Automated Lane Keeping Systems (ALKS) UN No. 157 Level 3

MMU 753 Project

ALKS

- ALKS controls the lateral and longitudinal movement of the vehicle for extended periods without further driver command. ALKS is a system whereby the activated system is in primary control of the vehicle. ALKS can be activated under certain conditions on roads where pedestrians and cyclists are prohibited and which, by design, are equipped with a physical separation that divides the traffic moving in opposite directions and prevent traffic from cutting across the path of the vehicle.

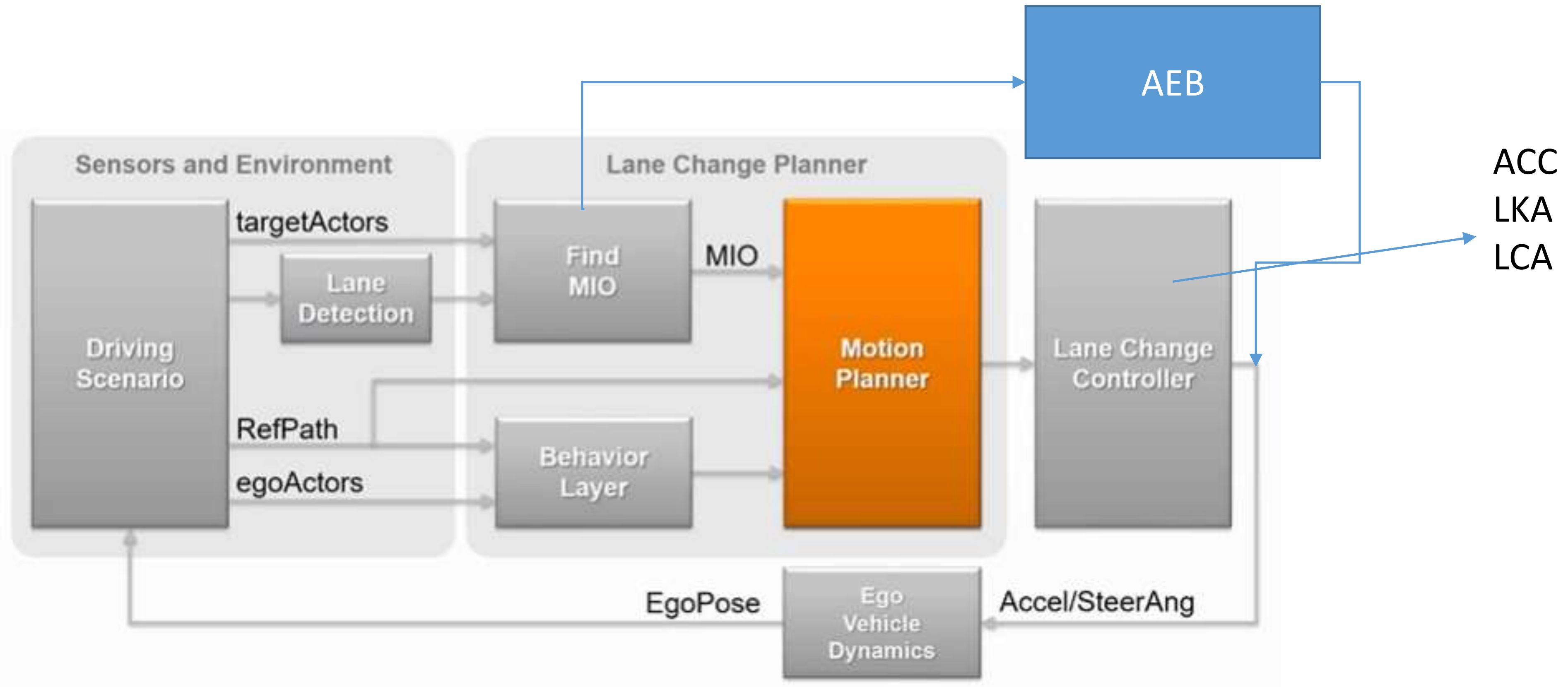
Controller Types

In the literature, there are several methods to represent a suitable trajectory function. Spline curves such as quartic and B-spline, trapezoidal acceleration curves, 3D Bezier curves and polynomial curves were researched.

