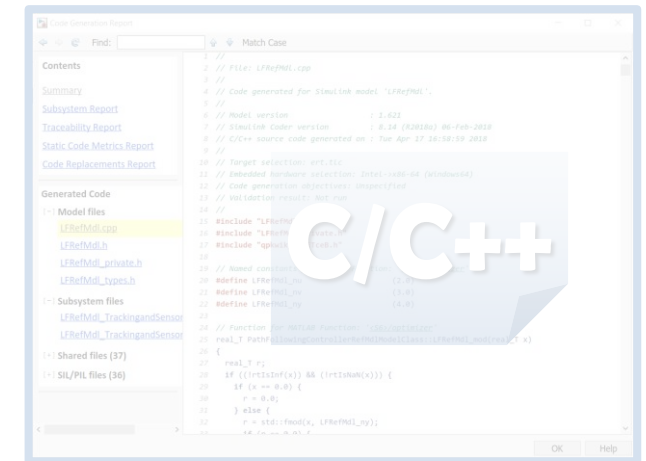
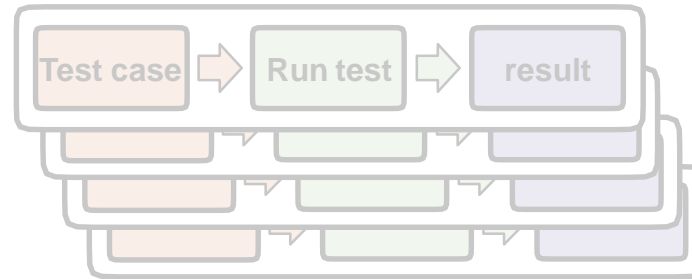
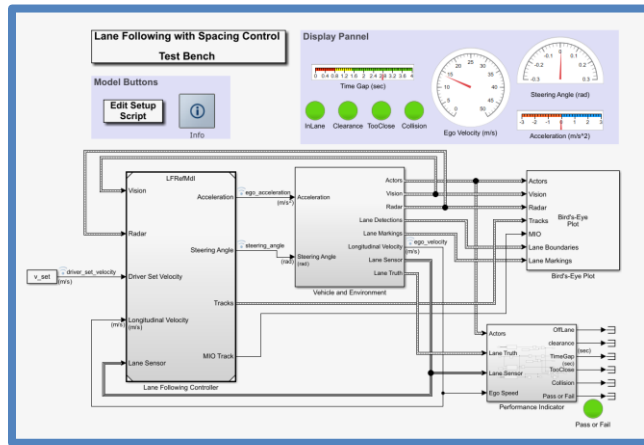
Lateral control with lane following



- Partial/conditional automation at level 2/3
 - Speed limit < 60~65 km/h
 - Dense traffic condition in highway

Automated Driving System Toolbox

Design and Test **Traffic Jam Assist**, *A Case study*



Design ACC and Lane Following Controller

- Create driving scenario
- Synthesize sensor detection
- Include Vehicle Dynamics
- Design sensor fusion algorithm
- Design controller using MPC

Automate Regression Test

- Define performance evaluation metrics
- Develop test cases
- Build test suites
- Verification and validation

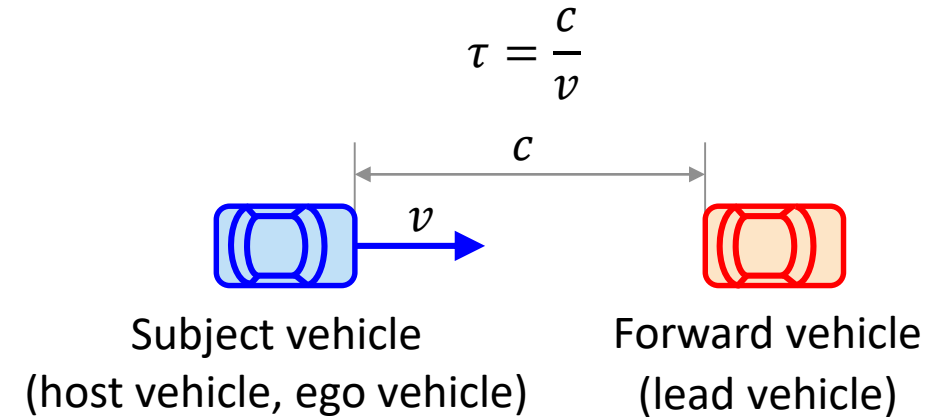
Generate and Verify Code

- SIL test
- Code generation
- Coverage test

ACC Performance Requirements

- **Ego velocity control :** $v \leq v_{set}$
where, v : ego velocity, v_{set} : set velocity

- **Time gap control:** $\tau \geq \tau_{min}$
where, $\tau = \frac{c}{v}$: time gap = 1.5 .. 2.2 sec
 τ_{min} : min time gap = 0.8 sec



- ACC operation limits
 - Minimum operational speed, $v_{min} = 5\text{m/s}$
 - Average automatic deceleration of ACC $\leq 3.5 \text{ m/s}^2$ (average over 2s)
 - Average automatic acceleration of ACC $\leq 2.0 \text{ m/s}^2$

Lane Following Performance Requirements

- Vehicle should follow the lane center with allowable lateral deviation.

$$|(d_{left} + d_{right})/2| \leq e_{max}$$

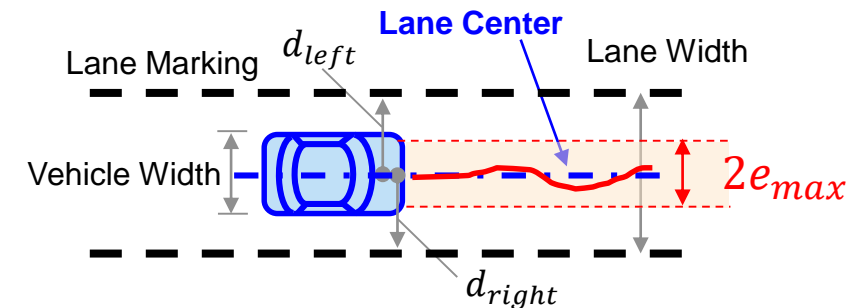
where,

d_{left} : lateral offset of left lane w.r.t. ego car

d_{right} : lateral offset of right lane w.r.t. ego car

e_{max} : allowable lateral deviation

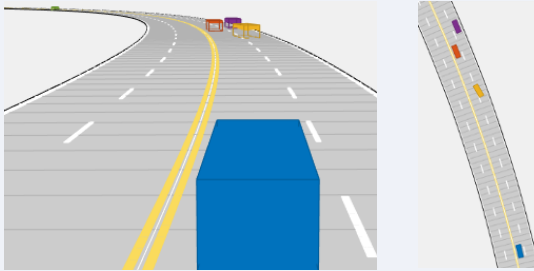
For example, $e_{max} = (LaneWidth - VehicleWidth)/2 = (3.6-1.8)/2 = 0.9$ m



Create Test Scenario using Driving Scenario Designer

Test Description

Lead car cut in and out in curved highway
(curvature of road = $1/500$ m)



Host car

initial velocity = 20.6m/s

HWT(Headway Time) to lead car = 4sec

HW(Headway) to lead car = ~80m

v_set (set velocity for ego car) = 21.5m/s

Lead Car

Initially, fast moving car (orange) at 19.4m/s

Passing car (yellow) at 19.6m/s cut in the ego path with HWT=2.3s, then cut out

Third Car

Slow moving car (purple) at 11.1m/s in the 2nd lane

Driving Scenario Designer - PFACC_05_Curve_CutInOut.mat - Scenario Canvas

DESIGNER

FILE SCENARIO SENSORS SIMULATE VIEW EXPORT

New Open Save Add Road Add Actor Add Camera Add Radar Go to Start Step Back Run Step Forward Settings Repeat Default Layout Export

Roads Actors Scenario Canvas Ego Centric View

Road: 1
Name:
Width (m): 14.7
Bank Angle (deg): 0

Lanes
Number of lanes: [2 2]
Lane Width (m): 3.6
Marking: 1.Solid

Road Centers

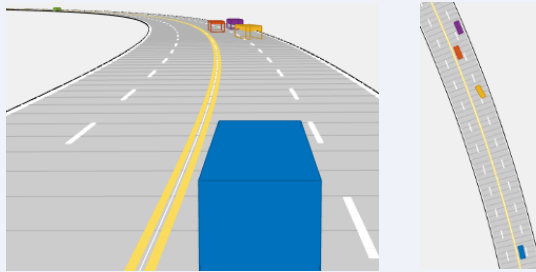
	x (m)	y (m)	z (m)
1	0	-500	
2	34.8782	-498.7820	
3	69.5866	-495.1340	
4	103.9558	-489.0738	
5	137.8187	-480.6308	
6	171.0101	-469.8463	
7	203.3683	-456.7727	
8	234.7358	-441.4738	
9	264.9596	-424.0240	
10	293.8926	-404.5085	

X (m)
Y (m)

Simulation with Simulink Model for Traffic Jam Assist

Test Description

Lead car cut in and out in curved highway
(curvature of road = $1/500$ m)



Host car

initial velocity = 20.6m/s
 HWT(Headway Time) to lead car = 4sec
 HW(Headway) to lead car = $\sim 80\text{m}$
 v_set (set velocity for ego car) = 21.5m/s

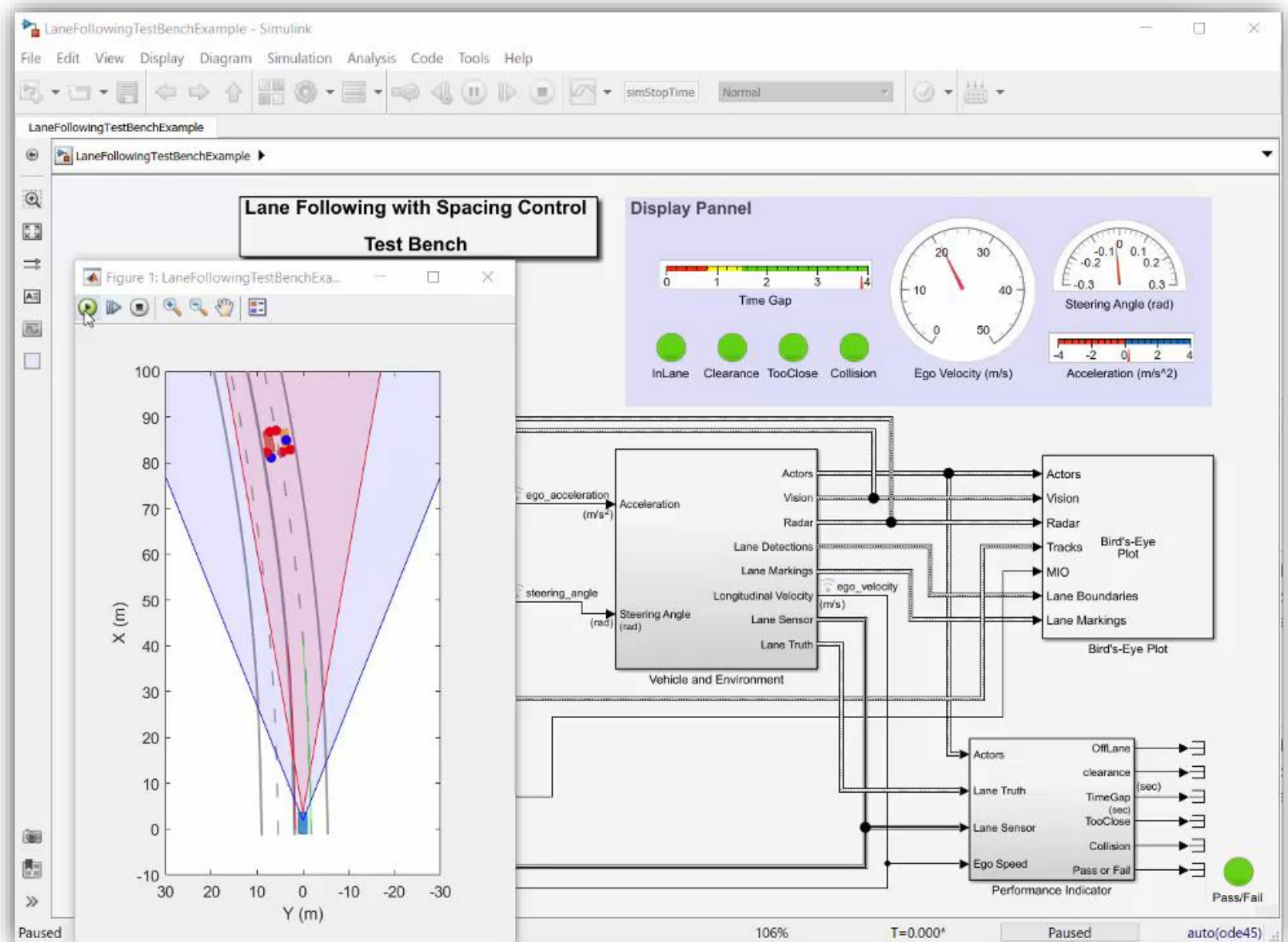
Lead Car

Initially, fast moving car (orange) at 19.4m/s

Passing car (yellow) at 19.6m/s cut in the ego path with $\text{HWT}=2.3\text{s}$, then cut out

Third Car

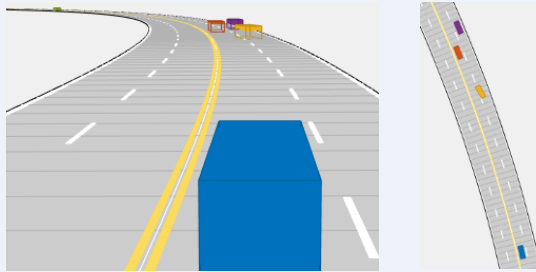
Slow moving car (purple) at 11.1m/s in the 2nd lane



Simulation with Simulink Model for Traffic Jam Assist

Test Description

Lead car cut in and out in curved highway (curvature of road = 1/500 m)



