
# Lund University

**2022 | AUTONOMOUS DRIVING SYSTEMS-**
**GENERATING CRITICAL DRIVING SCENARIOS USING**

**OPTIMIZATION TO TEST AUTONOMOUS EMERGENCY**

**BRAKING SYSTEMS (AEBS).**

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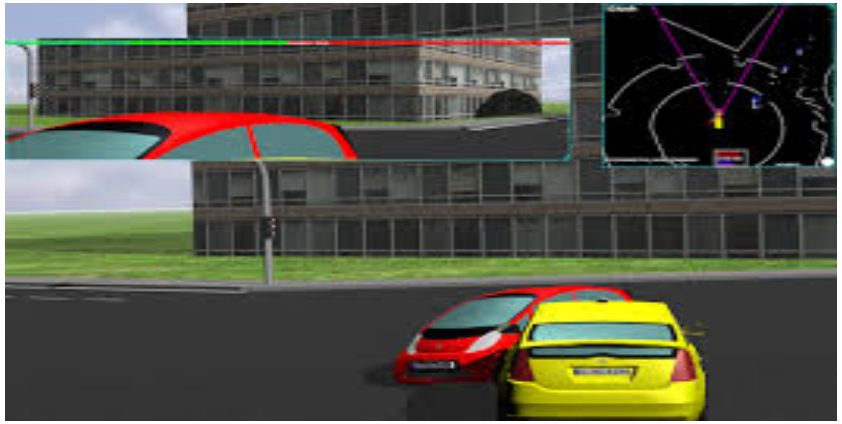
# Definition of Critical Driving Scenarios (CDS)

# Importance of Testing CDS

- ADAS has become increasingly popular.
- Ensure reliability and safety of ADAS.
- Discover potential defects & misbehavior in the system.
- Cover rare traffic situations. (Uber's case in USA 2018)
- Avoid relaying on substantial real-world testing or collecting real driving data at scale.
- Regular road traffic is considered non-critical.