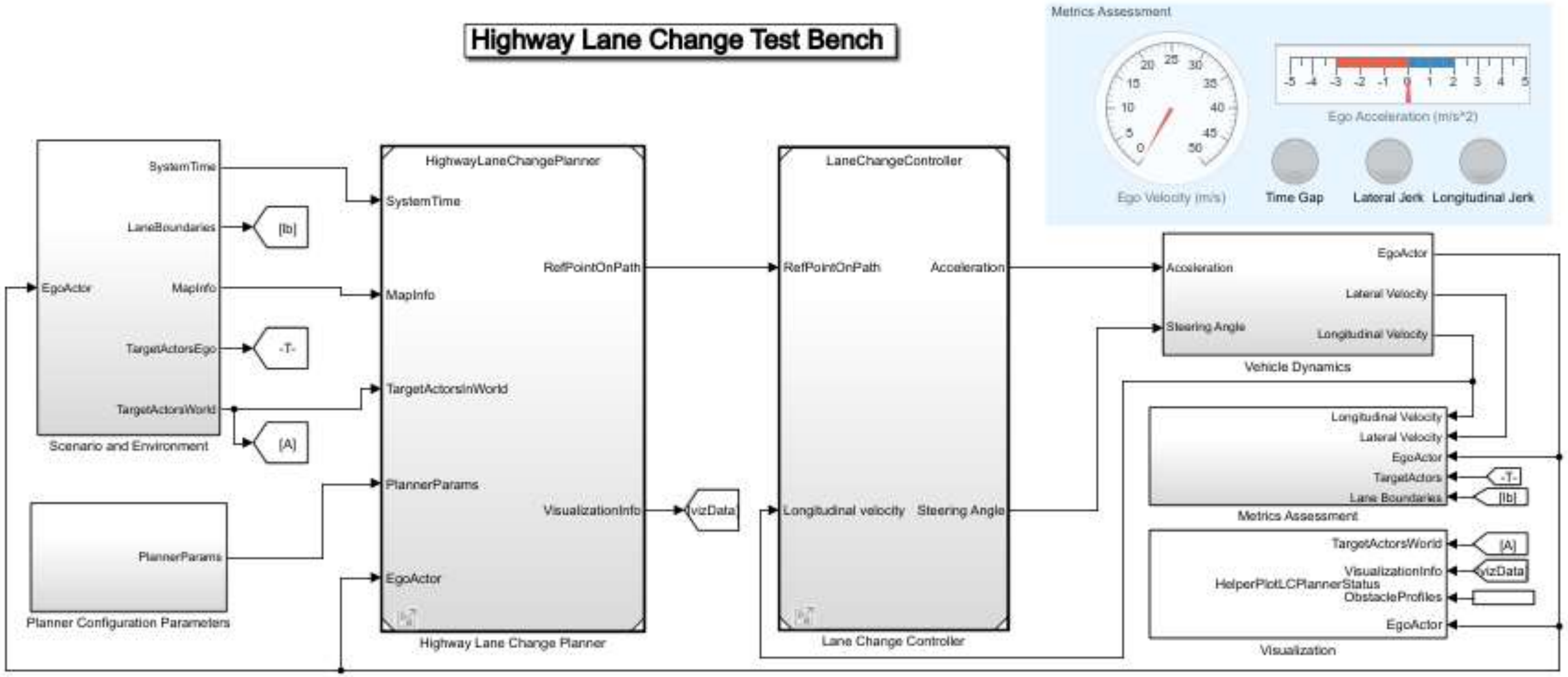
Path Following algorithms

- Hinfinity, P controller with FF
- Sliding mode control with a fuzzy boundary layer
- MPC, LQR
- the lack of real-world applicability (high velocity and/or low road adhesion coefficient)

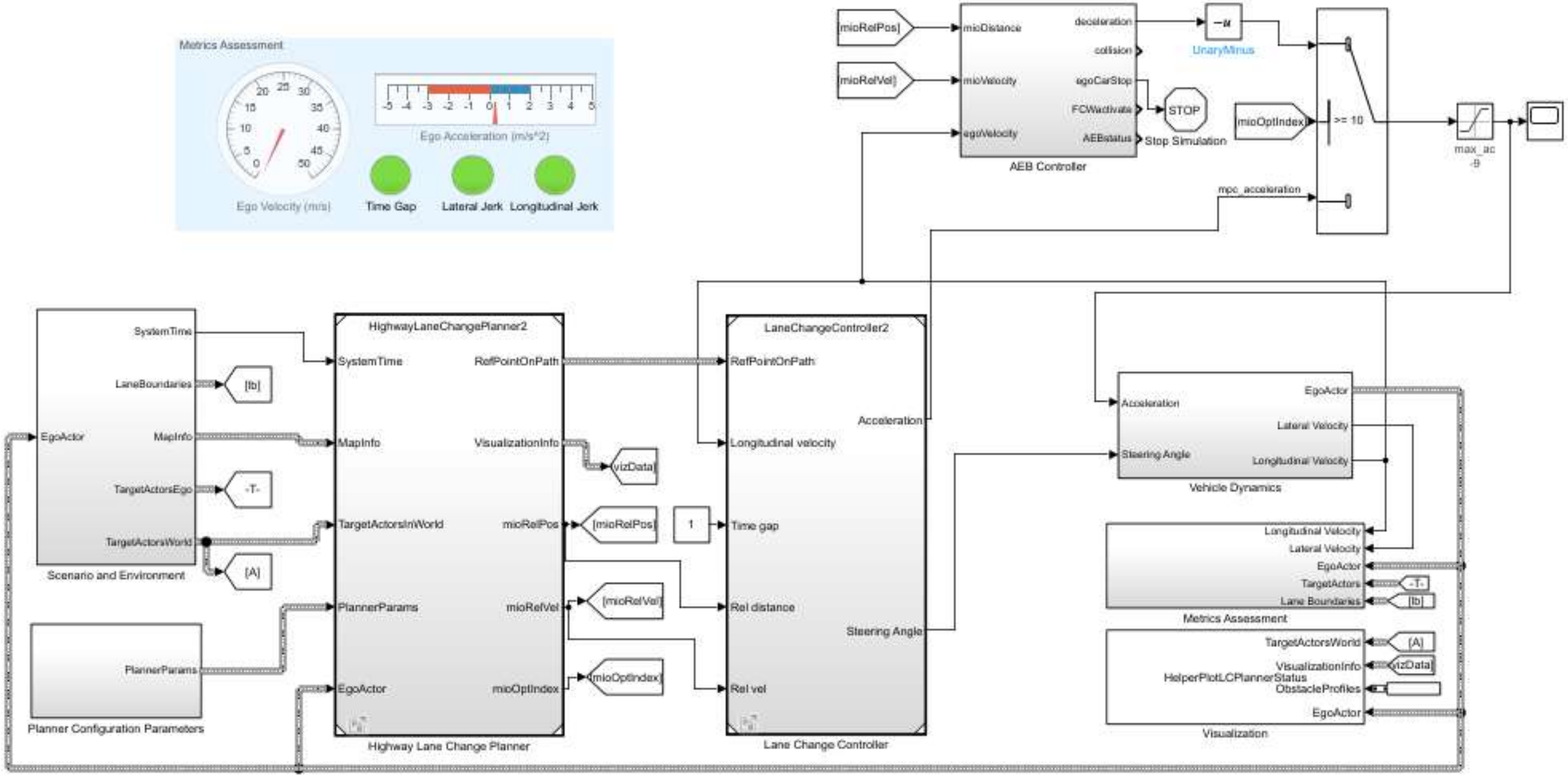
ALKS MODEL


AEB
ACC
LKA
LCA
Sensors and Environment
Lane Change Planner
Driving Scenario
targetActors
Lane Detection
RefPath
egoActors
Find MIO
MIO
Behavior Layer
Motion Planner
Lane Change Controller
EgoPose
Ego Vehicle Dynamics
Accel/SteerAng

LCA TEST Bench



ALKS TEST Bench



Trajectory Generation

Generate trajectory in Frenet coordinate using quintic polynomial

- Quintic polynomial

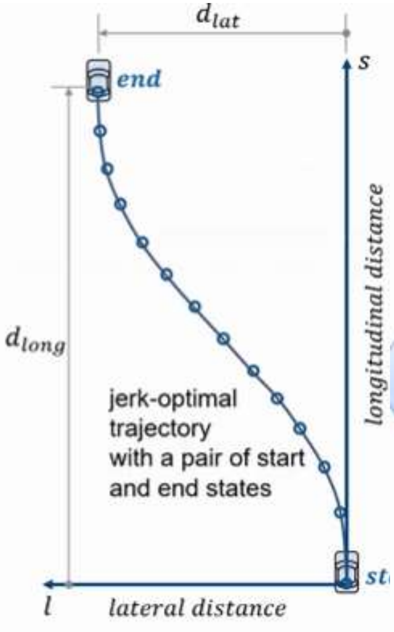
$$s(t) = a_5t^5 + a_4t^4 + a_3t^3 + a_2t^2 + a_1t + a_0$$
$$\dot{s}(t) = 5a_5t^4 + 4a_4t^3 + 3a_3t^2 + 2a_2t + a_1$$
$$\ddot{s}(t) = 20a_5t^3 + 12a_4t^2 + 6a_3t + 2a_2$$
$$where\ s = longitudinal\ or\ lateral\ distance$$