Host car

initial velocity = 20.6m/s

HWT(Headway Time) to lead car = 4sec

HW(Headway) to lead car = ~80m

v_set(set velocity for ego car) = 21.5m/s

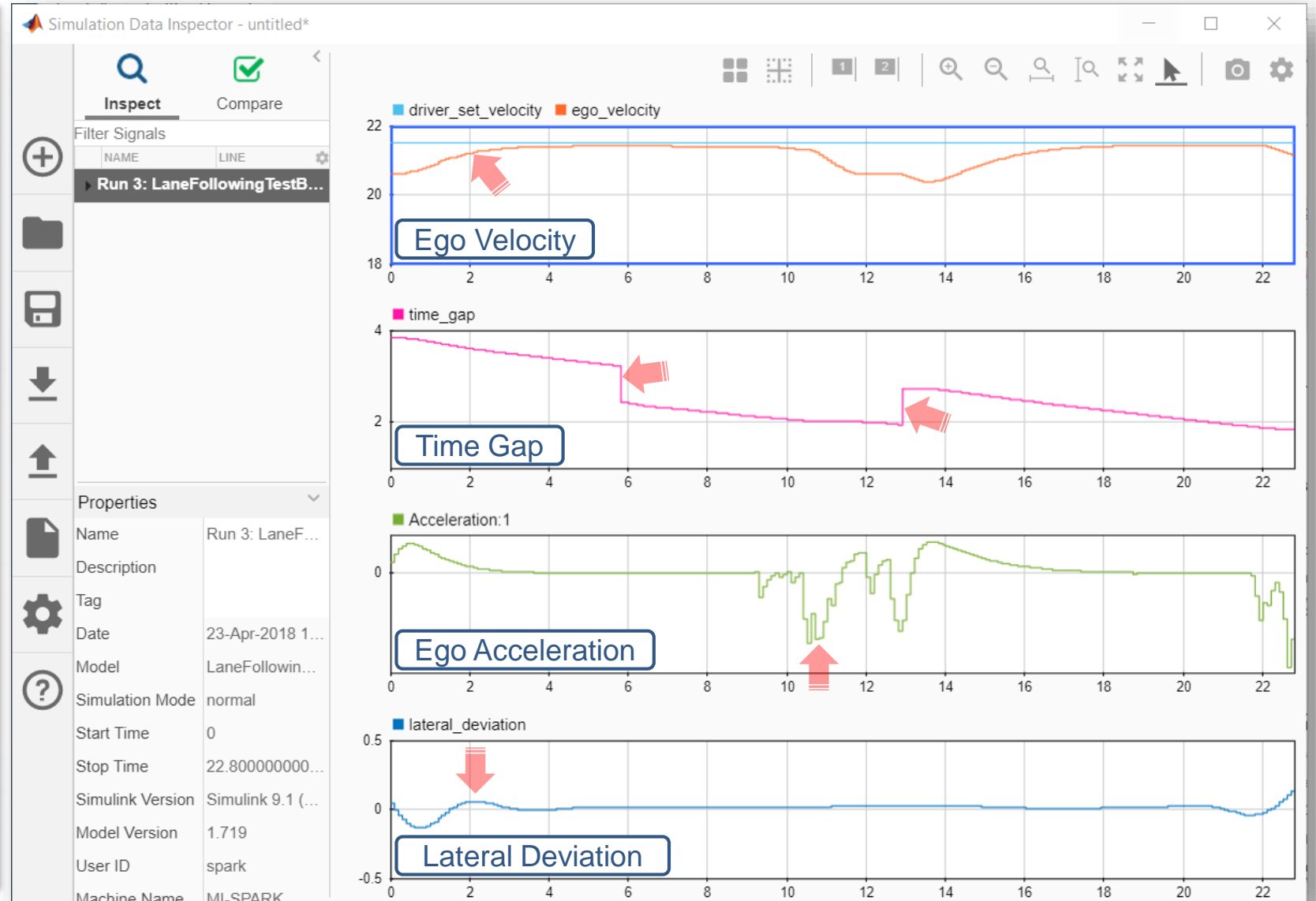
Lead Car

Initially, fast moving car (orange) at 19.4m/s

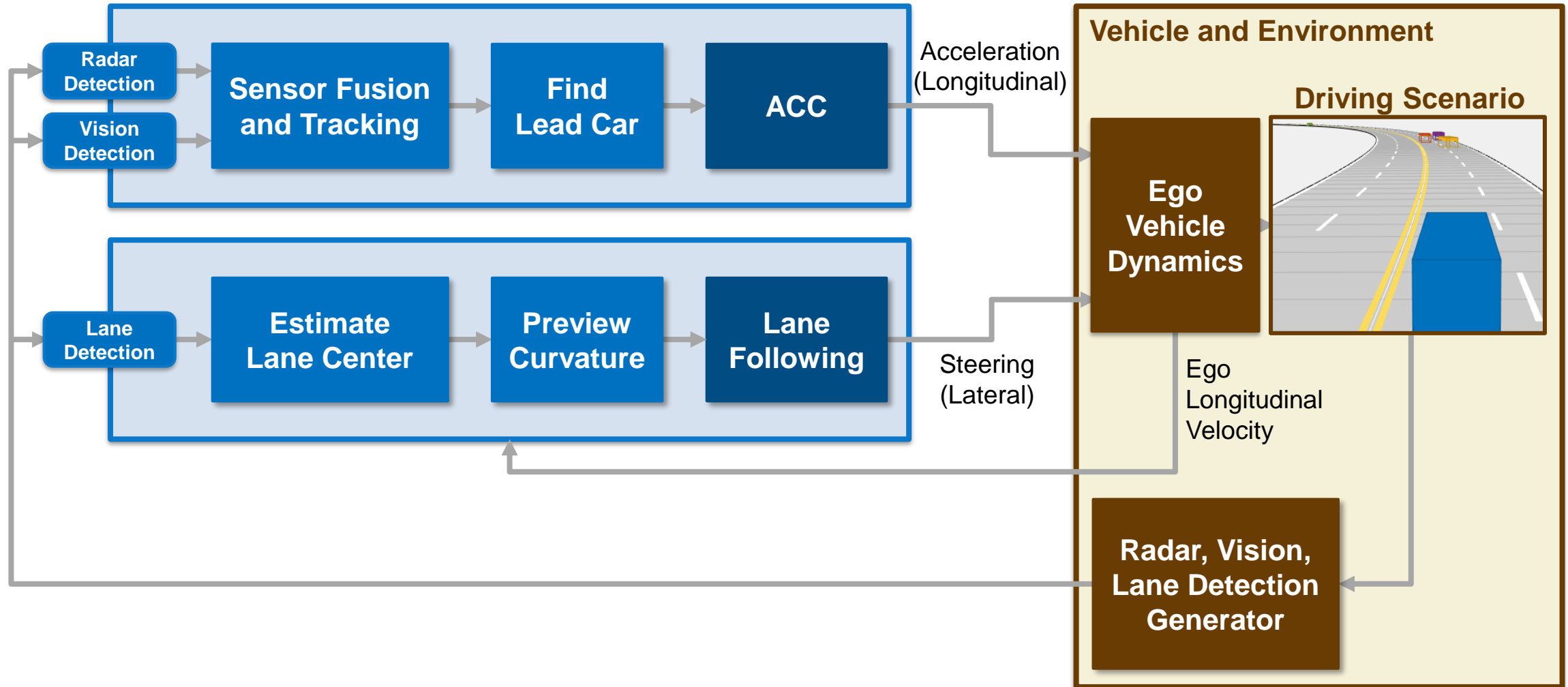
Passing car (yellow) at 19.6m/s cut in the ego path with HWT=2.3s, then cut out

Third Car

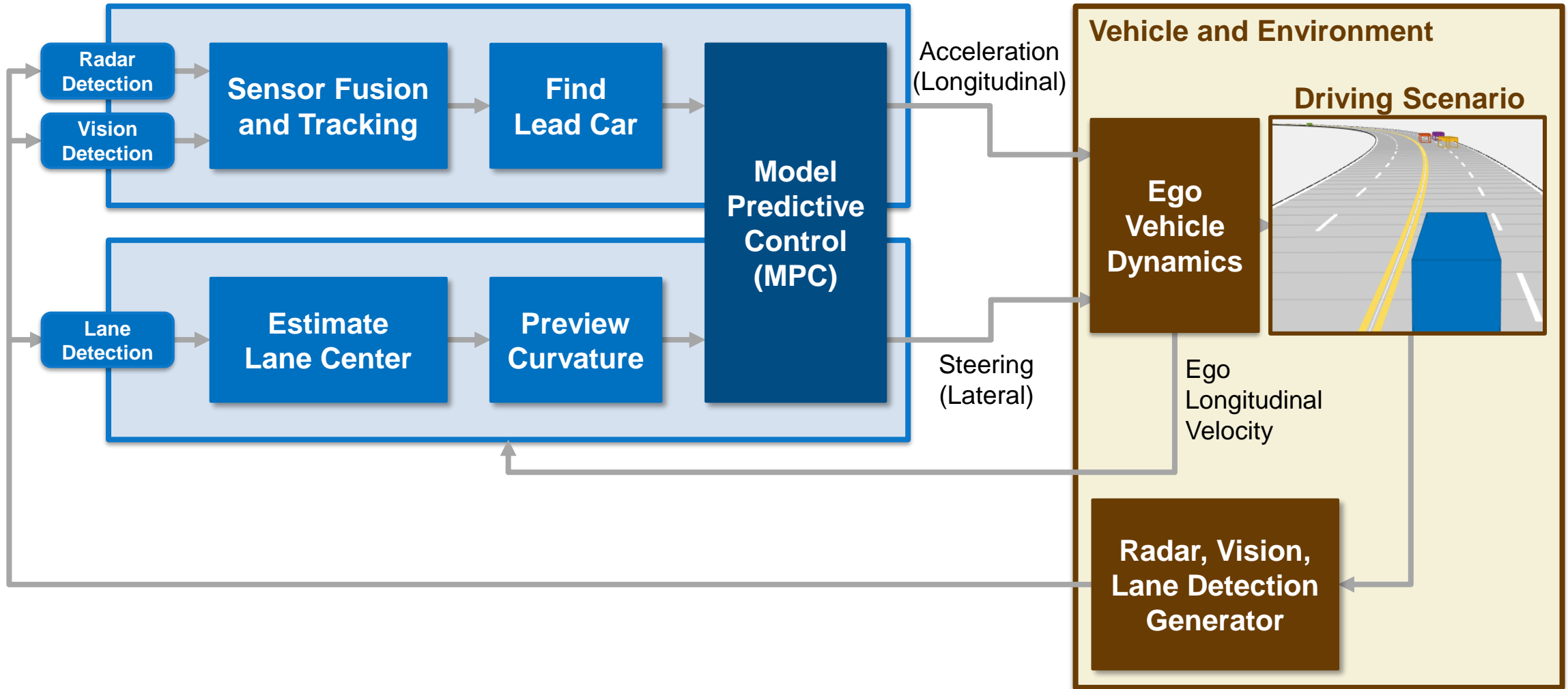
Slow moving car (purple) at 11.1m/s in the 2nd lane



Architecture for ACC and Lane Following Controller

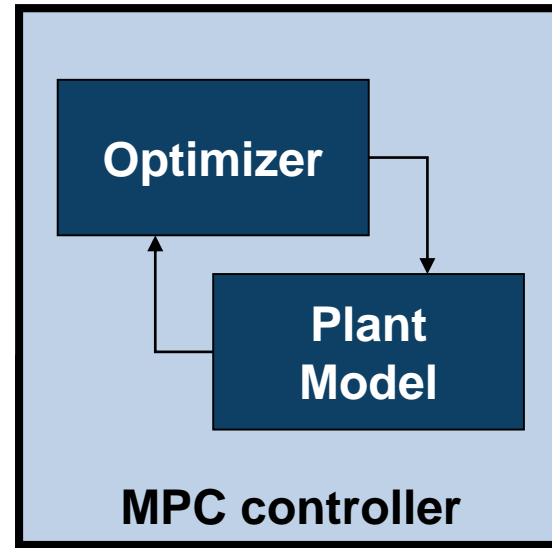


Architecture for ACC and Lane Following Controller



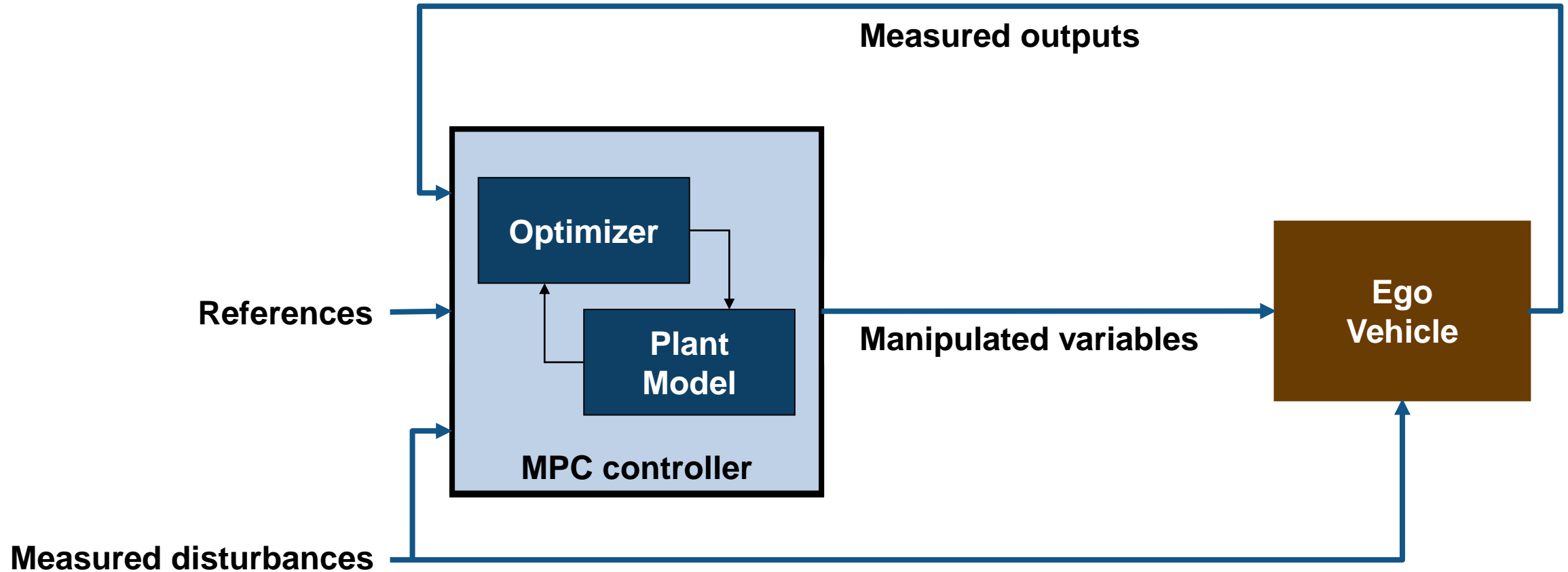
What is model predictive control (MPC)?

- **Multi-variable control** strategy leveraging an internal model to predict plant behavior in the near future
- **Optimizes** for the current timeslot while keeping future timeslots in account



- **Mature** control solution used in industrial applications
- **Gaining popularity in automated driving** applications to improve vehicle responsiveness while maintaining passenger comfort

What is model predictive control (MPC)?