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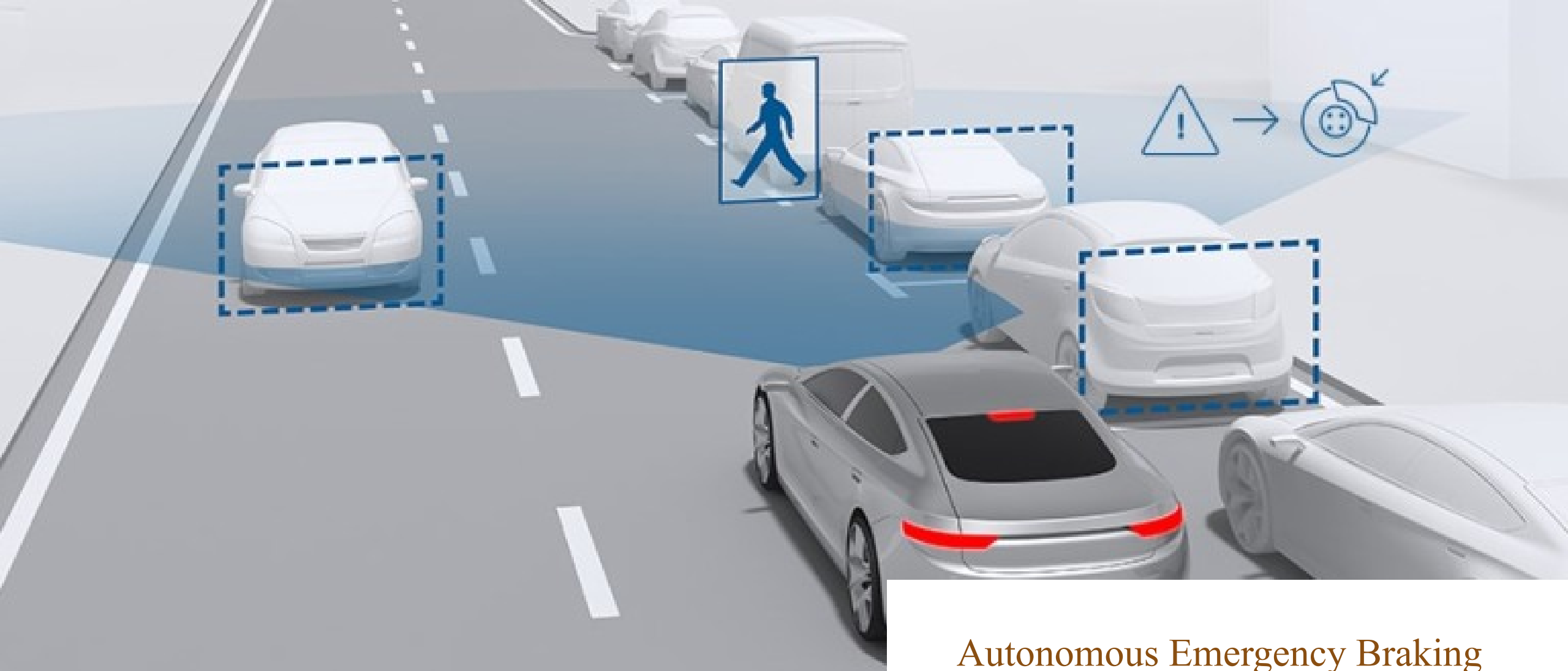
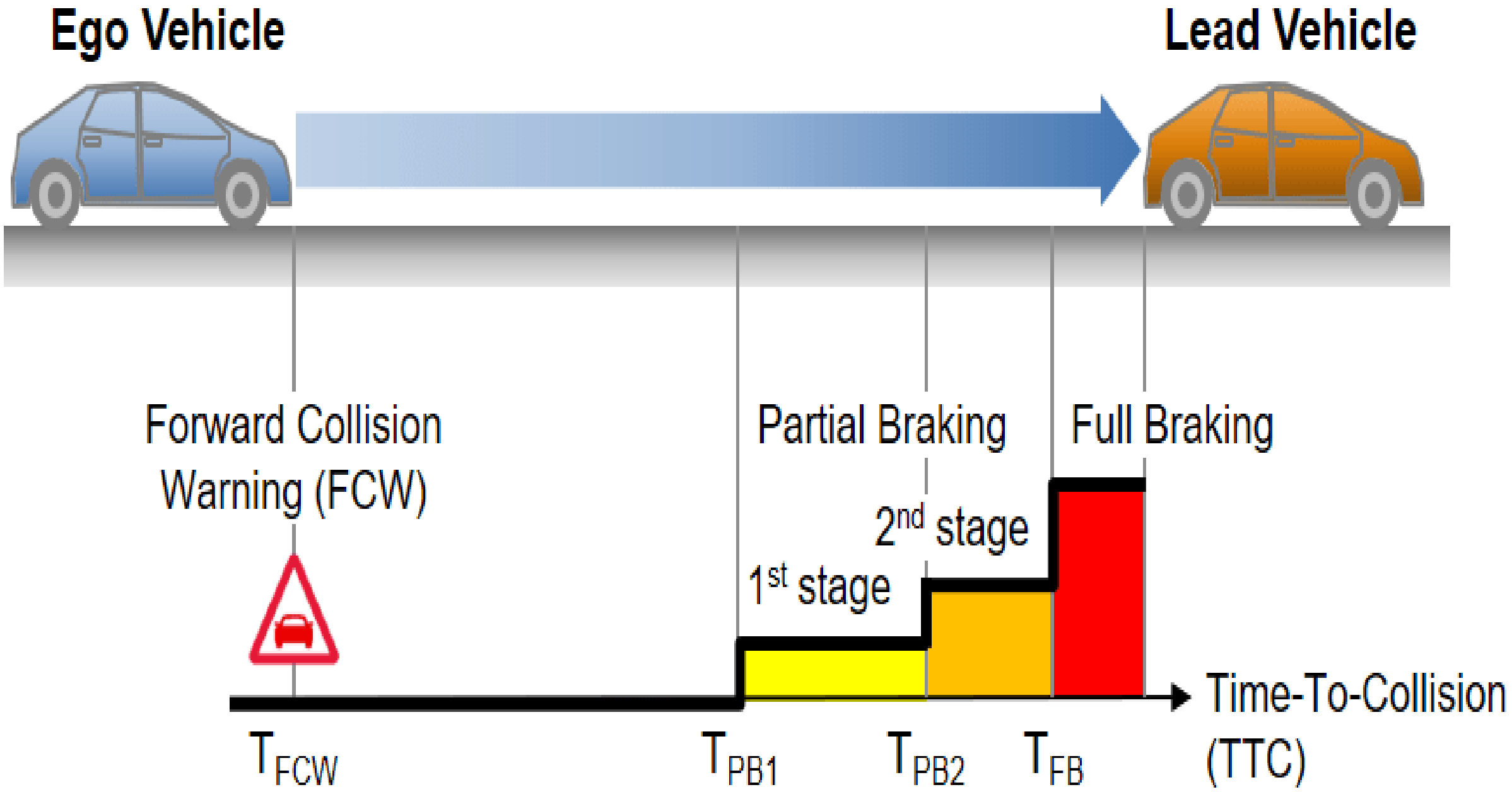


# Autonomous Emergency Braking System (AEBS)


Ego Vehicle
Lead Vehicle
Forward Collision Warning (FCW)
Partial Braking
Full Braking
2nd stage
1st stage
Time-To-Collision (TTC)
TFCW
TPB1
TPB2
TFB

# Methods

- Simulating AEBS

- Optimizing Critical Scenarios

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# Simulating AEBS:

- Using MATLAB AEBS model.
- Using AEBTestBench and a dataset consists of  26 important scenario categories  from Euro NCAP.
- Using 6 sub-models each one of them based on  an algorithm written in MATLAB.
- Using test requirements set.
- Using Parallel Automate Testing to increase the overall automate execution speed.