- Start boundary conditions $(t = 0)$

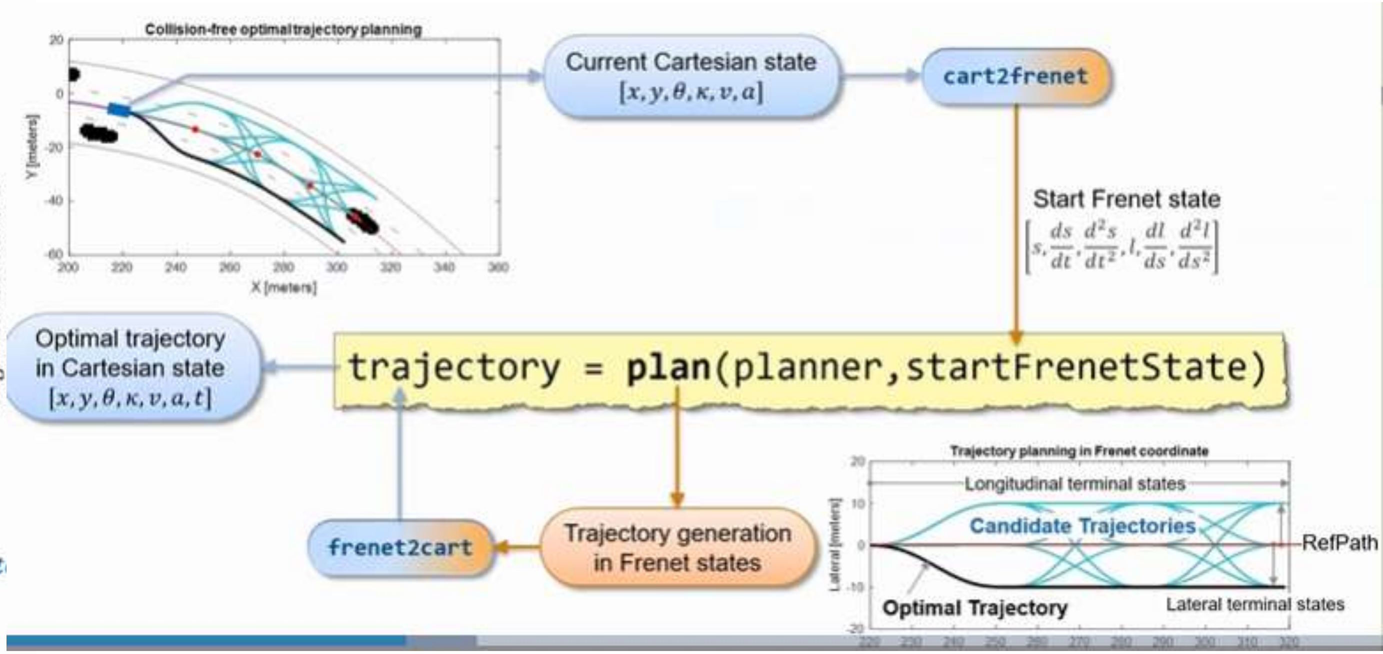
$$a_0 = s_{start}$$
$$a_1 = \dot{s}_{start}$$
$$2a_2 = \ddot{s}_{start}$$

- End boundary conditions $(t = t_f)$

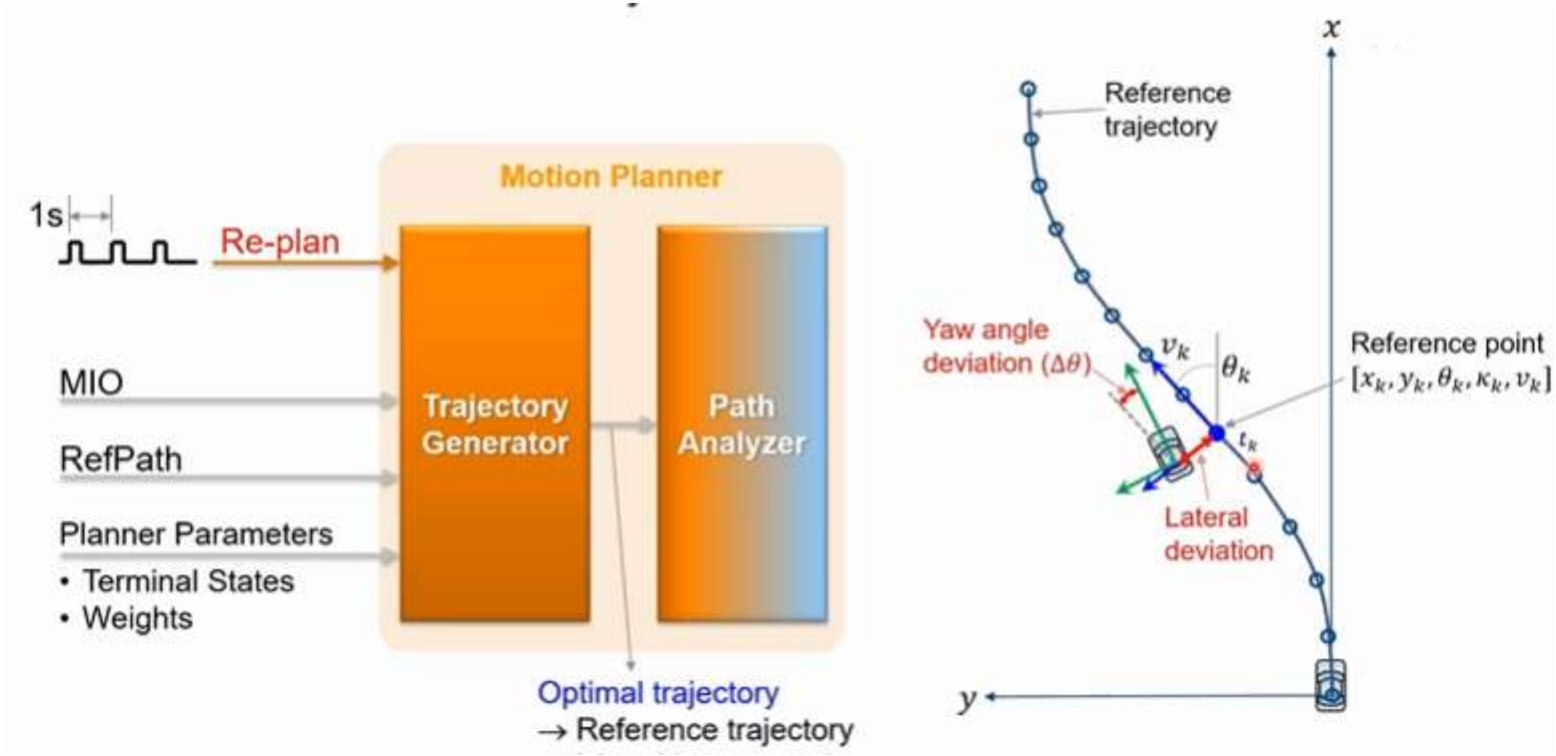
$$a_5t_f^5 + a_4t_f^4 + a_3t_f^3 + a_2t_f^2 + a_1t_f + a_0 = s_{end}$$
$$5a_5t_f^4 + 4a_4t_f^3 + 3a_3t_f^2 + 2a_2t_f + a_1 = \dot{s}_{end}$$
$$20a_5t_f^3 + 12a_4t_f^2 + 6a_3t_f + 2a_2 = \ddot{s}_{end}$$