How can MPC be applied to ACC and lane following control?

minimize:

$$w_1 |V_{ego} - V_{set}|^2 + w_2 |E_{lateral}|^2$$

References

- Ego velocity set point (V_{set})
- Target lateral deviation (=0)

Measured disturbances

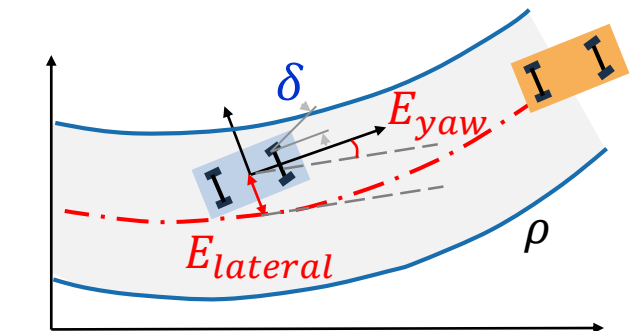
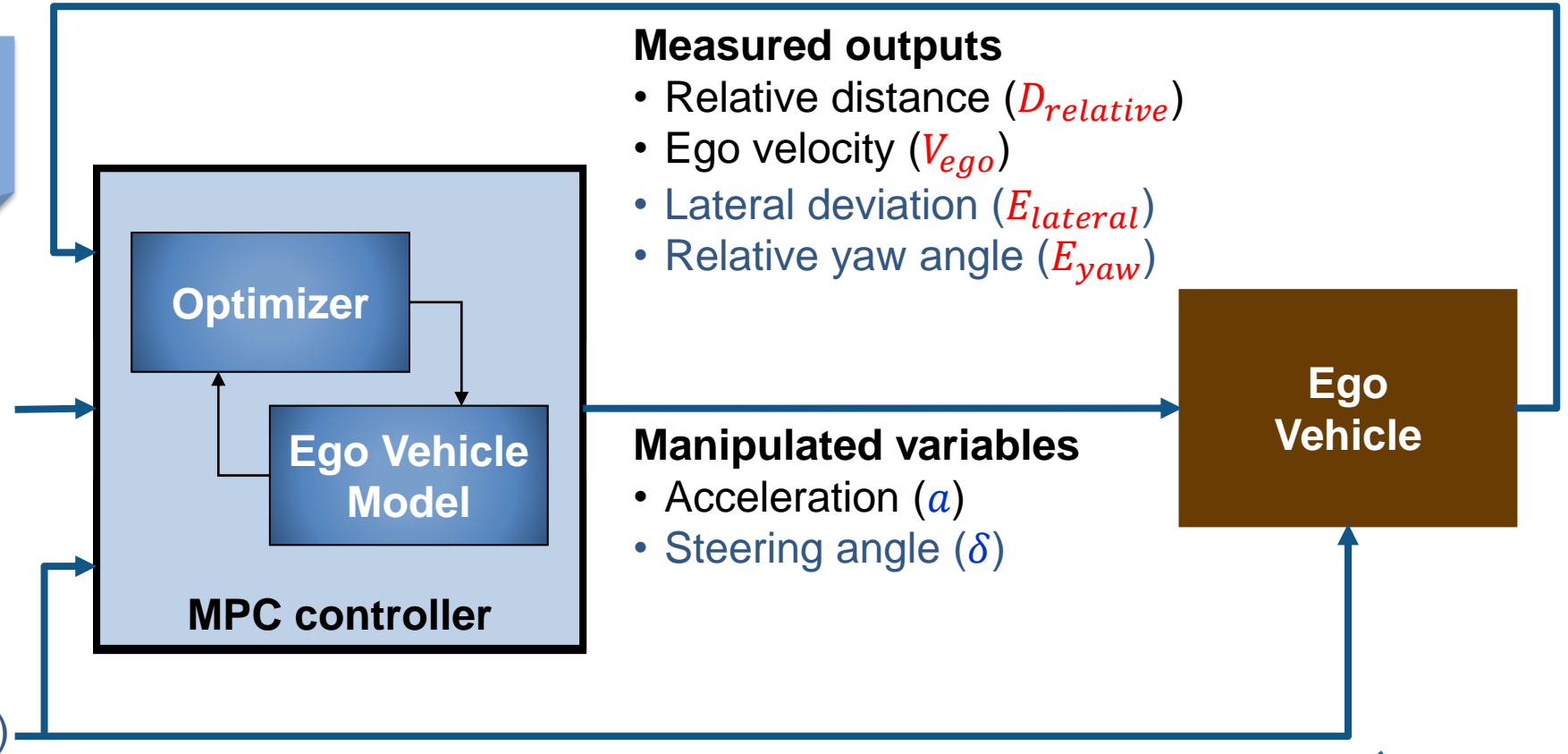
- MIO velocity (V_{mio})
- Previewed road curvature (ρ)

subject to:

$$D_{relative} \geq D_{safe}$$

$$a_{min} \leq a \leq a_{max}$$

$$\delta_{min} \leq \delta \leq \delta_{max}$$



Internal MPC model for ACC and Lane Following Controller



Longitudinal model for ACC

$$\begin{pmatrix} D_{relative} \\ V_{ego} \\ E_{lateral} \\ E_{yaw} \end{pmatrix} = sys \begin{pmatrix} a \\ V_{mio} \\ \delta \\ \rho \end{pmatrix}$$

Measured outputs (OV)

- Relative distance ($D_{relative}$)
- Ego velocity (V_{ego})
- Lateral deviation ($E_{lateral}$)
- Relative yaw angle (E_{yaw})

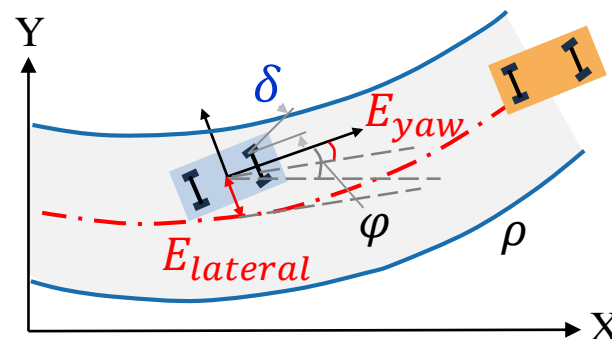
Manipulated variables (MV)

- Acceleration (a)
- Steering angle (δ)

Measured disturbance (MD)

- MIO velocity (V_{mio})
- Previewed road curvature (ρ)

Lateral model for Lane Following



Longitudinal and Lateral Model for MPC

- Longitudinal Model for ACC

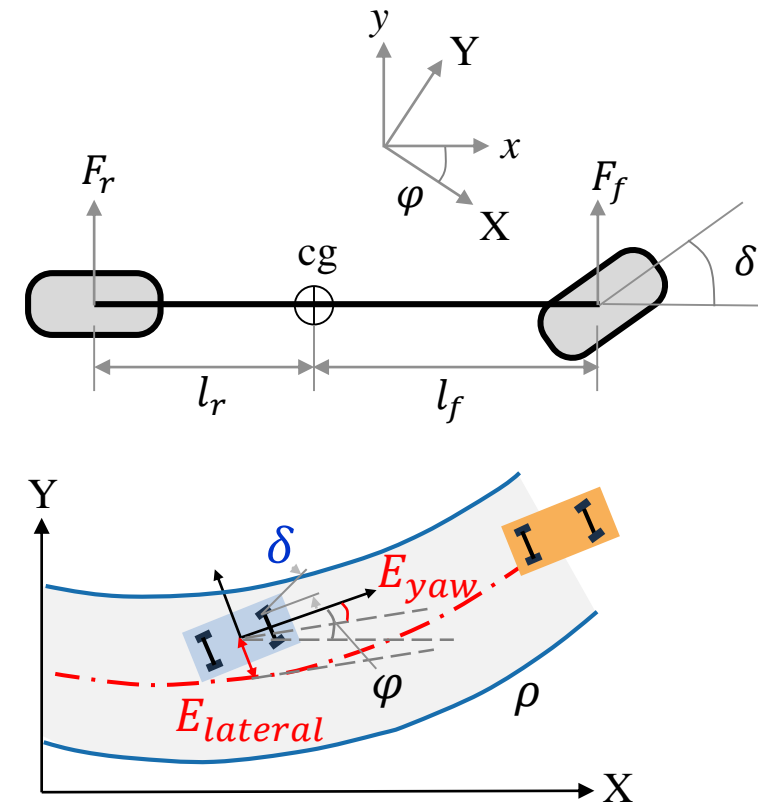
$$\frac{d}{dt} \begin{bmatrix} \dot{V}_x \\ V_x \\ D_{relative} \end{bmatrix} = \begin{bmatrix} -\frac{1}{\tau} & 0 & 0 \\ 1 & 0 & 0 \\ 0 & -1 & 0 \end{bmatrix} \begin{bmatrix} \dot{V}_x \\ V_x \\ D_{relative} \end{bmatrix} + \begin{bmatrix} \frac{1}{\tau} & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} a \\ V_{mio} \end{bmatrix}$$

$$\begin{bmatrix} D_{relative} \\ V_x \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} \dot{V}_x \\ V_x \\ D_{relative} \end{bmatrix}$$

- Lateral Model for Lane Following

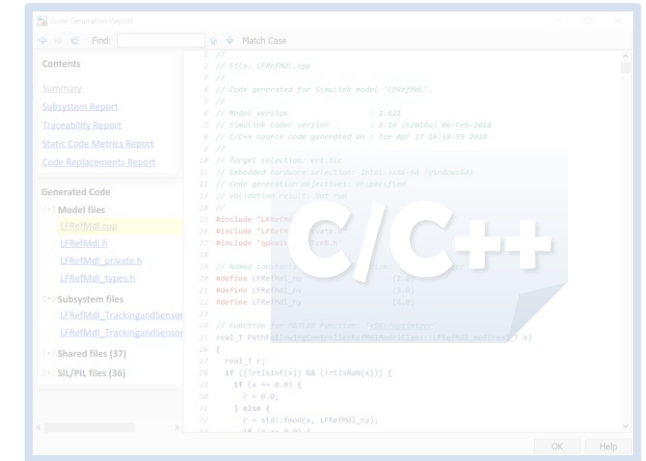
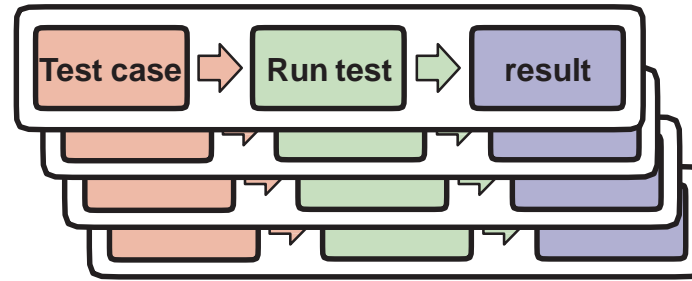
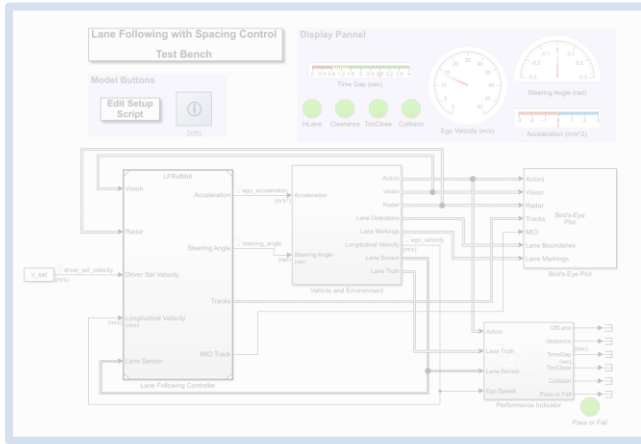
$$\frac{d}{dt} \begin{bmatrix} V_y \\ \dot{\phi} \\ E_{lateral} \\ E_{yaw} \end{bmatrix} = \begin{bmatrix} -\frac{2C_f + 2C_r}{mV_x} & -V_x - \frac{2C_f l_f - 2C_r l_r}{mV_x} & 0 & 0 \\ \frac{2C_f l_f - 2C_r l_r}{I_z V_x} & -\frac{2C_f l_f^2 + 2C_r l_r^2}{I_z V_x} & 0 & 0 \\ 1 & 0 & 0 & V_x \\ 0 & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} V_y \\ \dot{\phi} \\ E_{lateral} \\ E_{yaw} \end{bmatrix} + \begin{bmatrix} \frac{2C_f}{m} & 0 \\ \frac{2C_f l_f}{I_z} & 0 \\ 0 & 0 \\ 0 & -1 \end{bmatrix} \begin{bmatrix} \delta \\ V_x \rho \end{bmatrix}$$

$$\begin{bmatrix} E_{lateral} \\ E_{yaw} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} V_y \\ \dot{\phi} \\ E_{lateral} \\ E_{yaw} \end{bmatrix}$$



Automated Driving System Toolbox

Design and Test **Traffic Jam Assist**, *A Case study*



Design ACC and Lane Following Controller

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- Include Vehicle Dynamics
- Design sensor fusion algorithm
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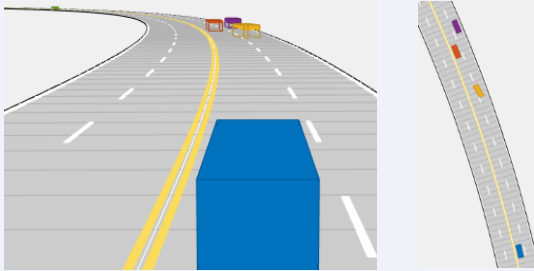
Generate and Verify Code

- SIL test
- Code generation
- Coverage test

Simulation result assessment

Test Description

Lead car cut in and out in curved highway
(curvature of road = 1/500 m)