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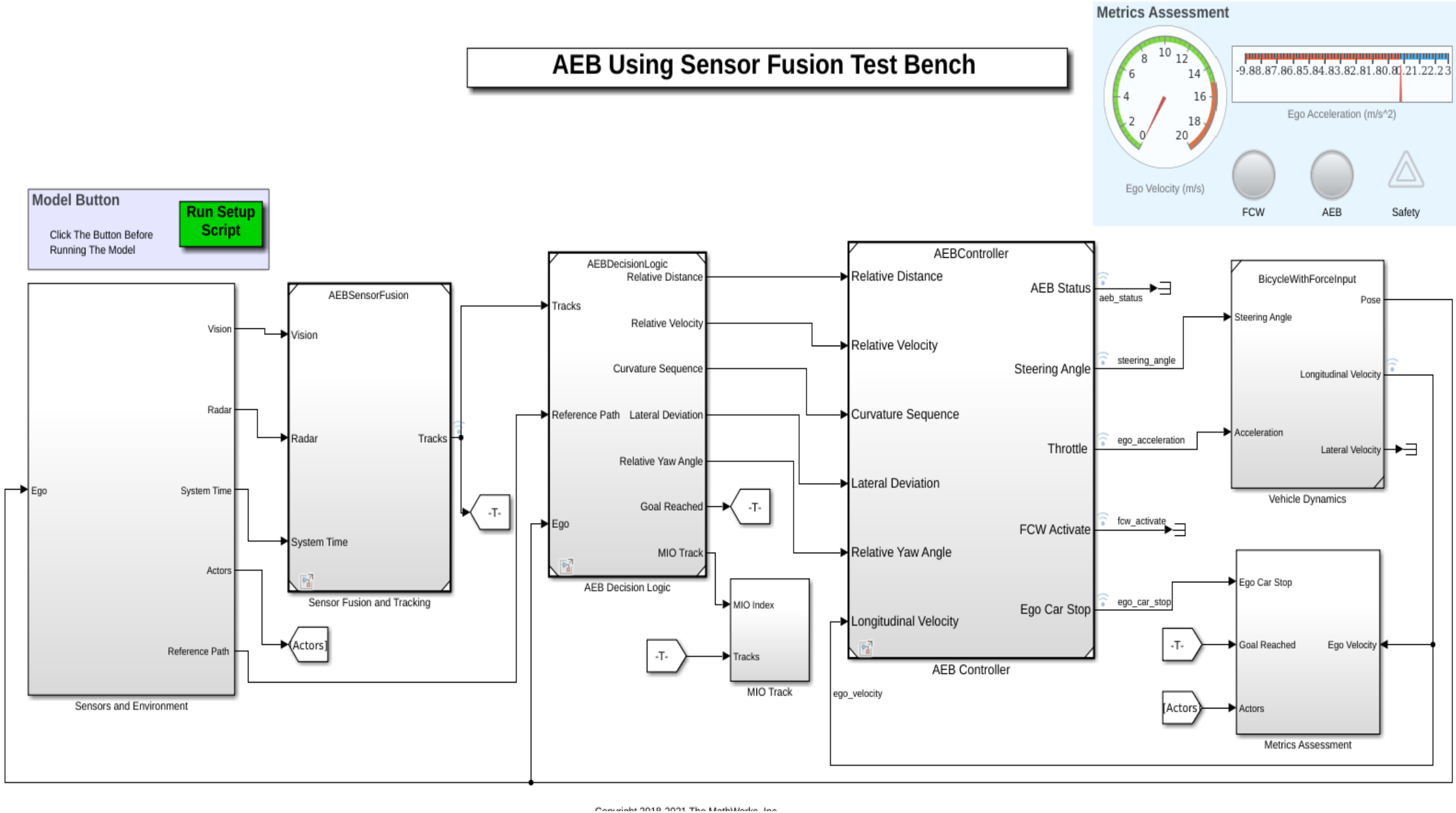

# Demos:

Demo of Scenario "Pedestrian_Child"
https://share.vidyard.com/watch/p3brAMW6kDhSd9x5iinYWn?

Demo of AEBS "Pedestrian_Child"
https://share.vidyard.com/watch/6S6ekdJQSgwM6ddfTzJga7?