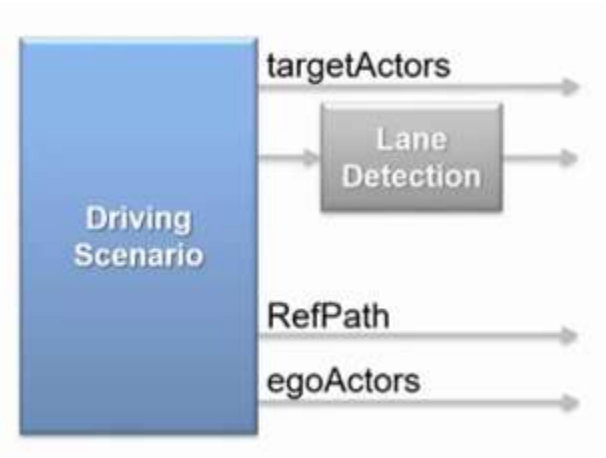
Frenet Coordinate

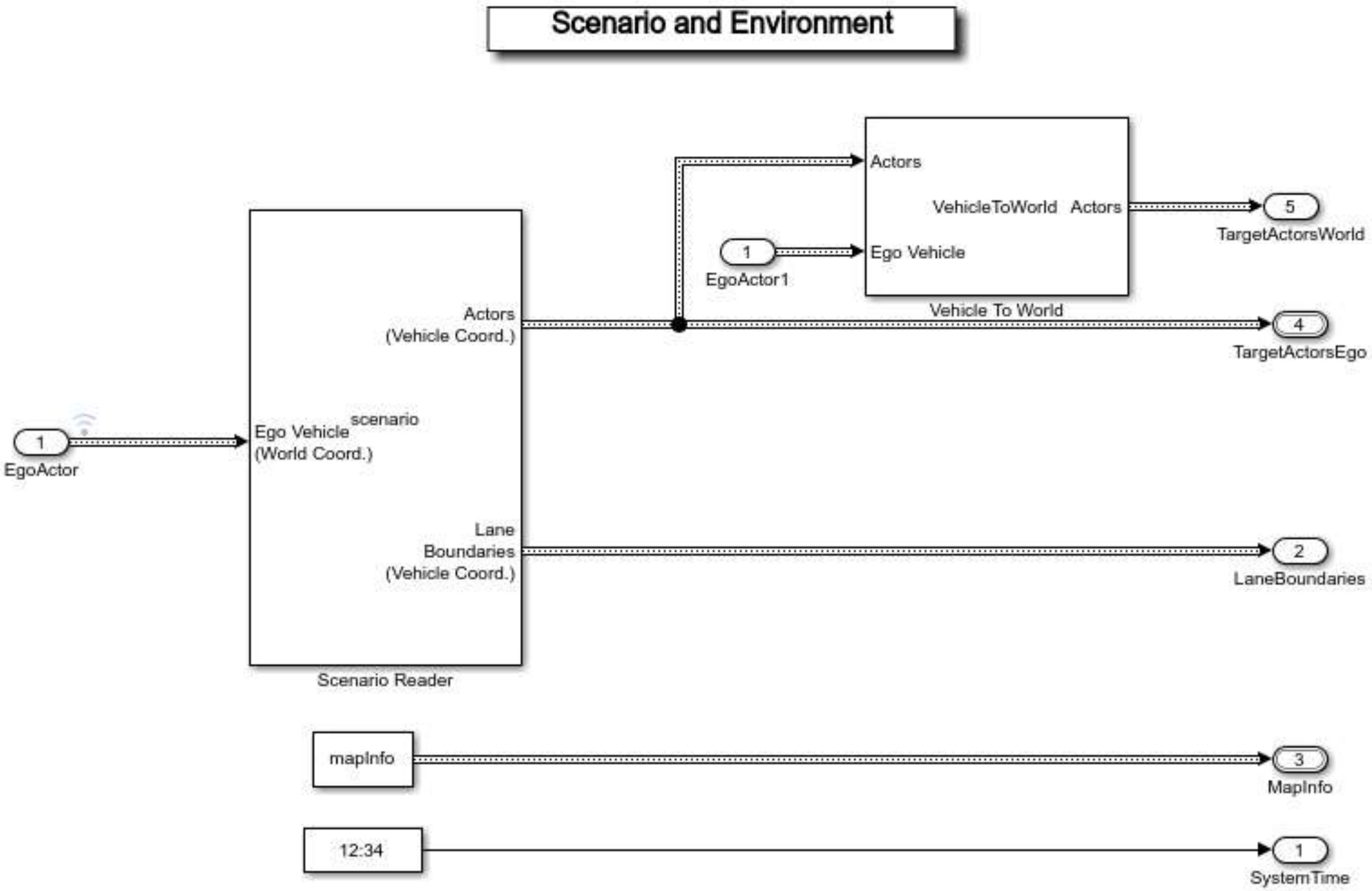


Path Analyzer



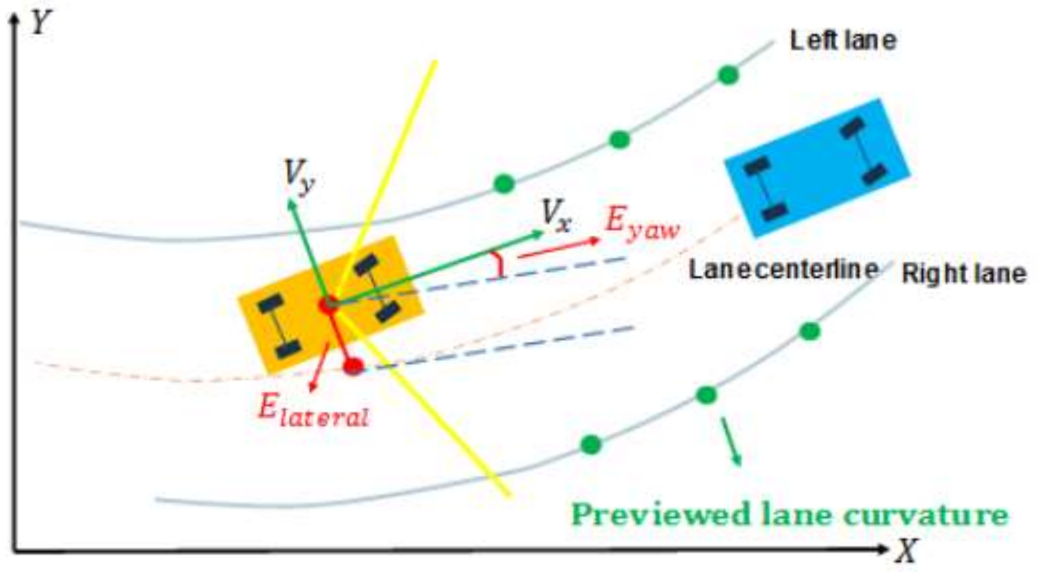
Scenario Reader





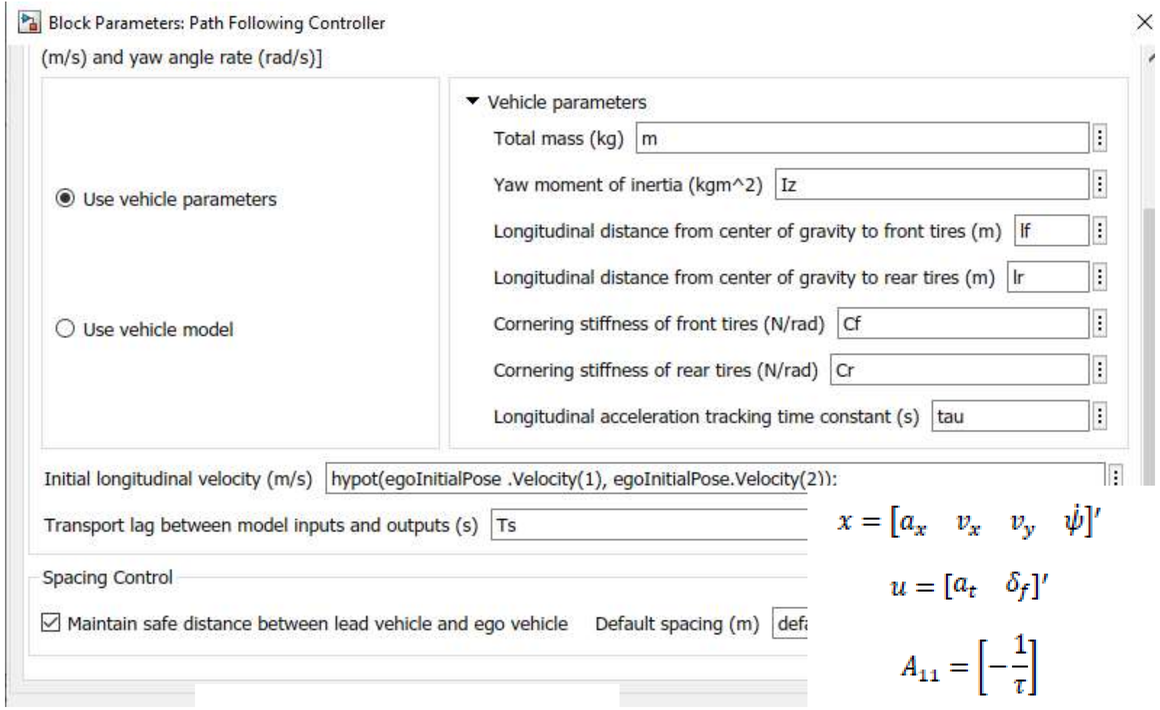
Path Following MPC

- The Path Following Control System block simulates a path-following control (PFC) system that keeps an ego vehicle traveling along the center of a straight or curved road while tracking a set velocity and maintaining a safe distance from a lead vehicle. To do so, the controller adjusts both the longitudinal acceleration and front steering angle of the ego vehicle. The block computes optimal control actions while satisfying safe distance, velocity, acceleration, and steering angle constraints using adaptive model predictive control (MPC).



Path Following MPC

- The Path following MPC has state-space representations for the longitudinal and lateral vehicle modes. The models are used to estimate the vehicle's states



The longitudinal states are defined as:

$$x = [a_x \quad v_x]'$$

The longitudinal throttle input is defined as:

$$u = [a_t]'$$

The Longitudinal Predictive Model state-space representatio

$$\dot{x} = Ax + Bu$$

$$A_{11} = \left[-\frac{1}{\tau}\right]$$

$$B_{11} = \left[\frac{1}{\tau}\right]$$

$$\dot{x} = \begin{bmatrix} A_{11} & 0 \\ 1 & 0 \end{bmatrix} x + \begin{bmatrix} B_{11} \\ 0 \end{bmatrix} u$$

The lateral states are defined as:

$$x = [v_y \quad \dot{\psi}]'$$

The lateral input steering angle is defined as:

$$u = [\delta_f]'$$

The Lateral Predictive Model state-space representation is

$$A_{11} = \left[-\frac{2(C_f + C_r)}{mU}\right]$$

$$A_{12} = \left[-U - \frac{2(aC_f - l_r C_r)}{mU}\right]$$

$$A_{21} = \left[-\frac{2(aC_f - l_r C_r)}{I_{zz} U}\right]$$

$$A_{22} = \left[-\frac{2(l_f{}^2 C_f + l_r{}^2 C_r)}{I_{zz} U}\right]$$

$$B_{11} = \left[-\frac{2C_f}{m}\right]$$

$$B_{21} = \left[\frac{2 l_f C_f}{I_{zz}}\right]$$

$$\dot{x} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} x + \begin{bmatrix} B_{11} \\ B_{12} \end{bmatrix} u$$