Host car

initial velocity = 20.6m/s
HWT(Headway Time) to lead car = 4sec
HW(Headway) to lead car = ~80m
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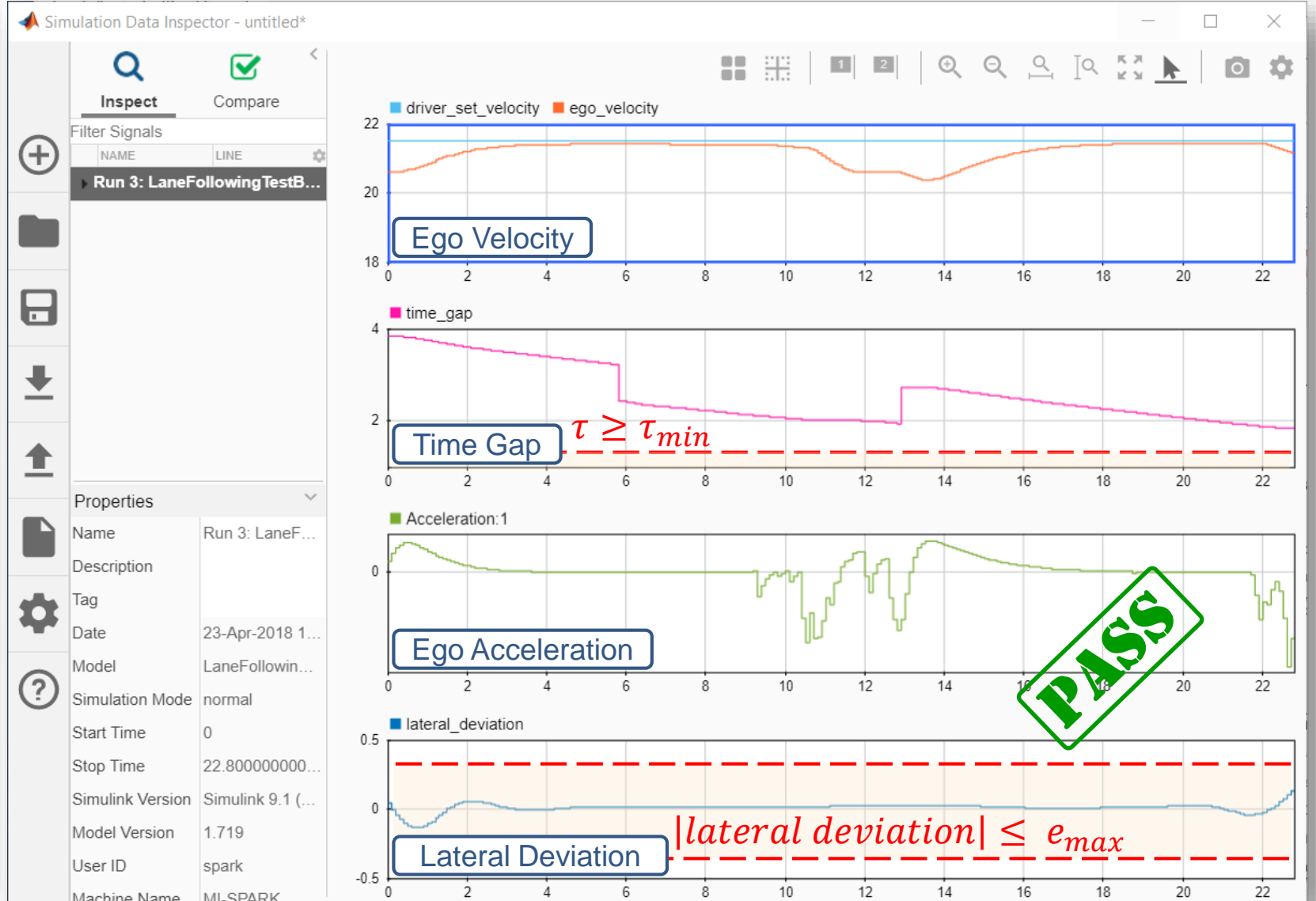
Lead Car

Initially, fast moving car (orange) at 19.4m/s

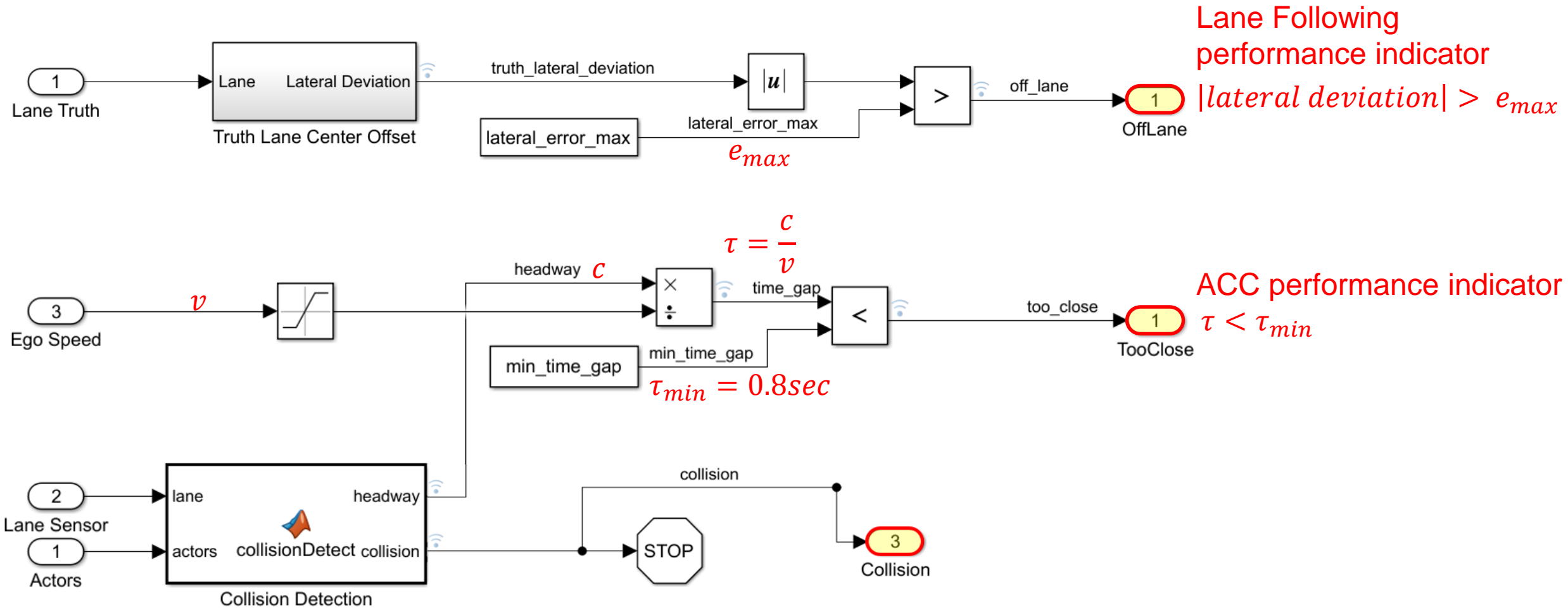
Passing car (yellow) at 19.6m/s cut in the ego path with HWT=2.3s, then cut out

Third Car

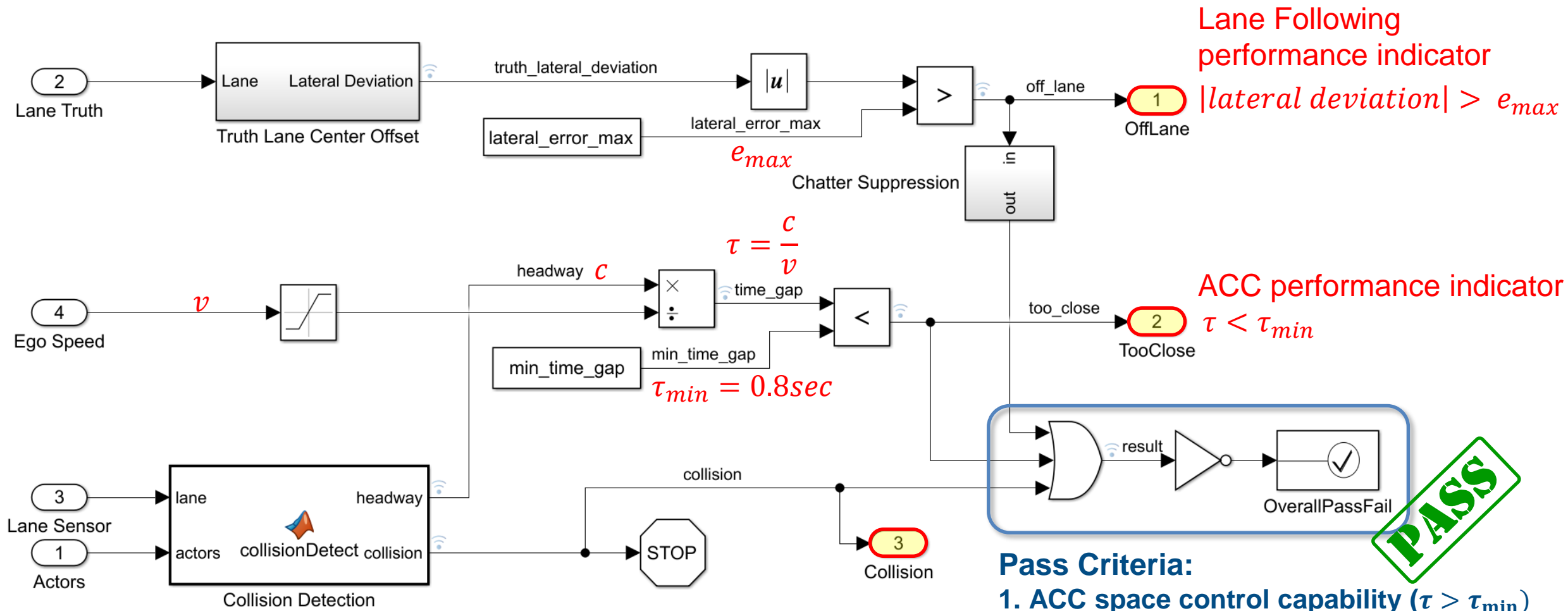
Slow moving car (purple) at 11.1m/s in the 2nd lane



Performance Indicator

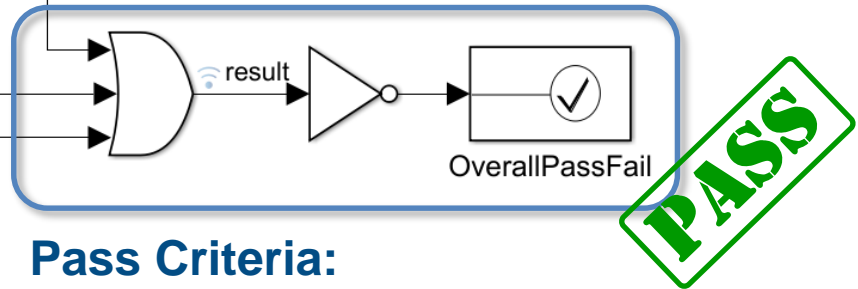


Performance Indicator



Lane Following performance indicator
 $|lateral\ deviation| > e_{max}$

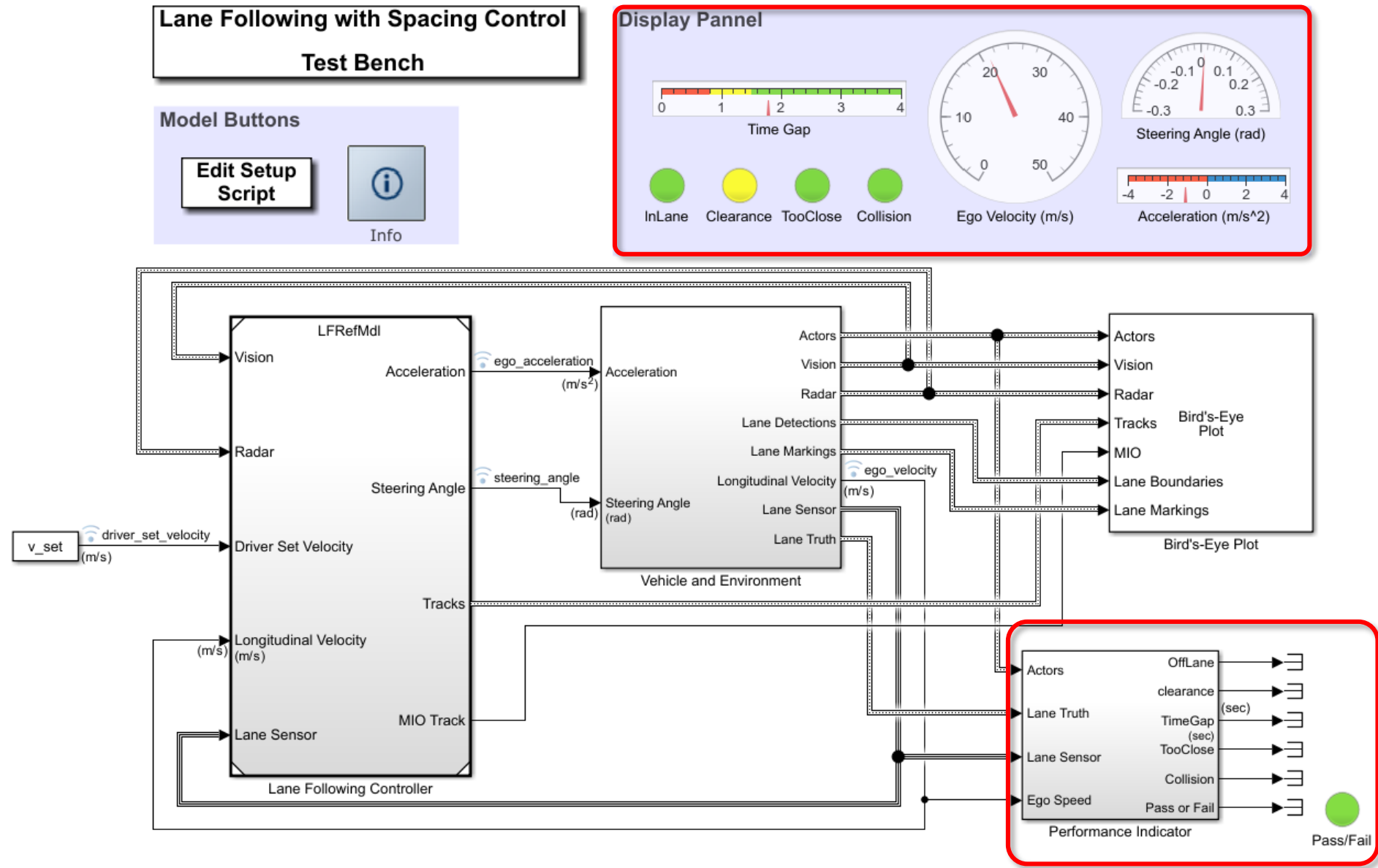
ACC performance indicator
 $\tau < \tau_{min}$



- Pass Criteria:**
1. ACC space control capability ($\tau > \tau_{min}$)
 2. Lane following capability
 3. No collision detected