# Optimizing Critical Scenarios:

- Using modeFrontier tool.
- Using multi-strategy self-adapting algorithm that combines the advantages of local and global search, in self initializing mode, which is called pilOPT.
- Integrating MATLAB node with modeFrontier.
- Creating a workflow of different nodes.
- Define the objective as minimizing TTC while specifying upper & lower bounds for the egoVehicle's velocity as input parameters.
- Run pilOPT with 1000 evaluations.
- Plot the optimized results and define a thresh hold to get extreme CDS.

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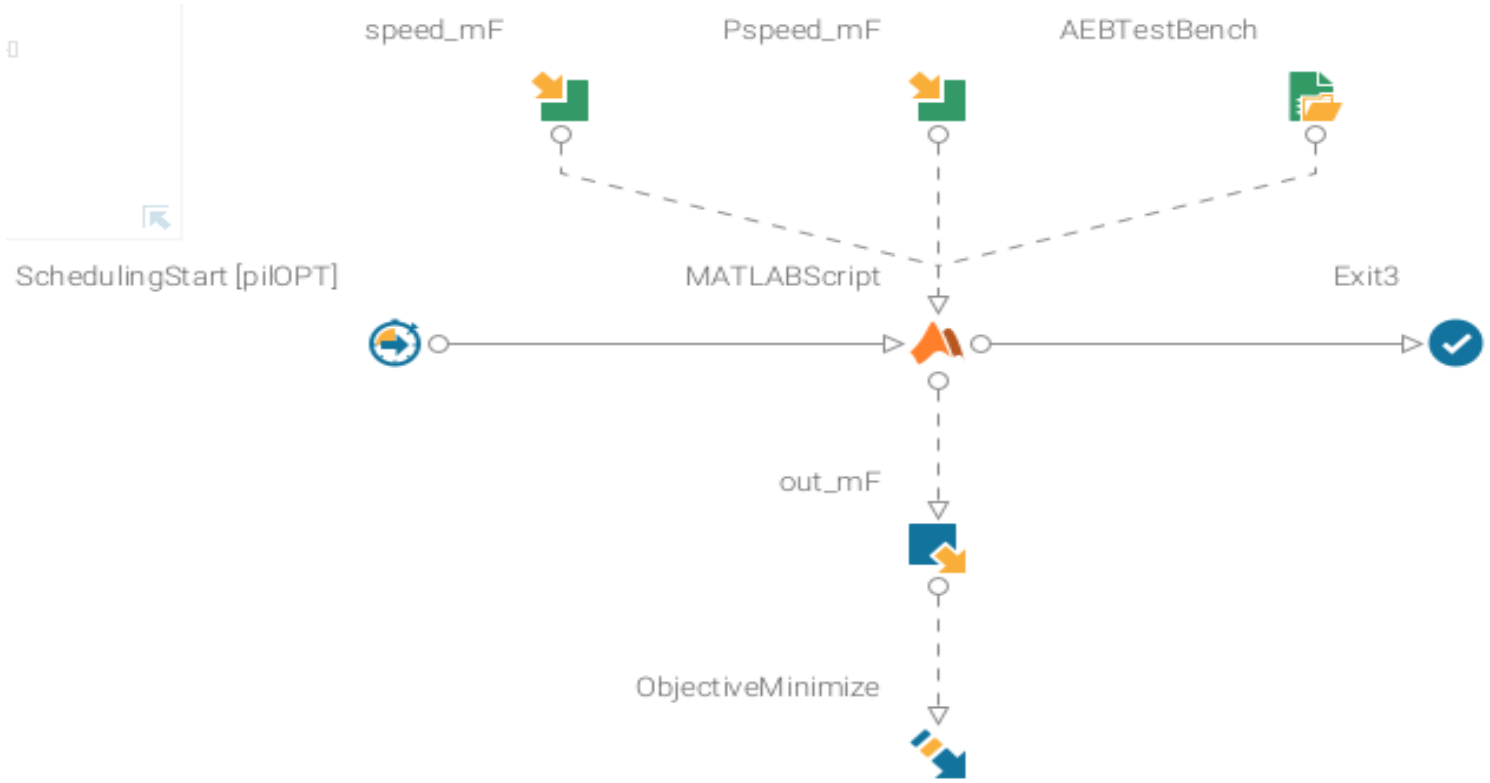
# The Workflow:

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# Results

- First Phase:

1) The entire dataset, that is, the 26 CDS imported from Euro NCAP, is passed and verified by AEBS. In each one of them, the check safety goal is achieved and the collisions are mitigated.

1) All test requirements are met.