$$x = [a_x \quad v_x \quad v_y \quad \dot{\psi}]'$$

$$u = [a_t \quad \delta_f]'$$

$$A_{11} = \left[-\frac{1}{\tau}\right]$$

$$A_{33} = \left[-\frac{2(C_f + C_r)}{mU}\right]$$

$$A_{34} = \left[-U - \frac{2(l_f C_f - l_r C_r)}{mU}\right]$$

$$A_{43} = \left[-\frac{2(l_f C_f - l_r C_r)}{I_{zz} U}\right]$$

$$A_{44} = \left[-\frac{2(l_f{}^2 C_f + l_r{}^2 C_r)}{I_{zz} U}\right]$$

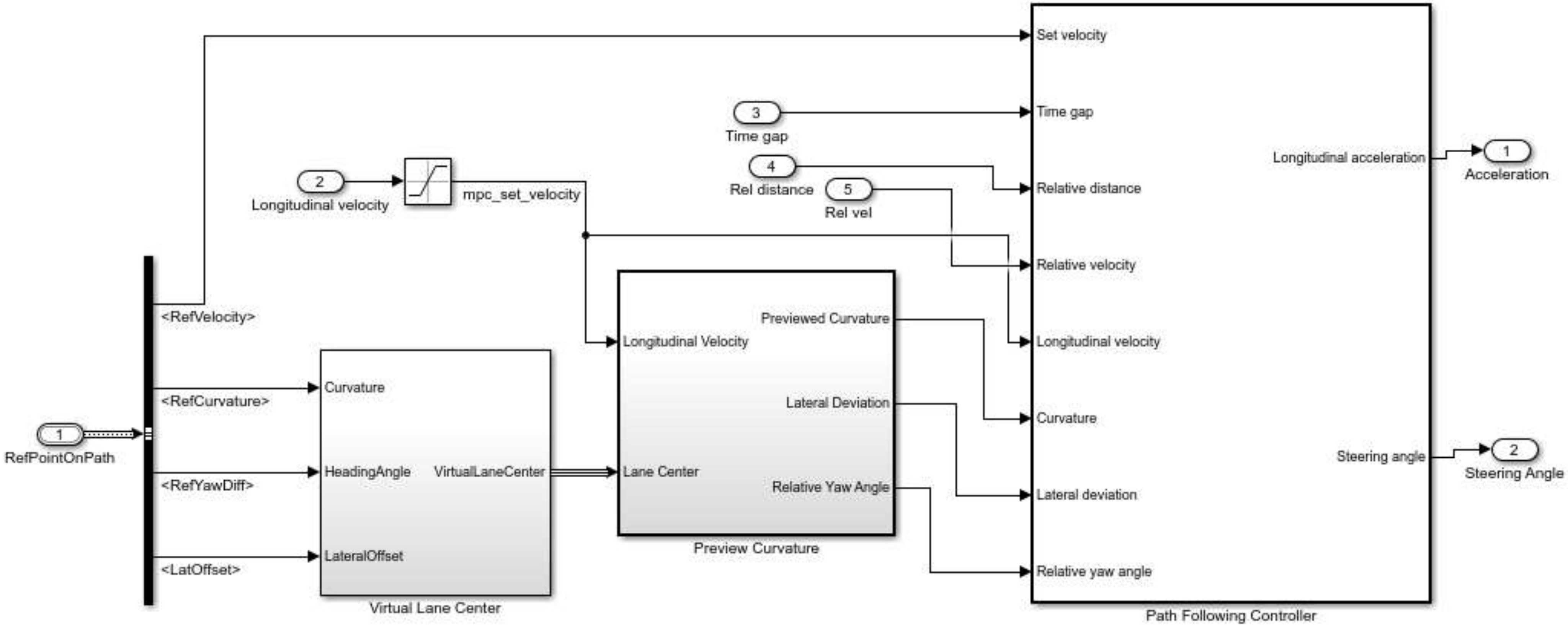
$$B_{11} = \left[\frac{1}{\tau}\right]$$

$$B_{31} = \left[-\frac{2C_f}{m}\right]$$

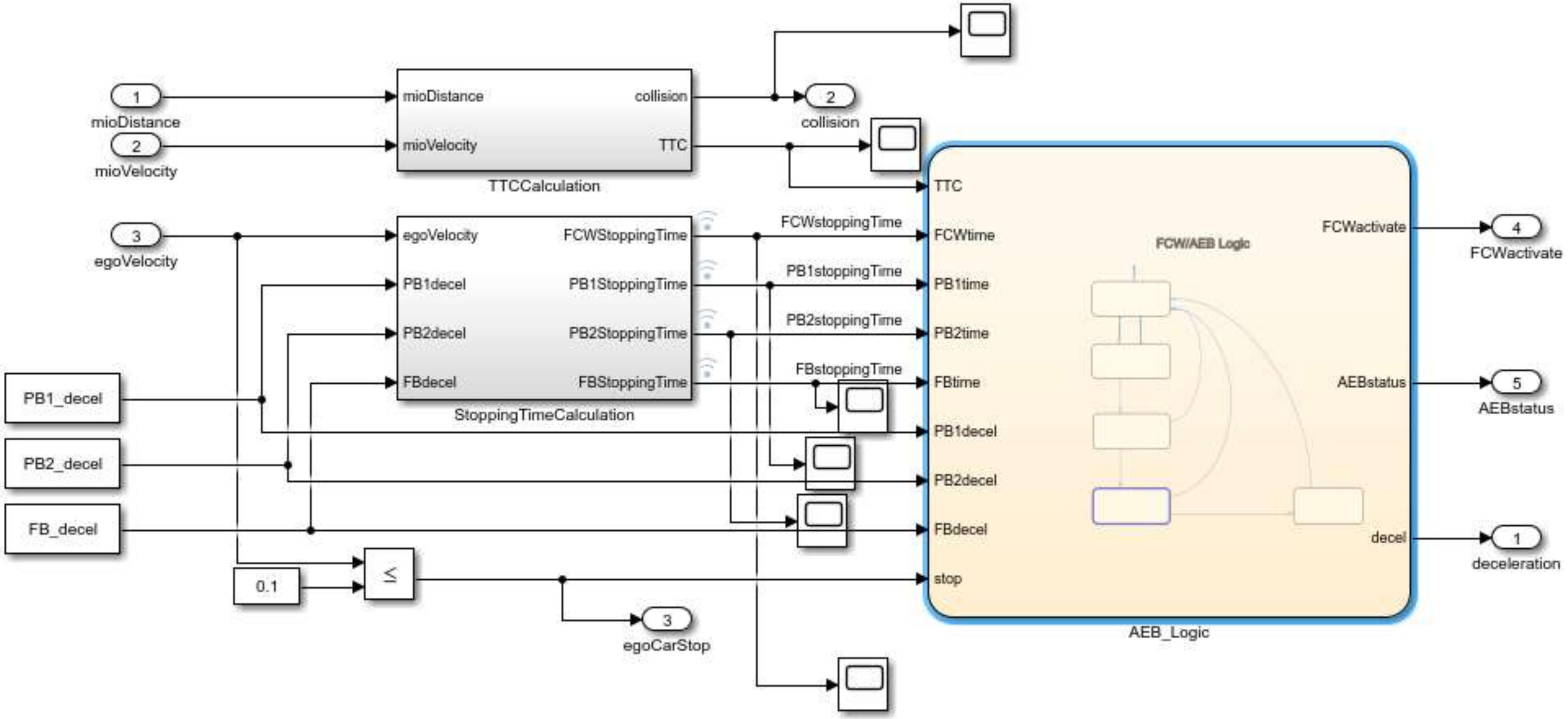
$$B_{41} = \left[\frac{2 l_f C_f}{I_{zz}}\right]$$

$$\dot{x} = \begin{bmatrix} A_{11} & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & A_{33} & A_{34} \\ 0 & 0 & A_{43} & A_{44} \end{bmatrix} x + \begin{bmatrix} B_{11} \\ 0 \\ B_{31} \\ B_{41} \end{bmatrix} u$$