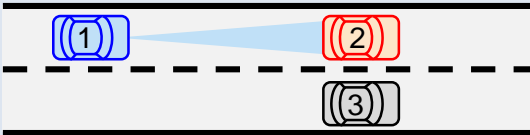
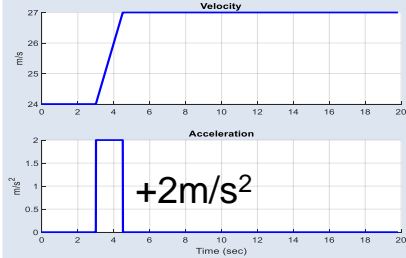
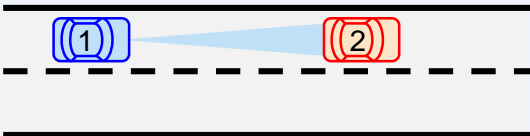
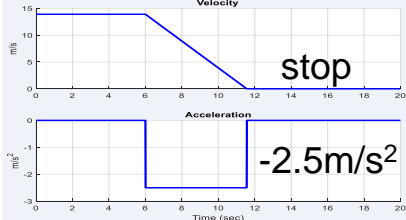
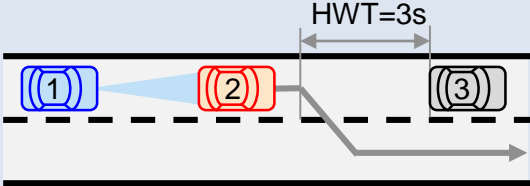


Performance indicator and dashboard in Simulink model



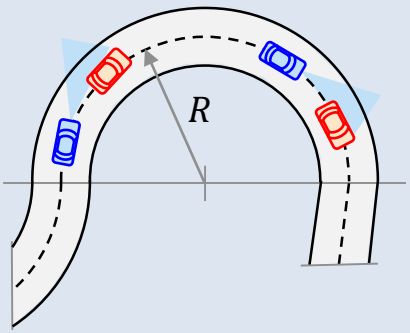
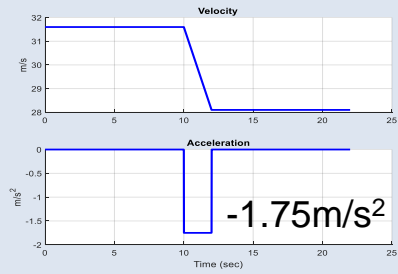
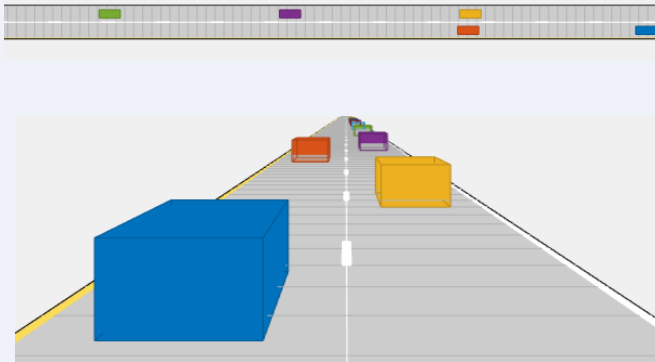
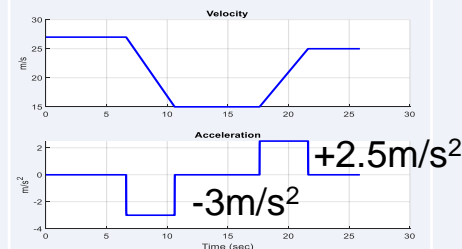
Test scenarios (1/4)

HW : Headway
 HWT : Headway time
 v_set : set velocity for ego car

No	Test Name	Test Description	Host car	Lead car	Third car	Spec
1	ACC_01_ISO _TargetDiscriminationTest	Target Discrimination Test 	initial velocity = 30m/s HWT = 2.2sec (HW = 66m) v_set = 30m/s	constant accel 24m/s → 27m/s @ 2m/s ² V _{end} = 27m/s (97.2kph) 	24m/s	ISO 15622 ISO 22178
2	ACC_02_ISO _AutoDecelTest	Automatic Deceleration Test 	initial velocity = 15m/s HWT = 2.2sec (HW = 33m) v_set = 15m/s	initial velocity = 13.9m/s decelerates to full stop with 2.5m/s ² 	none	ISO 22178
3	ACC_03_ISO _AutoRetargetTest	Automatic Retargeting Capability Test 	initial velocity = 15m/s HWT = 2.2sec (HW = 33m) v_set = 15m/s	initial velocity = 13.9m/s Lead car changes lane @ HWT=3s to overtake slow moving car	constant speed = 2.1m/s	ISO 22178

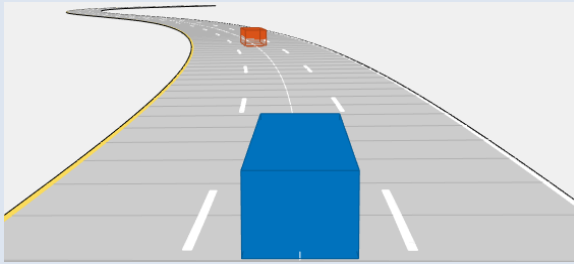
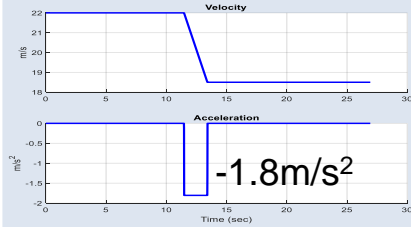
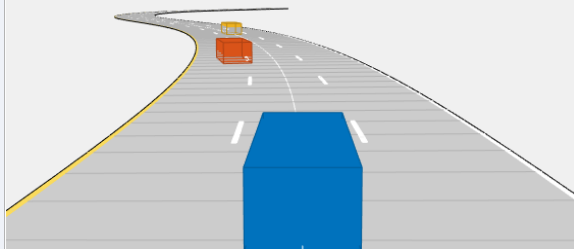
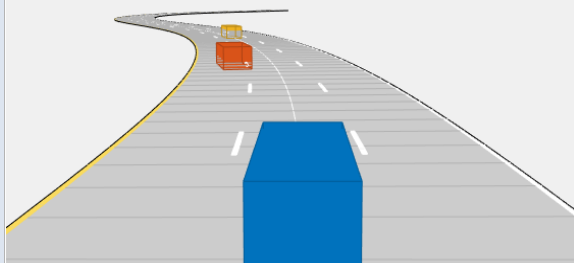
Test scenarios (2/4)

HW : Headway
 HWT : Headway time
 v_set : set velocity for ego car

No	Test Name	Test Description	Host car	Lead car	Third car	Spec
4	ACC_04_ISO_CurveTest	Curve Capability Test (curvature of test track = 1/500 m) 	initial velocity = 31.6m/s HWT = 1.5sec (HW = 47.4m) v_set = 31.6m/s	initial velocity = 31.6m/s Drive at a constant speed for 10s, decrease speed by 3.5m/s in 2s, and keep it constant. 	none	ISO 15622 ISO 22178
5	ACC_05_StopnGo	Stop and Go in highway 	initial velocity = 27m/s HWT = 1.5sec (HW = 40.5m) v_set = 27m/s	initial velocity = 27m/s Lead car slows down to 15m/s at -3m/s ² and stay constant for 7s, then speed up to 25m/s at 2.5m/s ² 	8 slow moving cars at 12m/s in the second lane	Real-world scenario

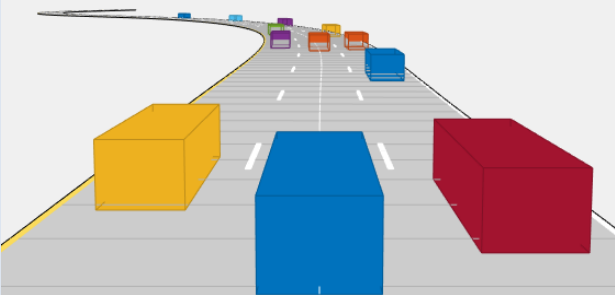
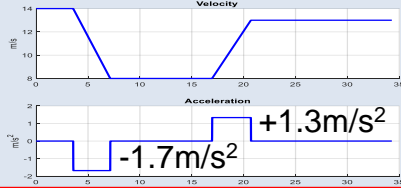
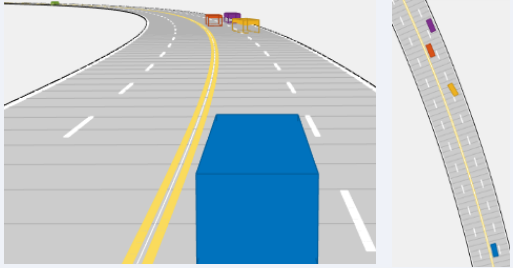
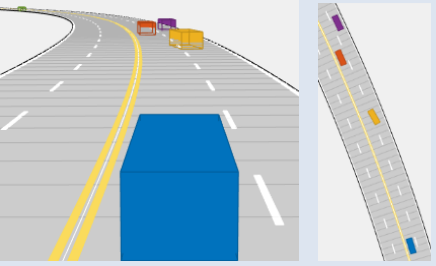
Test scenarios (3/4)

HW : Headway
 HWT : Headway time
 v_set : set velocity for ego car

No	Test Name	Test Description	Host car	Lead car	Third car	Spec
6	LFACC_01_DoubleCurve_DecelTarget (Similar with ACC_04_ISO_CurveTest)	Automatic Deceleration Test 	initial velocity = 22m/s HWT = 2sec (HW = 44m) v_set = 22m/s	initial velocity = 22m/s Drive at a constant speed for about 11s, decrease speed by 3.5m/s in 2s (deceleration: -1.8 m/s^2) and keep it const. 	none	Real-world scenario
7	LFACC_02_DoubleCurve_AutoRetarget_TooSlow (Similar with ACC_03_ISO_AutoRetargetTest)	Automatic Retargeting Capability Test 	initial velocity = 15m/s HWT = 2.8sec (HW = 43m) v_set = 15m/s	initial velocity = 13.9m/s Lead car changes lane @ HWT=3s to overtake slow moving car	Slow moving car at constant speed = 2.1m/s	~ISO 22178
8	LFACC_03_DoubleCurve_AutoRetarget (Similar with ACC_03_ISO_AutoRetargetTest)	Automatic Retargeting Capability Test 	initial velocity = 15m/s HWT = 2.8sec (HW = 43m) v_set = 15m/s	initial velocity = 13.9m/s Lead car changes lane @ HWT=3s to overtake slow moving car	Slow moving car at constant speed = 10m/s	~ISO 22178

Test scenarios (4/4)

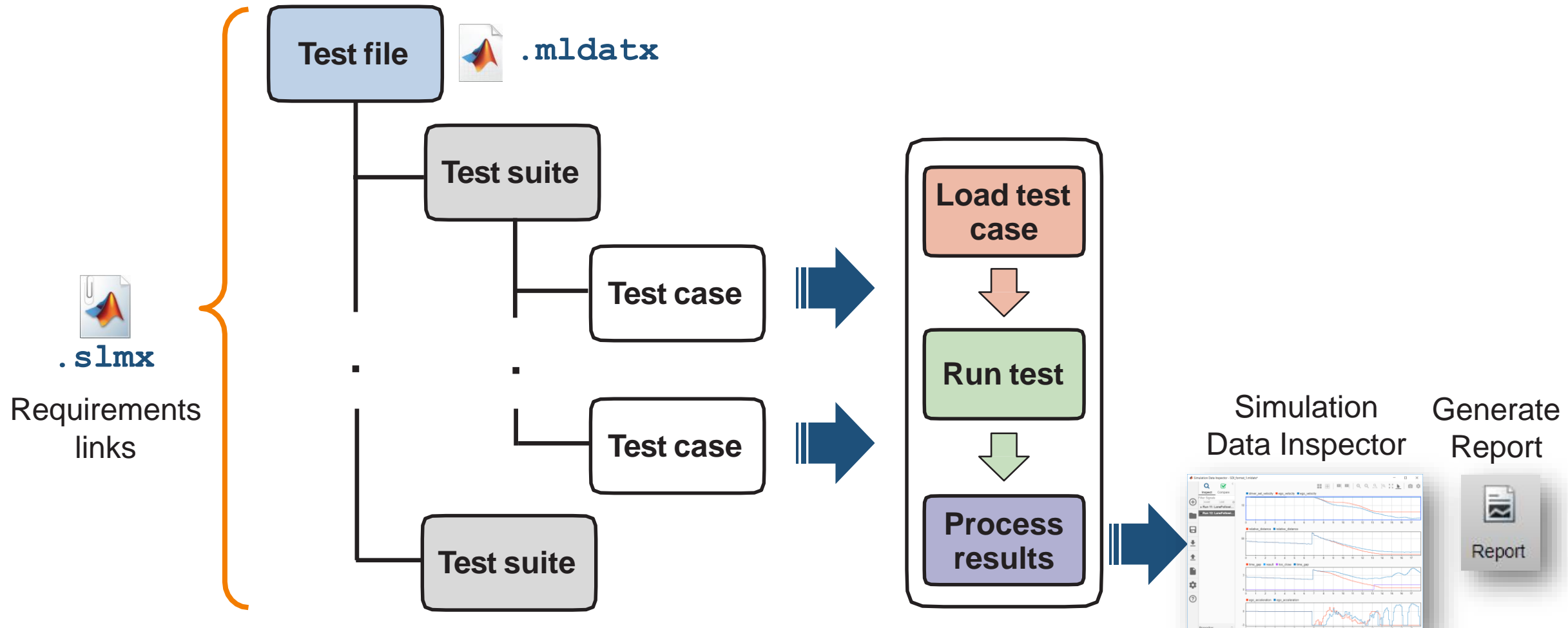
HW : Headway
 HWT : Headway time
 v_set : set velocity for ego car

No	Test Name	Test Description	Host car	Lead car	Third car	Spec
9	LFACC_04_DoubleCurve_StopnGo (Similar with ACC_05_StopnGo)	Stop and Go in curved highway 	initial velocity = 14m/s HWT = 3.6sec (HW = 50m) v_set = 14m/s	initial velocity = 14m/s Lead car slows down to 8m/s at 8m/s in the 3 rd lane at -1.7m/s ² and stay constant for 10s, then speed up to 13m/s at 1.3m/s ² 	10 slow moving cars 3 fast moving cars at 15m/s in the 1 st lane	Real-world scenario
10	LFACC_05_Curve_CutInOut	Lead car cut in and out in curved highway (curvature of road = 1/500 m) 	initial velocity = 20.6m/s HWT = 4sec (HW = ~80m) v_set = 21.5m/s	Initially, fast moving car (orange) at 19.4m/s Passing car (yellow) at 19.6m/s cut in the ego path with HWT=2.3s, then cut out	Slow moving car (purple) at 11.1m/s in the 2 nd lane	Real-world scenario
11	LFACC_06_Curve_CutInOut_TooClose	Lead car cut in and out in curved highway (curvature of road = 1/500 m) 	initial velocity = 20.6m/s HWT = 4sec (HW = ~80m) v_set = 21.5m/s	Initially, fast moving car (orange) at 19.4m/s Passing car (yellow) at 19.6m/s cut in the ego path with HWT=1.5s, then cut out	Slow moving car (purple) at 11.1m/s in the 2 nd lane	Real-world scenario

Representative test scenario

Test Manager in Simulink® Test™

- Automate Simulink model testing using test cases with pass-fail criteria



Test Report with baseline parameter set for 11 test cases

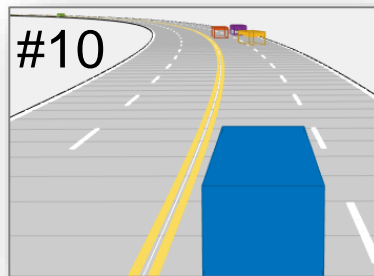
Report Generated by Test Manager

Title: ACCAndLaneFollowing (baseline)
Author: Seo-Wook Park
Date: 21-Apr-2018 16:01:50

Test Environment

Platform: PCWIN64
MATLAB: (R2018a)

Note) Baseline parameter set was tuned based on a single test scenario.