REQUIREMENTS

New Requirement Set | Open | Save | Import | Close — FILE

Profile Editor — PROFILE

Add Requirement | Delete | Promote Requirement | Demote Requirement — REQUIREMENTS

Add Link | Delete | Clear Issue | Preferences — LINKS

Show Requirements | Show Links | Refresh | Columns | Information — VIEW

Search — EDIT

Traceability Matrix | Traceability Diagram | Model Testing Dashboard — ANALYSIS

Export — SHARE

| Index | ID | Summary | Verified |
|---|---|---|---|
| Autonomou... | | | |
| 1 | 1 | scenario_01_AEB_Bicyclist_Longitudinal_25width | |
| 2 | 2 | scenario_02_AEB_Bicyclist_Longitudinal_50width | |
| 3 | 3 | scenario_03_AEB_Bicyclist_Longitudinal_75width | |
| 4 | 4 | scenario_04_AEB_CCRb_2_initialGap_12m | |
| 5 | 5 | scenario_05_AEB_CCRb_2_initialGap_40m | |
| 6 | 6 | scenario_06_AEB_CCRb_6_initialGap_12m | |
| 7 | 7 | scenario_07_AEB_CCRb_6_initialGap_40m | |
| 8 | 8 | scenario_08_AEB_CCRm_50overlap | |
| 9 | 9 | scenario_09_AEB_CCRm_-50overlap | |
| 10 | 10 | scenario_10_AEB_CCRm_75overlap | |
| 11 | 11 | scenario_11_AEB_CCRm_-75overlap | |
| 12 | 12 | scenario_12_AEB_CCRm_100overlap | |
| 13 | 13 | scenario_13_AEB_CCRs_50overlap | |
| 14 | 14 | scenario_14_AEB_CCRs_-50overlap | |
| 15 | 15 | scenario_15_AEB_CCRs_75overlap | |
| 16 | 16 | scenario_16_AEB_CCRs_-75overlap | |
| 17 | 17 | scenario_17_AEB_CCRs_100overlap | |
| 18 | 18 | scenario_18_AEB_Pedestrian_Farside_50width | |
| 19 | 19 | scenario_19_AEB_Pedestrian_Longitudinal_25width | |
| 20 | 20 | scenario_20_AEB_Pedestrian_Longitudinal_50width | |
| 21 | 21 | scenario_21_AEB_Pedestrian_Nearside_25width | |
| 22 | 22 | scenario_22_AEB_Pedestrian_Nearside_75width | |

Requirement: 2

Details

**Properties**

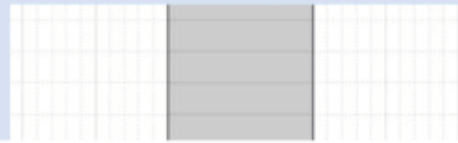
Type: Functional

Index: 2

Custom ID: 2

Summary: scenario_02_AEB_Bicyclist_Longitudinal_50width

Description | Rationale

| Test Description | Target vehicles | Requirements on Vehicle Under Test |
|---|---|---|
| **scenario_02_AEB_Bicyclist_Longitudinal_50width**  | **Bicyclist**: Travels with a constant velocity of 4.17 m/s. | Travels with constant velocity: 6.94 m/s. **Expected behavior:** |

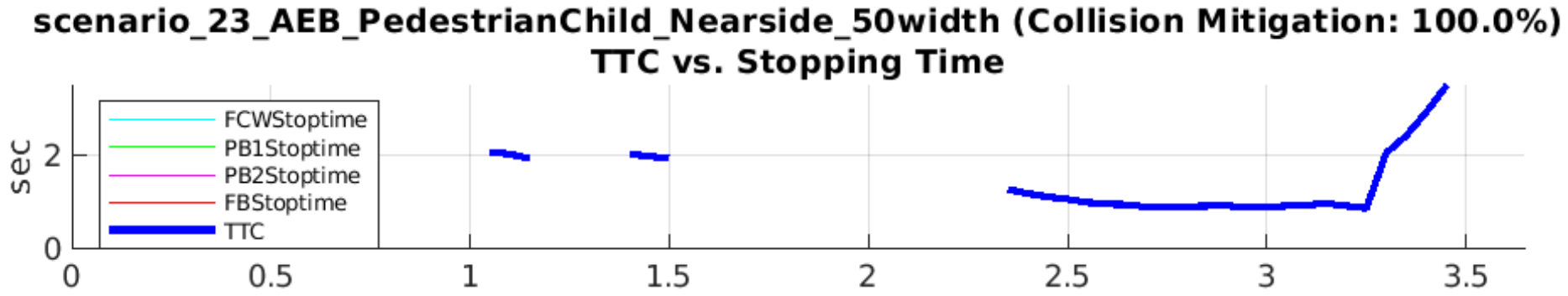
Keywords:

Revision information:

**Links**

**Verified by:**

scenario_02_AEB_Bicyclist_Longitudinal_50width

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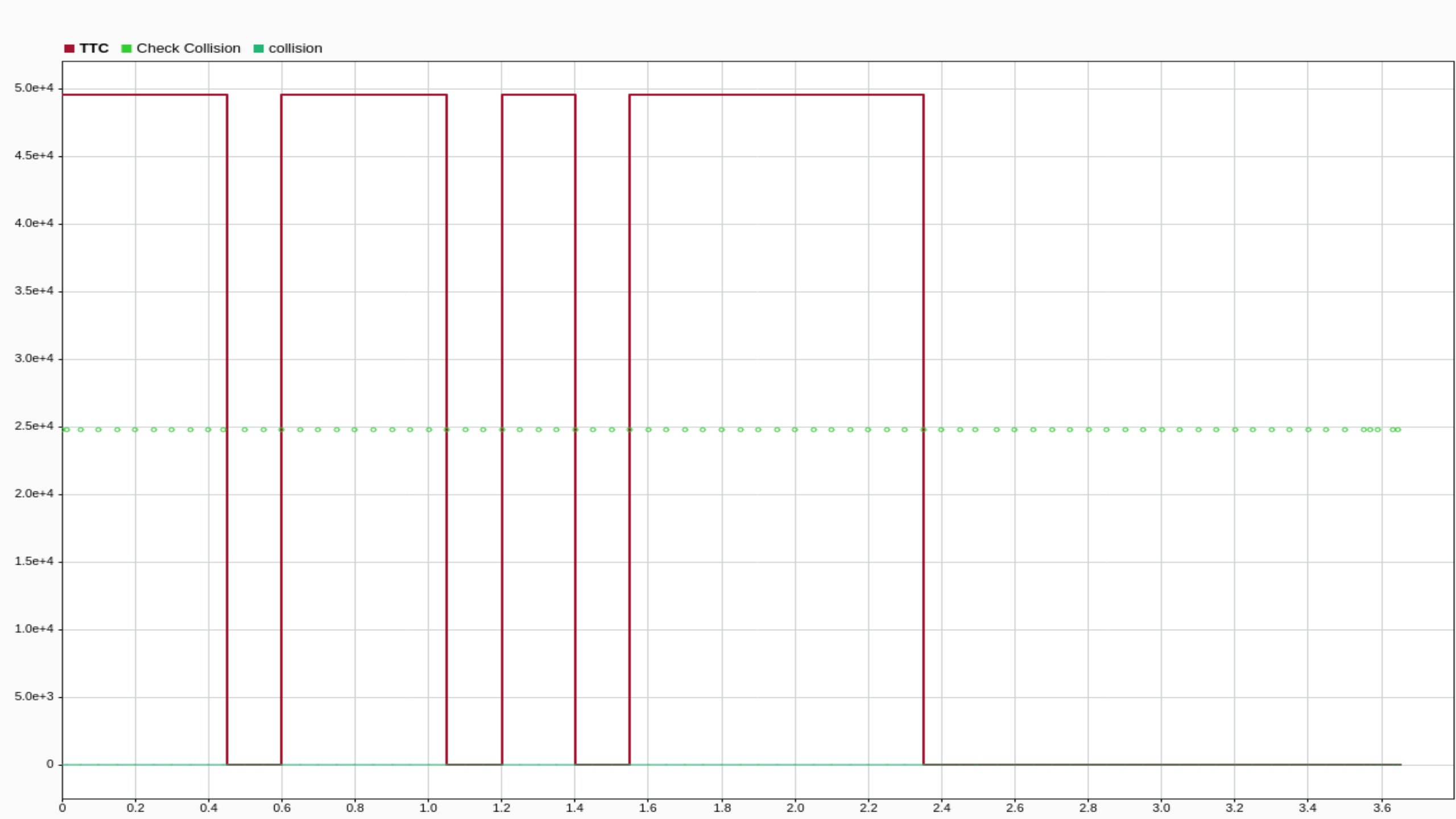
TTC
Check Collision
collision
5.0e+4
4.5e+4
4.0e+4
3.5e+4
3.0e+4
2.5e+4
2.0e+4
1.5e+4
1.0e+4
5.0e+3
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6

# Results

- Second Phase:

1) As part of the integration process, I discovered a bug in modeFrontier, which stuck during the simulation. I have logged the issue, reported it to modeFrontier's team, and they have confirmed it.

1) Due to the bug, the optimization could not be carried out as planned. However, manually checking the AEBS through manual optimization, revealed a defect in which the collision could not be mitigated, and the car collided with the pedestrian/child.