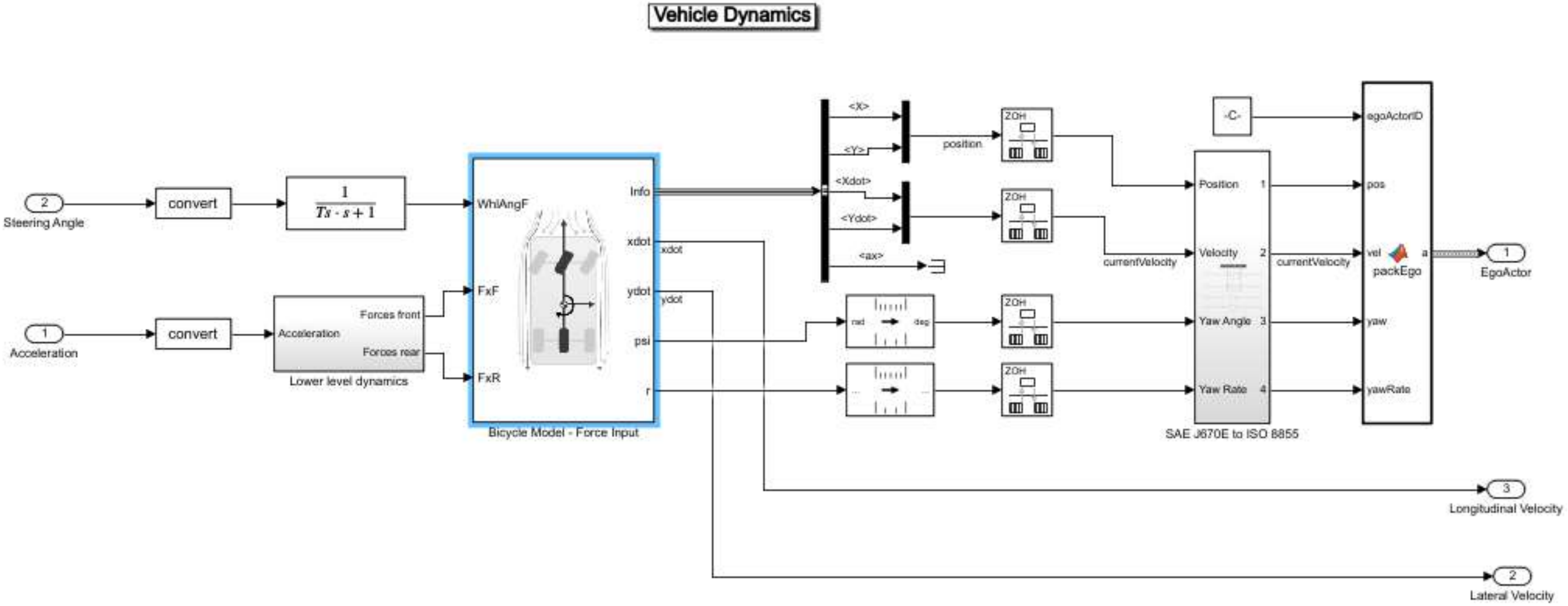
Path Following Controller Simulink



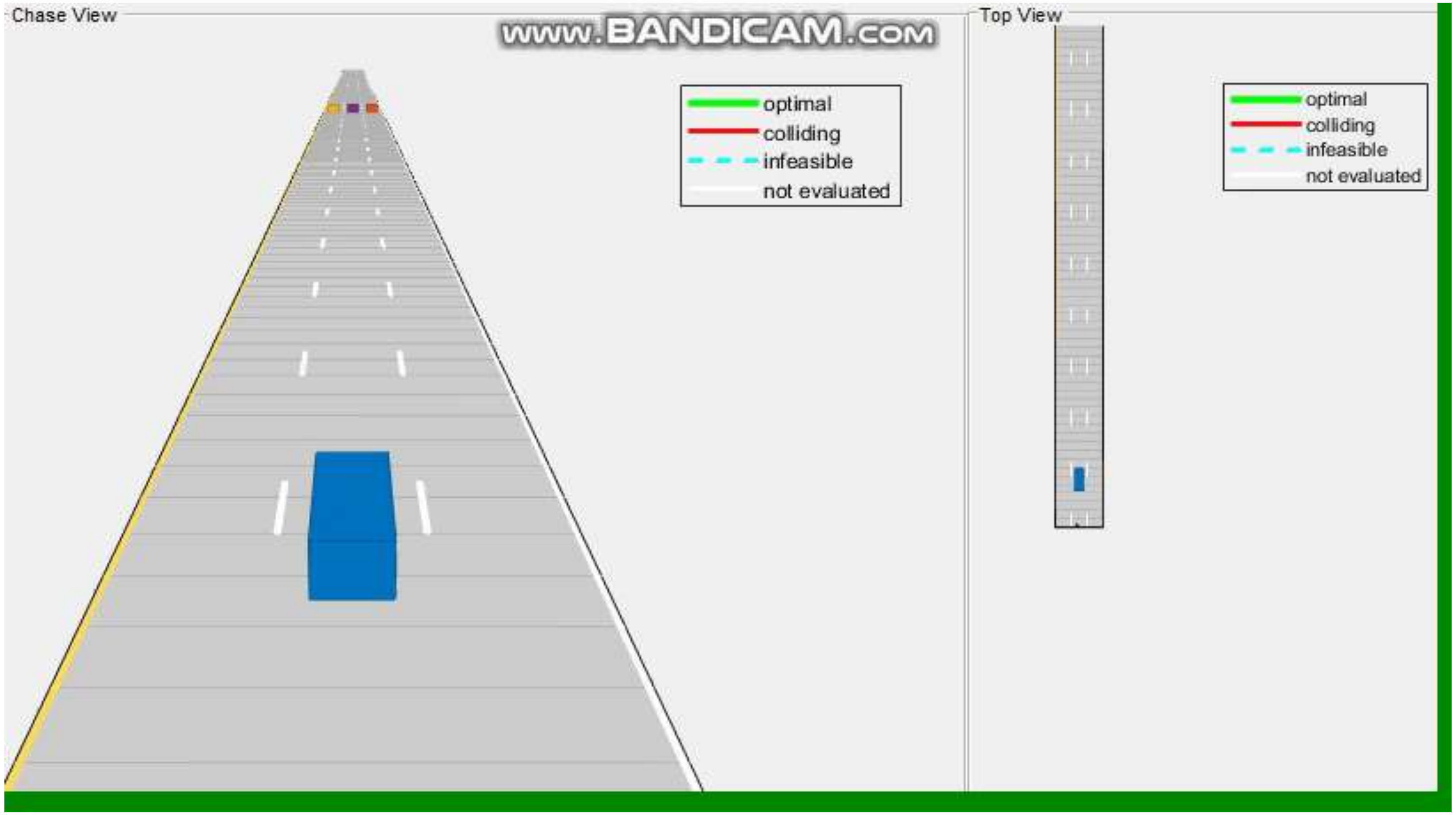
AEB Controller Simulink



Vehicle Model

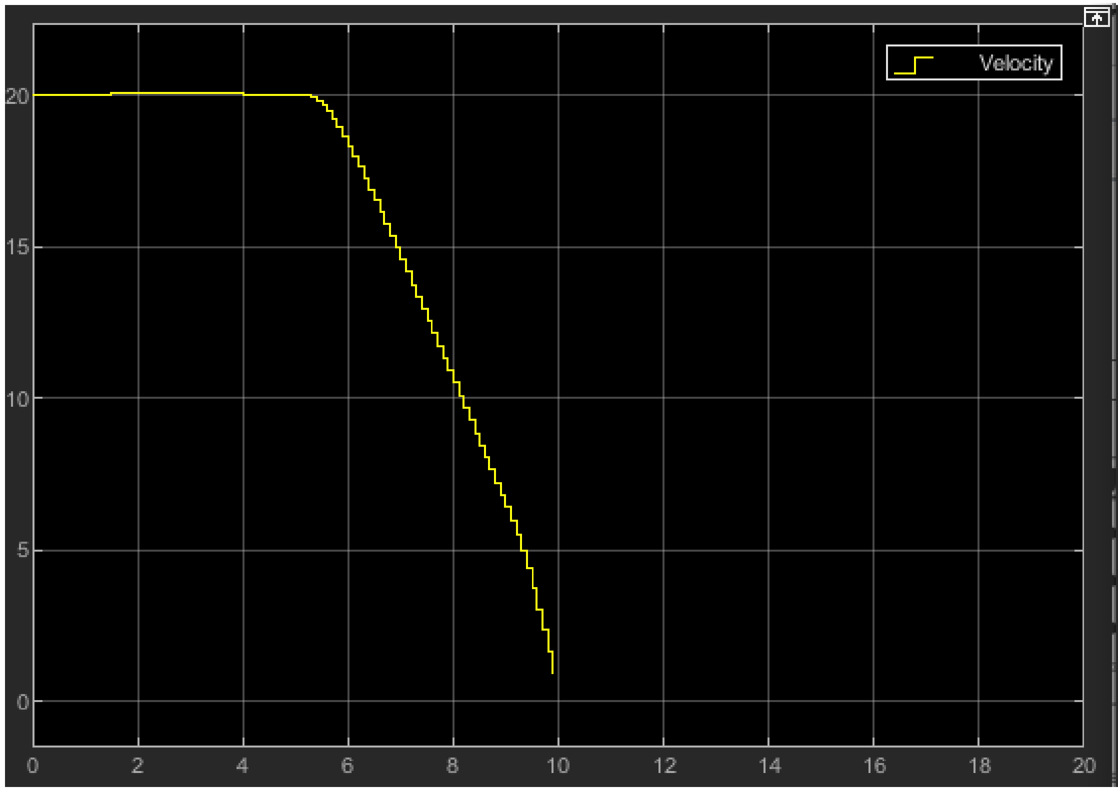