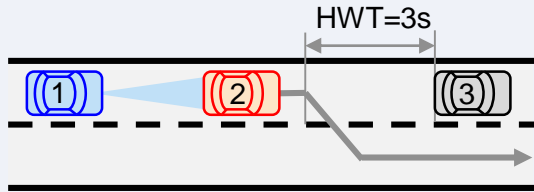
Summary

Name	Outcome	Duration (Seconds)
TestScenarios Baseline	8 ✓ 3 ✗	565
ACCTest	3 ✓ 2 ✗	210
ACC 01 ISO TargetDiscriminationTest	✓	35
ACC 02 ISO AutoDecelTest	✗	22
ACC 03 ISO AutoRetargetTest	✗	32
ACC 04 ISO CurveTest	✓	43
ACC 05 StopnGo	✓	73
LFACCTest	5 ✓ 1 ✗	354
LFACC 01 DoubleCurve DecelTarget	✓	43
LFACC 02 DoubleCurve AutoRetarget TooS low	✗	36
LFACC 03 DoubleCurve AutoRetarget	✓	65
LFACC 04 DoubleCurve StopnGo	✓	111
LFACC 05 Curve CutInOut	✓	48
LFACC 06 Curve CutInOut TooClose	✓	49

Fine-tune control parameters (1/3)

Test Description

Automatic Retargeting Capability Test



Host car

initial velocity = 15m/s

HWT = 2.2sec (HW = 33m)

v_set = 15m/s

Lead Car

initial velocity = 13.9m/s

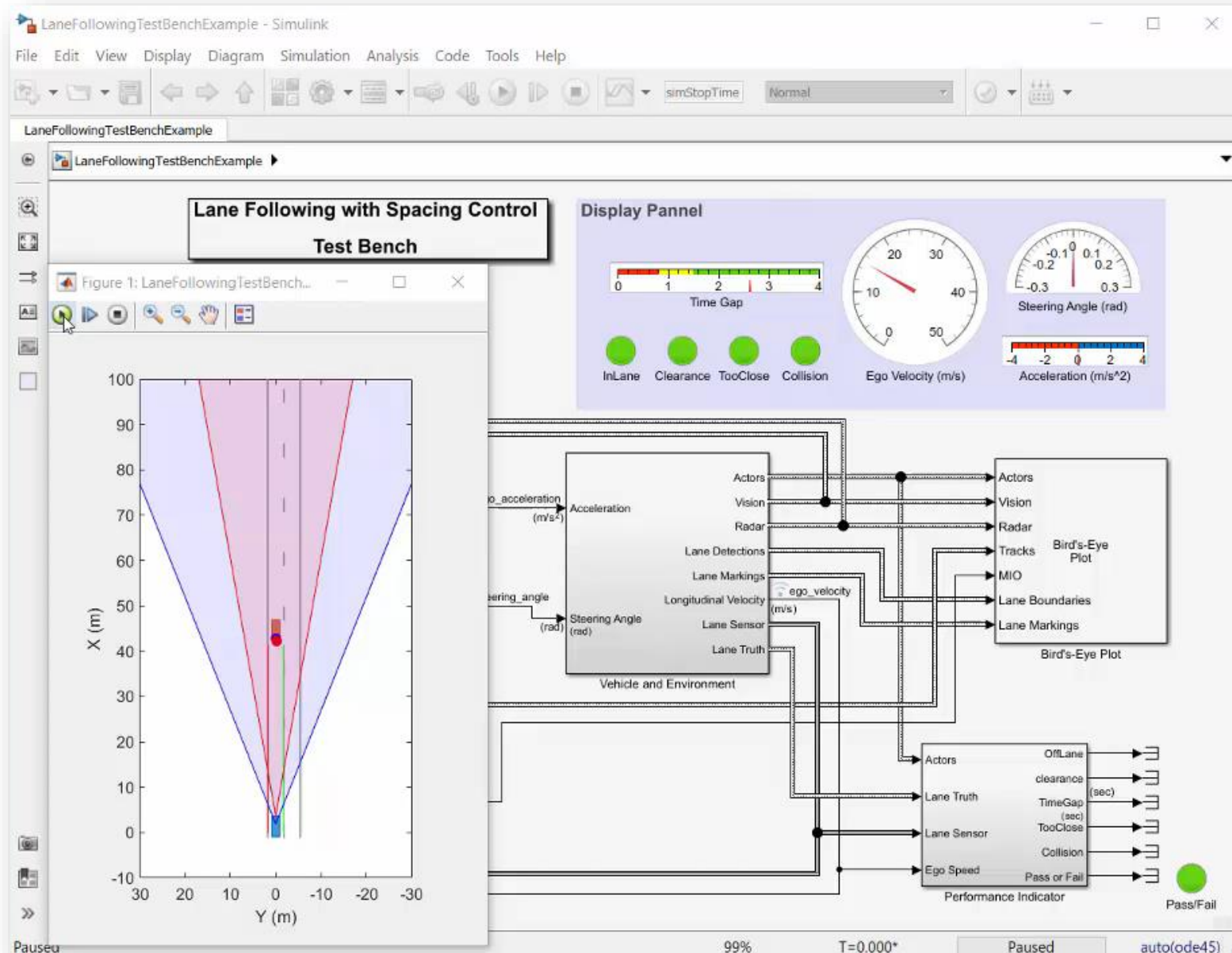
Lead car changes lane @ HWT=3s to overtake slow moving car

Third Car

constant speed = 2.1m/s

Spec

ISO 22178



Fine-tune control parameters (1/3)

Test Description
Automatic Retargeting Capability Test

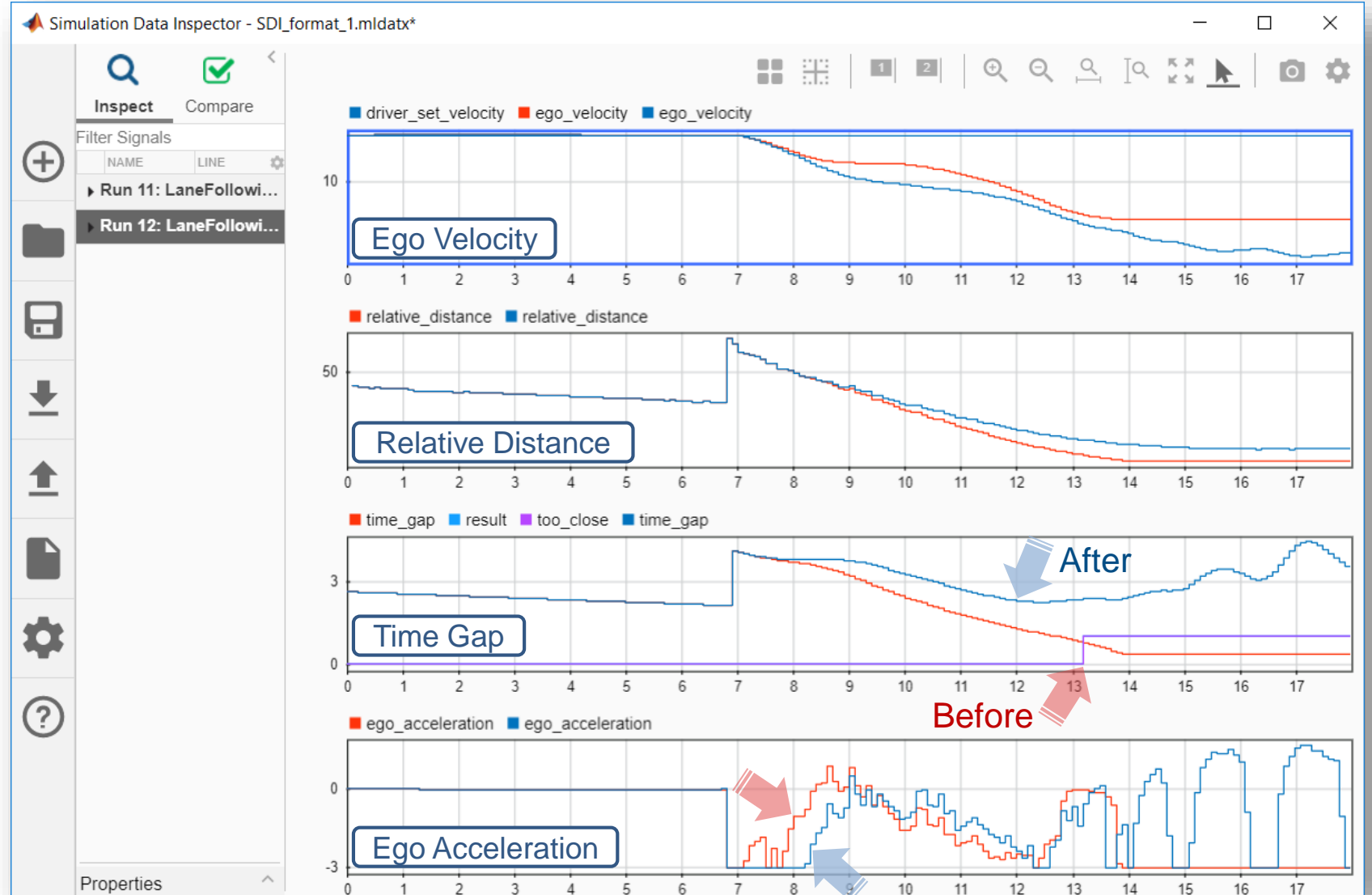
Host car
 initial velocity = 15m/s
 HWT = 2.2sec (HW = 33m)
 v_set = 15m/s

Lead Car
 initial velocity = 13.9m/s

Lead car changes lane @ HWT=3s to overtake slow moving car

Third Car
 constant speed = 2.1m/s

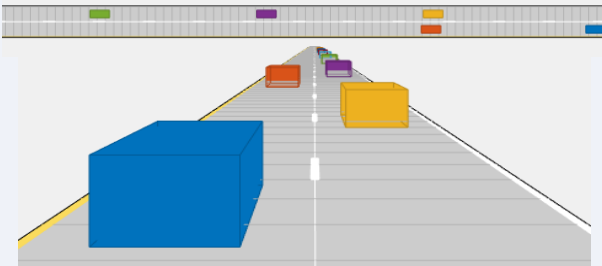
Spec
 ISO 22178



Fine-tune control parameters (2/3)

Test Description

Stop and Go in highway



Host car

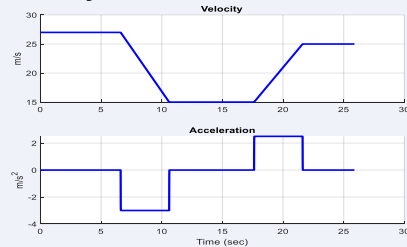
initial velocity = 27m/s

HWT = 1.5sec (HW = 40.5m)

v_set = 27m/s

Lead Car

initial velocity = 27m/s



Third Car

8 slow moving cars at 12m/s

in the second lane

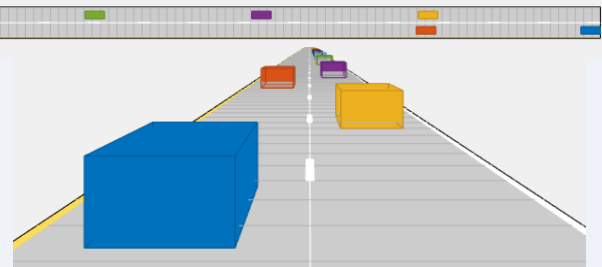
Spec

Real-world scenario

The screenshot displays the Simulink environment for the 'LaneFollowingTestBenchExample'. The main workspace shows a 'Lane Following with Spacing Control Test Bench' block. To its right is a 'Display Panel' with four gauges: 'Time Gap' (0-4), 'Steering Angle (rad)' (-0.3 to 0.3), 'Ego Velocity (m/s)' (0-50), and 'Acceleration (m/s^2)' (-4 to 4). Below these are four indicator lights labeled 'InLane', 'Clearance', 'TooClose', and 'Collision'. A 'Bird's-Eye Plot' shows the car's trajectory in a lane, with a 'Vehicle and Environment' block providing inputs like 'Acceleration' and 'Steering Angle (rad)'. A 'Performance Indicator' block outputs various metrics: 'Actors', 'Vision', 'Radar', 'Tracks', 'Bird's-Eye Plot', 'MIO', 'Lane Boundaries', 'Lane Markings', 'OffLane', 'clearance (sec)', 'TimeGap (sec)', 'TooClose', 'Collision', and 'Pass or Fail'. The status bar at the bottom indicates 'Paused' and 'T=0.000*'. The status bar also shows '99%' and 'auto(ode45)'.