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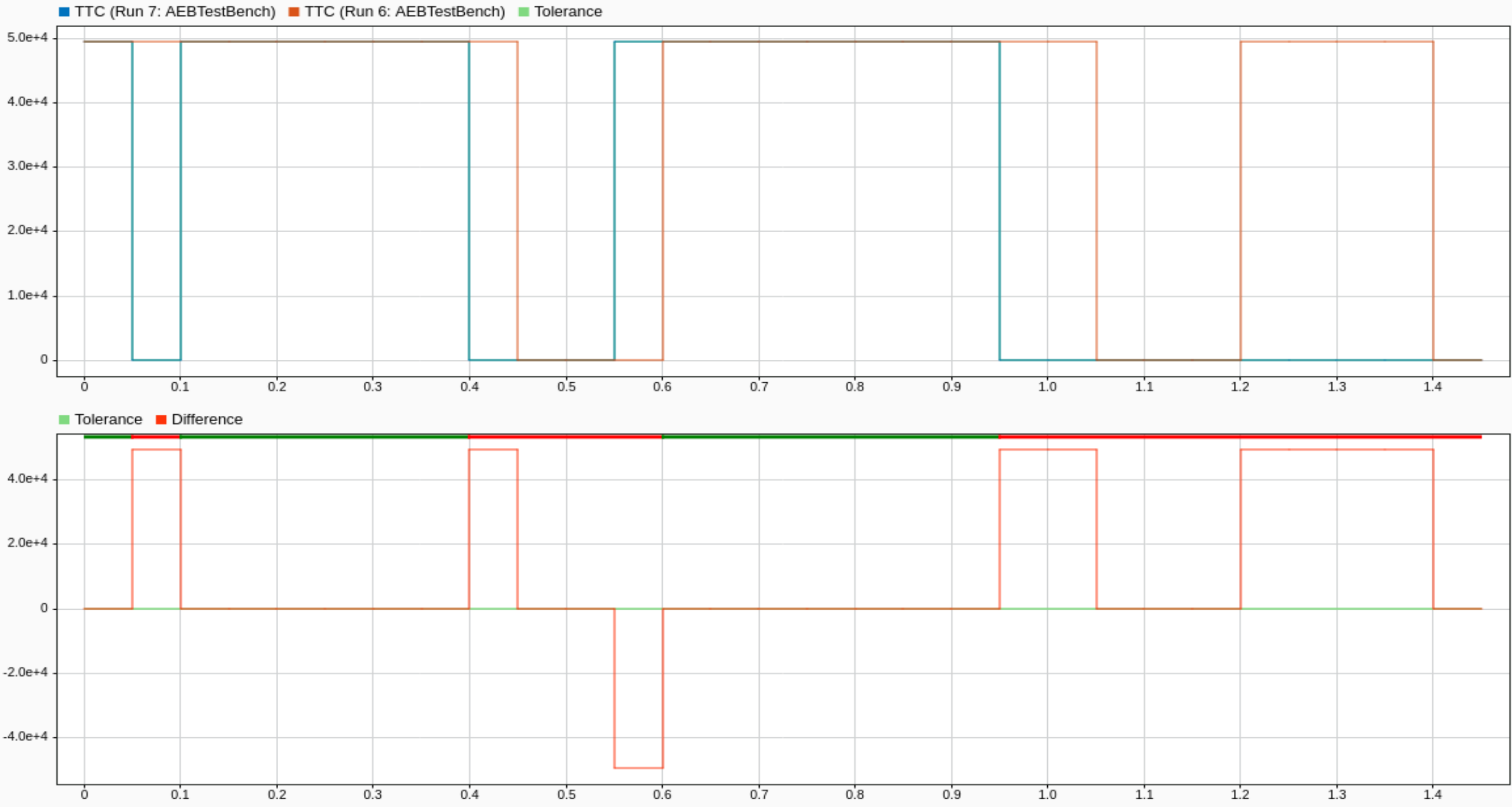

TTC (Run 7: AEBTestBench)
TTC (Run 6: AEBTestBench)
Tolerance
5.0e+4
4.0e+4
3.0e+4
2.0e+4
1.0e+4
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
Tolerance
Difference
4.0e+4
2.0e+4
0
-2.0e+4
-4.0e+4
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4


TTC
Check Collision
collision
Fail
Pass
Untested
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6

AEBTestBench * - Simulink academic use

DEBUG MODELING FORMAT APPS

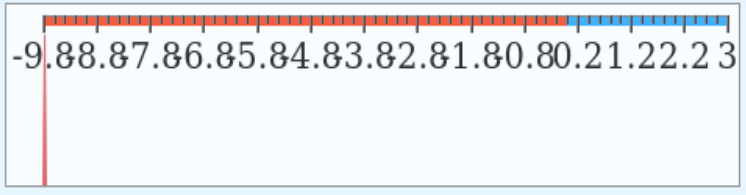
New Open Save Print — FILE
Library Browser — LIBRARY
Log Signals Log Events — PREPARE
Stop Time scenario.S | Normal | Fast Restart
Step Back Run Step Forward Stop — SIMULATE
Data Inspector — REVIEW RESULTS