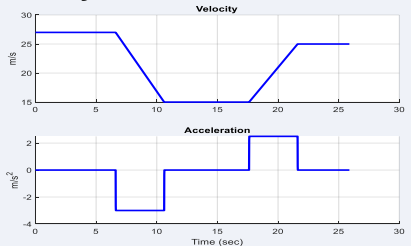
Fine-tune control parameters (2/3)

Test Description
Stop and Go in highway



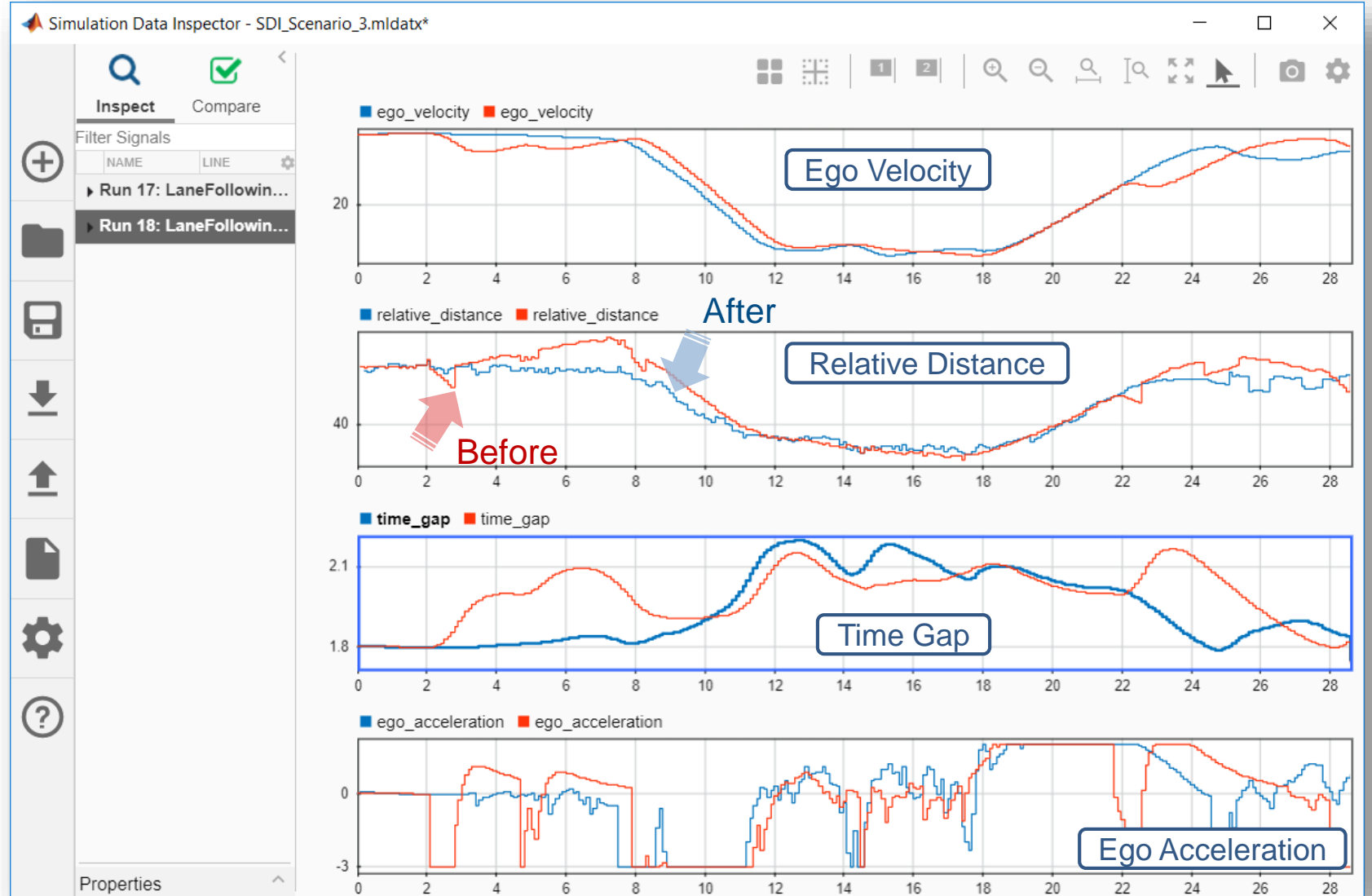
Host car
 initial velocity = 27m/s
 HWT = 1.5sec (HW = 40.5m)
 v_set = 27m/s

Lead Car
 initial velocity = 27m/s



Third Car
 8 slow moving cars at 12m/s
 in the second lane

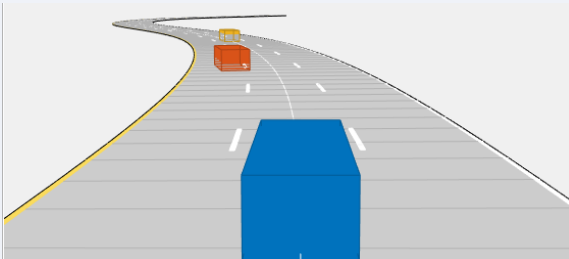
Spec
 Real-world scenario



Fine-tune control parameters (3/3)

Test Description

Automatic Retargeting Capability Test



Host car

initial velocity = 15m/s

HWT = 2.8sec (HW = 43m)

v_set = 15m/s

Lead Car

initial velocity = 13.9m/s

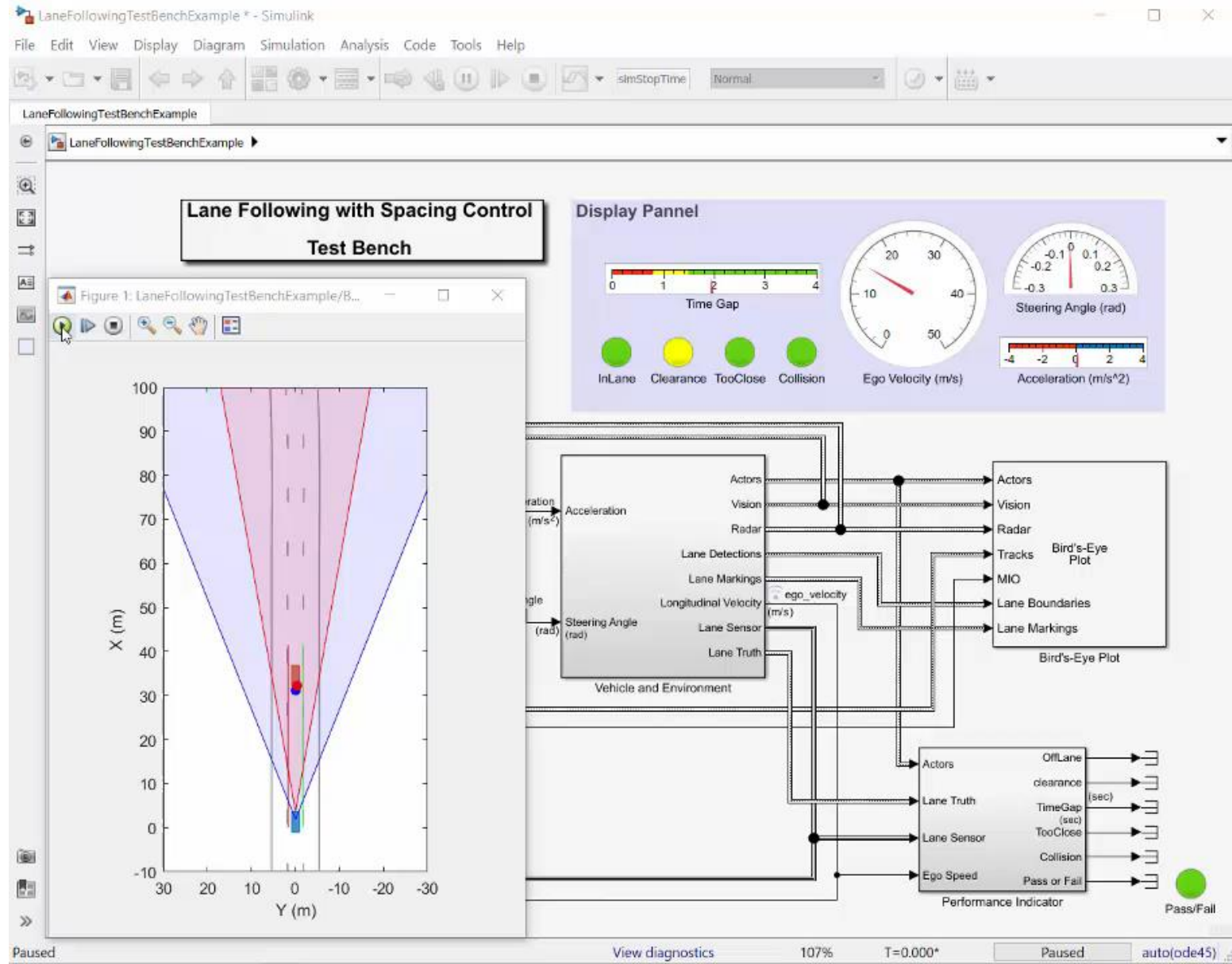
Lead car changes lane @ HWT=3s to overtake slow moving car

Third Car

Slow moving car at constant speed, 2.1m/s

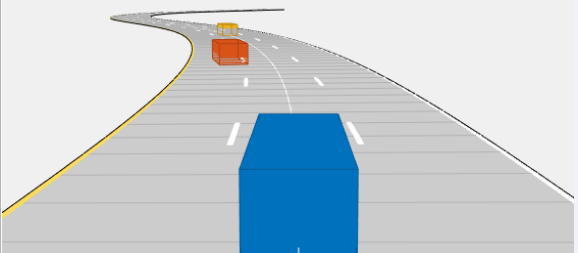
Spec

~ISO 22178



Fine-tune control parameters (3/3)

Test Description
Automatic Retargeting Capability Test



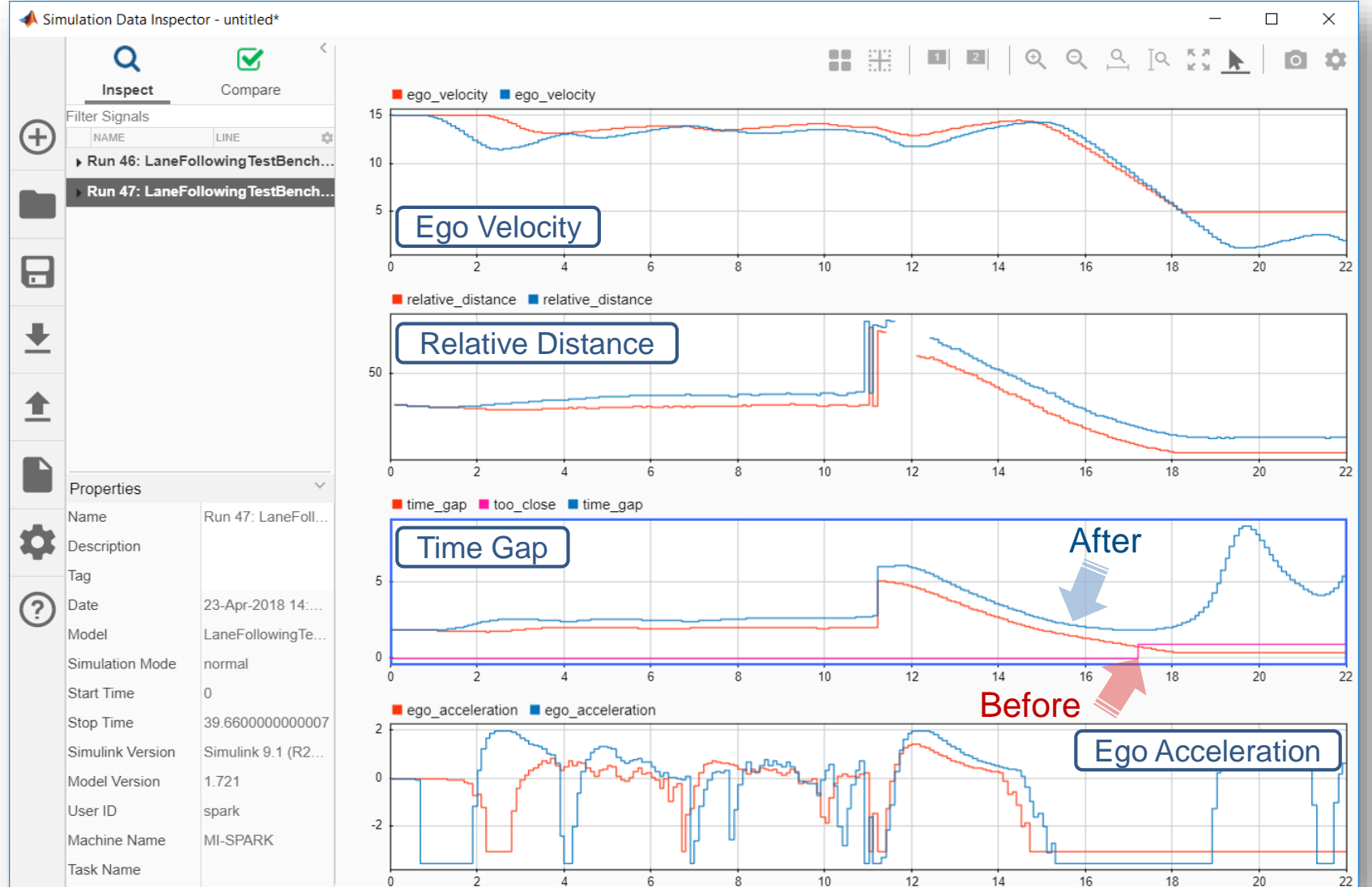
Host car
 initial velocity = 15m/s
 HWT = 2.8sec (HW = 43m)
 v_set = 15m/s

Lead Car
 initial velocity = 13.9m/s

Lead car changes lane @ HWT=3s to overtake slow moving car

Third Car
 Slow moving car at constant speed, 2.1m/s

Spec
 ~ISO 22178



Baseline vs. Fine-tuned parameters

Parameter Name	Description	Baseline	Fine-tuned
<code>assigThresh</code>	Detection assignment threshold for <code>multiObjectTracker</code>	50	20
<code>time_gap</code>	ACC time gap (sec)	1.5	2.0
<code>default_spacing</code>	ACC safe distance margin (m)	0	10
<code>min_ac</code>	Minimum acceleration (m/s ²)	-3.0	-3.5

Test Report with fine-tuned parameter set for 11 test cases





























Report Generated by Test Manager

Title: ACCAndLaneFollowing **Fine-tuned**
Author: Seo-Wook Park
Date: 26-Apr-2018 13:53:39

Test Environment

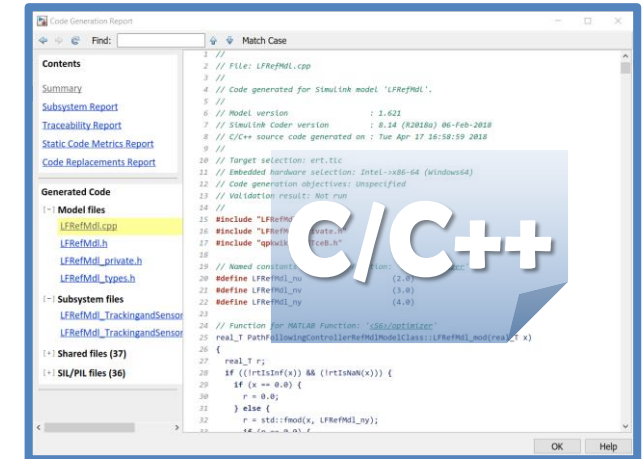
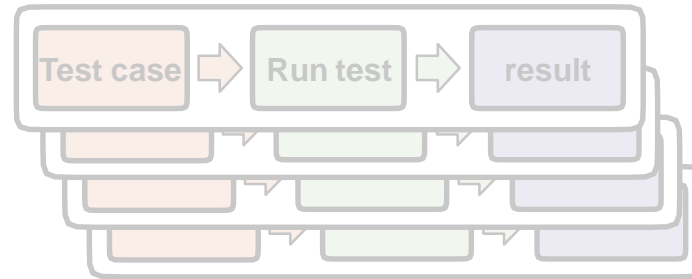
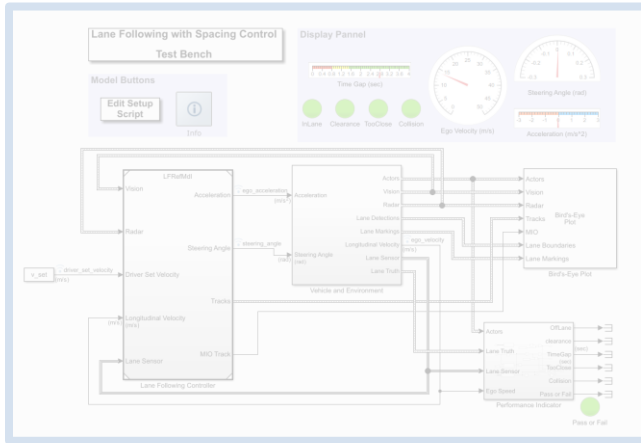
Platform: PCWIN64
MATLAB: (R2018a)

Summary

Name	Outcome	Duration (Seconds)
 TestScenarios FineTuned	11 	3541
 ACCTest	5 	1521
 ACC 01 ISO TargetDiscriminationTest		245
 ACC 02 ISO AutoDecelTest		323
 ACC 03 ISO AutoRetargetTest		262
 ACC 04 ISO CurveTest		331
 ACC 05 StopnGo		360
 LFACCTest	6 	2015
 LFACC 01 DoubleCurve DecelTarget		333
 LFACC 02 DoubleCurve AutoRetarget TooS low		380
 LFACC 03 DoubleCurve AutoRetarget		291
 LFACC 04 DoubleCurve StopnGo		398
 LFACC 05 Curve CutInOut		335
 LFACC 06 Curve CutInOut TooClose		278

Automated Driving System Toolbox

Design and Test Traffic Jam Assist, A Case study



Design ACC and Lane Following Controller

- Create driving scenario
- Synthesize sensor detection
- Include Vehicle Dynamics
- Design sensor fusion algorithm
- Design controller using MPC

Automate Regression Test

- Define performance evaluation metrics
- Develop test cases
- Build test suites
- Verification and validation

Generate and Verify Code

- SIL test
- Code generation
- Coverage test

Simulation with SIL mode

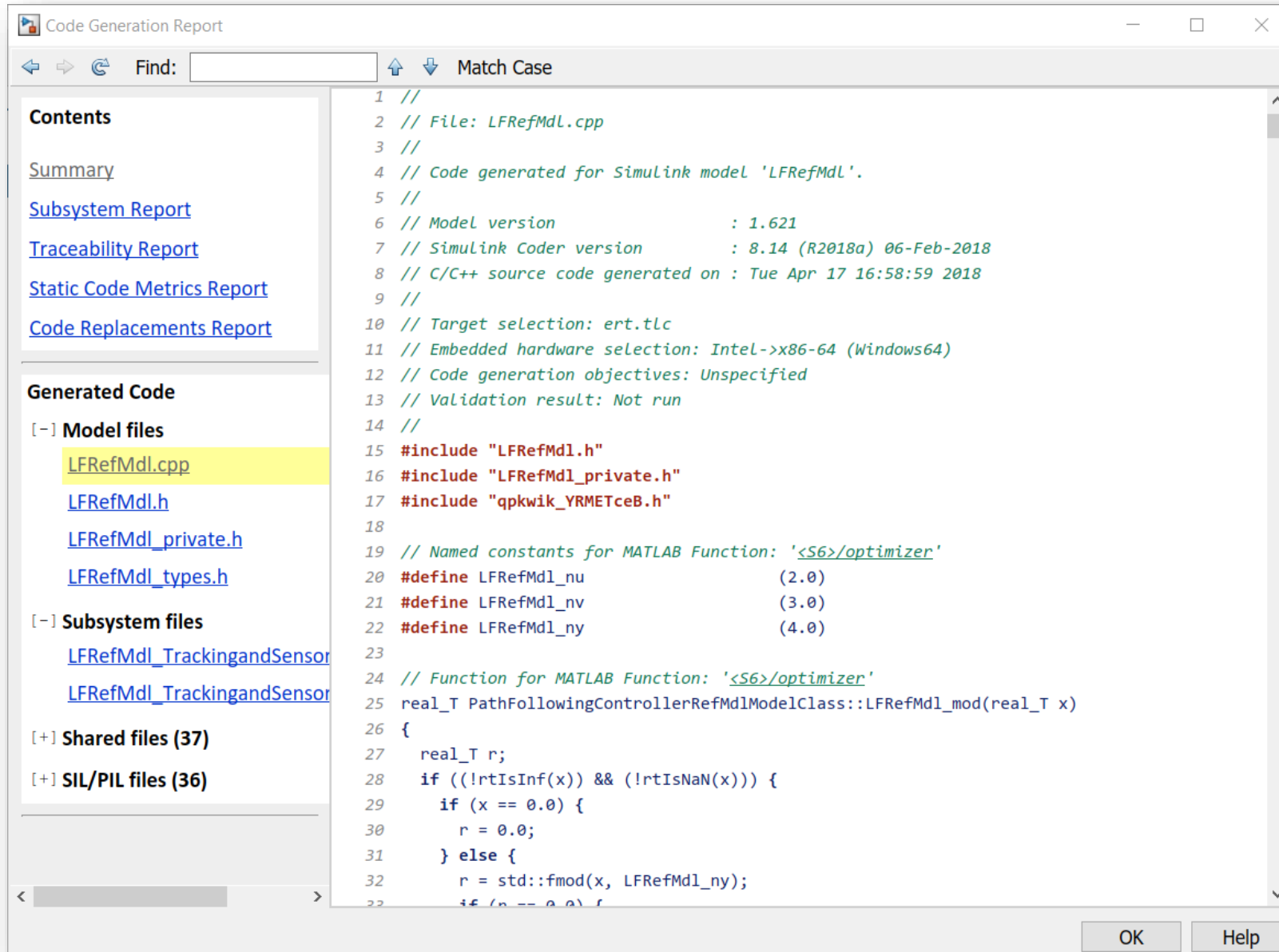
The screenshot displays the Simulink environment for a 'Lane Following Test Bench Example'. The main workspace shows a 'Lane Following Controller' block with inputs for Vision, Radar, Driver Set Velocity, and Lane Sensor. The 'v_set' block provides the 'driver_set_velocity' input. The controller outputs 'Acceleration', 'Steering Angle', 'Tracks', and 'MIO Track'. A 'Display Panel' is visible in the background, showing gauges for acceleration and steering angle.

The 'Block Parameters: Lane Following Controller' dialog box is open, showing the following settings:

- Model Reference: Reference the specified model.
- Main Arguments:
 - Model name: LFRefMdl
 - Simulation mode: Software-in-the-loop (SIL)
 - Code interface: Accelerator
 - Model events simulation: Software-in-the-loop (SIL)
- Options:
 - Show model initialize port:
 - Show model terminate port:
 - Show model periodic event ports:

Buttons at the bottom of the dialog include 'OK', 'Cancel', 'Help', and 'Apply'. The status bar at the bottom of the Simulink window shows 'Ready', '110%', and 'VariableStepAuto'.

Code Generation Report



Code Generation Report

Find: Match Case

Contents

- [Summary](#)
- [Subsystem Report](#)
- [Traceability Report](#)
- [Static Code Metrics Report](#)
- [Code Replacements Report](#)

Generated Code

- [-] Model files**
 - [LRefMdl.cpp](#)
 - [LRefMdl.h](#)
 - [LRefMdl_private.h](#)
 - [LRefMdl_types.h](#)
- [-] Subsystem files**
 - [LRefMdl_TrackingandSensor](#)
 - [LRefMdl_TrackingandSensor](#)
- [+] Shared files (37)**
- [+] SIL/PIL files (36)**

```

1 //
2 // File: LRefMdl.cpp
3 //
4 // Code generated for Simulink model 'LRefMdl'.
5 //
6 // Model version           : 1.621
7 // Simulink Coder version   : 8.14 (R2018a) 06-Feb-2018
8 // C/C++ source code generated on : Tue Apr 17 16:58:59 2018
9 //
10 // Target selection: ert.tlc
11 // Embedded hardware selection: Intel->x86-64 (Windows64)
12 // Code generation objectives: Unspecified
13 // Validation result: Not run
14 //
15 #include "LRefMdl.h"
16 #include "LRefMdl_private.h"
17 #include "qpkwik_YRMETceB.h"
18
19 // Named constants for MATLAB Function: '<S6>/optimizer'
20 #define LRefMdl_nu           (2.0)
21 #define LRefMdl_nv           (3.0)
22 #define LRefMdl_ny           (4.0)
23
24 // Function for MATLAB Function: '<S6>/optimizer'
25 real_T PathFollowingControllerRefMdlModelClass::LRefMdl_mod(real_T x)
26 {
27     real_T r;
28     if (!(rtIsInf(x)) && (!rtIsNaN(x))) {
29         if (x == 0.0) {
30             r = 0.0;
31         } else {
32             r = std::fmod(x, LRefMdl_ny);
33         }
34     }
35 }

```

OK Help

Aggregated Code Coverage Report



Report Generate

Title: ACCAndLane
Author: Seo-Wook Pa
Date: 26-Apr-2018

Test Environment

Platform: PCWIN64
 MATLAB: (R2018a)

Summary

File/Complexity

TOTAL COVERAGE

1. [LRefMdl.cpp](#)
2. [LRefMdl_TrackingandS](#)
3. [rtGetInf.cpp](#)
4. [rtGetNaN.cpp](#)
5. [rt_nonfinite.cpp](#)

Summary By Model

Model Object

1. [LRefMdl](#)
2. [Controller](#)
3. [MPC Controller](#)
4. [MPC](#)
5. [optimizer](#)
6. [Safe distance](#)
7. [Estimate Lane Center](#)
8. [Center from Left](#)
9. [Center from Left and](#)
10. [Center from Right](#)
11. [MATLAB Function](#)
12. [Preview curvature](#)
13. [Tracking and Sensor Fus](#)
14. [Clock](#)
15. [Counter Limited](#)
16. [Find Lead Car](#)

```

1778 static boolean_T LRefMdl_objectTrack_checkPromotion(const
1779   driving_internal_objectTrack_LRefMdl_T *track)
1780 {
1781   boolean_T toPromote;
1782   real_T history;
1783   int32_T b;
1784   boolean_T track_data[50];
1785   int32_T track_size[2];
1786   if (track->ObjectClassID != 0.0) {
1787     toPromote = true;
1788   } else {
1789     if ((track->pUsedHistoryLength < track->ConfirmationParameters[1]) ||

```

Decisions analyzed:

(track->pUsedHistoryLength < track->ConfirmationParameters[1]) rtIsNaN(track->ConfirmationParameters[1])	50%
false	13038/13038
true	0/13038

Conditions analyzed:

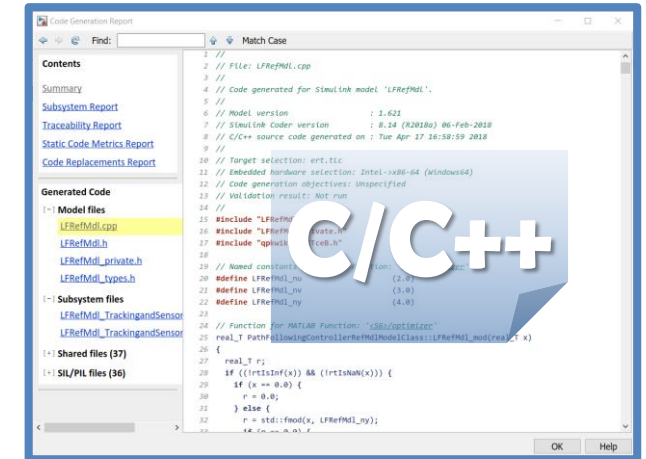
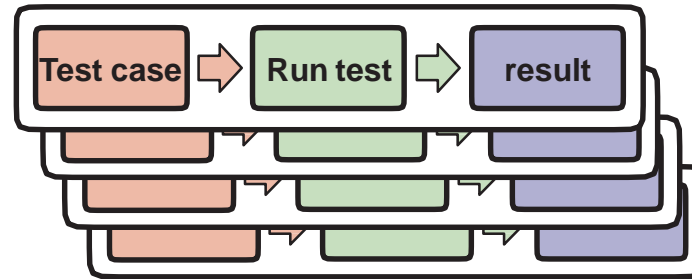
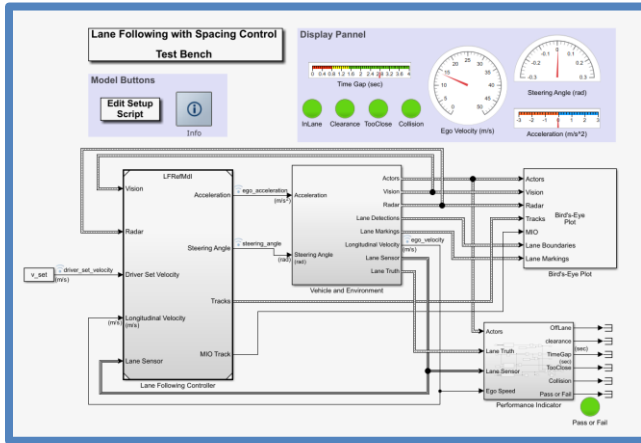
Description:	True	False
track->pUsedHistoryLength < track->ConfirmationParameters[1]	0	13038
rtIsNaN(track->ConfirmationParameters[1])	0	13038

MC/DC analysis (combinations in parentheses did not occur)

decision outcomes:	True Out	False Out
Conditions:		
track->pUsedHistoryLength < track->ConfirmationParameters[1]	(Tx)	FF
rtIsNaN(track->ConfirmationParameters[1])	(FT)	FF

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- SIL test
- Code generation
- Coverage test

Thank you for your attention !!

Email: seo-wook.park@mathworks.com