AEBTestBench

AEBTestBench ▸

## Metrics Assessment


Ego Velocity (m/s)




Ego Acceleration (m/s^2)

FCW AEB Safety

tic Viewer

209% ode45

eturns the

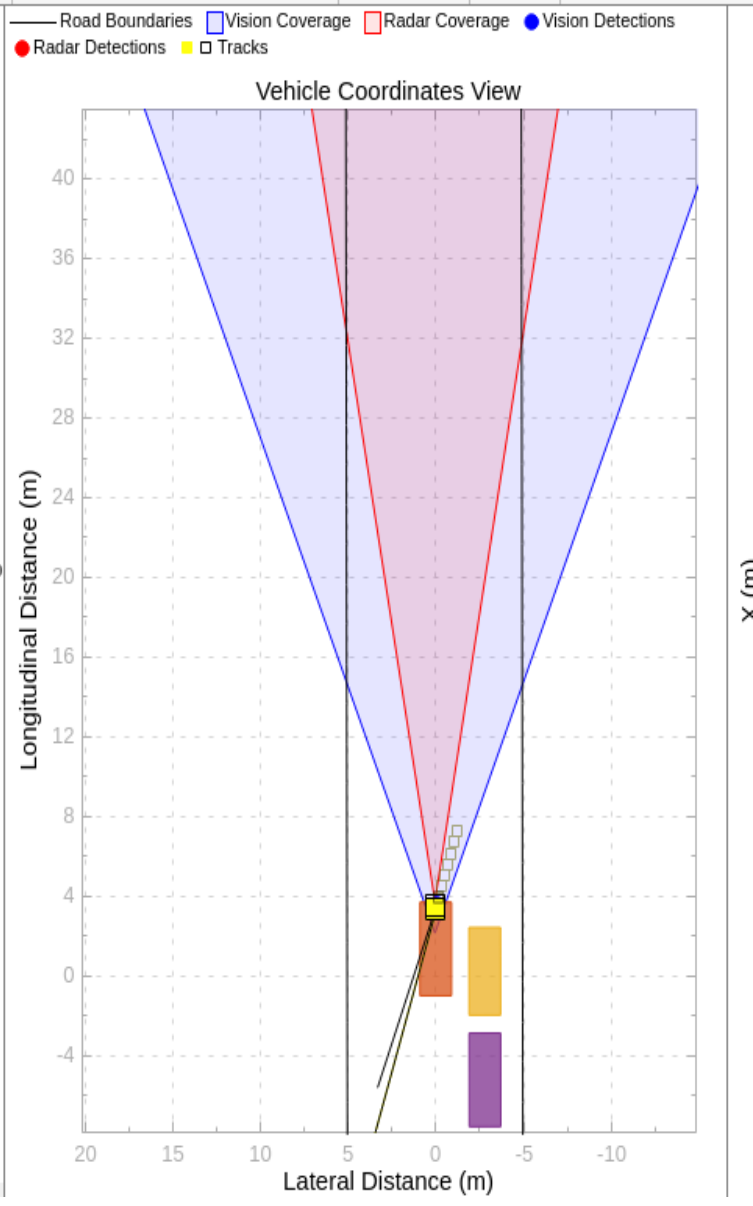
scenario_23_AEB_PedestrianChild_Nearside...

```
56
57  vehicle(scenario, ...
58      'ClassID', 1, ...
59      'Position', [21.8 -2.8 0], ...
```

BIRD'S-EYE SCOPE

Update Signals | Add Group | Delete Group — SIGNALS
Settings — SETTINGS
Stepping Options Run Step Forward Stop — SIMULATE
World Coordinates — VIEW
Legend — DISPLAY

- Ground Truth
  - Road Boundaries
  - Lane Markings
  - Barriers
- Actors
  - Actor 2 (ego vehicle)
  - Scenario Reader
    - Actor 1
    - Actor 3
    - Actor 4
- Sensor Coverage
  - Vision
    - 1 Vision Detection Generator
  - Radar
    - 2 Driving Radar Data Generato
  - Lidar
- Detections
  - Vision
    - Vision Detection Generator
  - Radar
    - Driving Radar Data Generator
  - Lidar
- Tracks
  - mio_track
  - Sensor Fusion and Tracking
- Other Applicable Signals
  - Rate Transition1
  - Pack Ego Actor



# Conclusion

For autonomous vehicles, safety and reliability are essential attributes. In addition, due to the complexity of driving scenarios and the uncertainty of the operational environment, traditional requirements-driven testing approaches are impeded. Thus, it is necessary to identify the most critical scenarios for testing the autonomous driving systems and to uncover defects and misbehaviors. As we have seen in Uber's case, it is a life or death matter.

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