AEB test

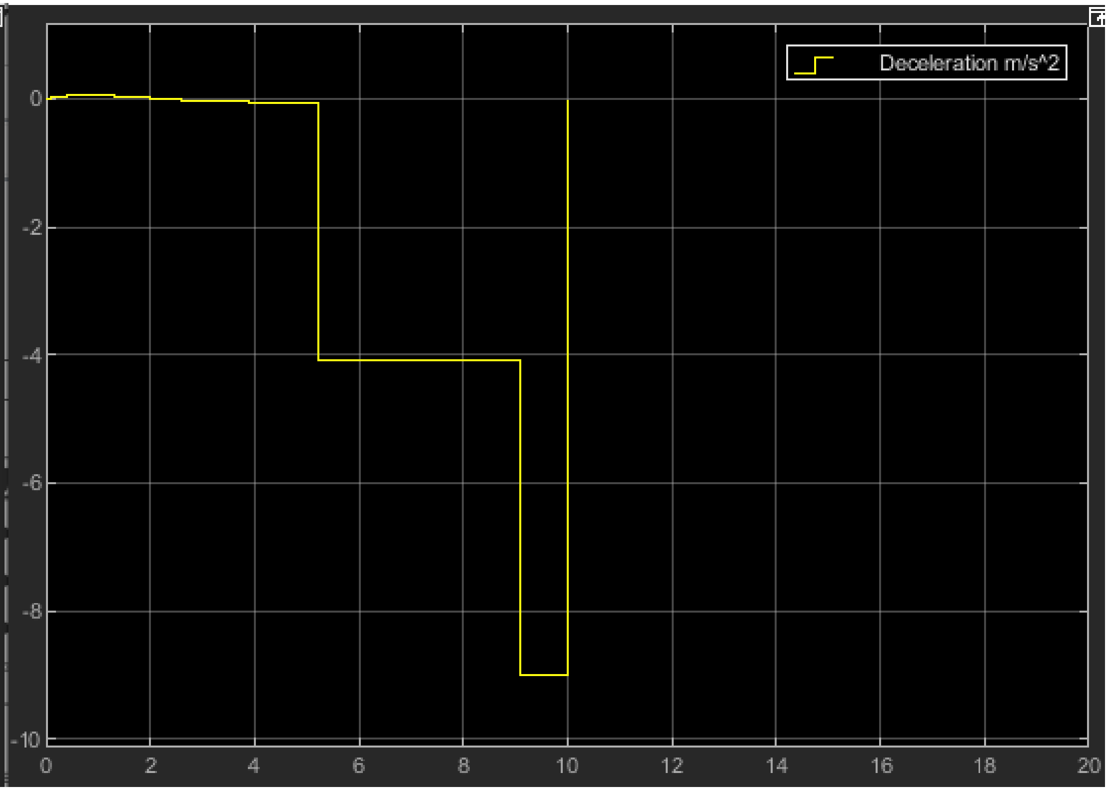


Chase View
www.BANDICAM.com
optimal
colliding
infeasible
not evaluated
Top View
optimal
colliding
infeasible
not evaluated

AEB test

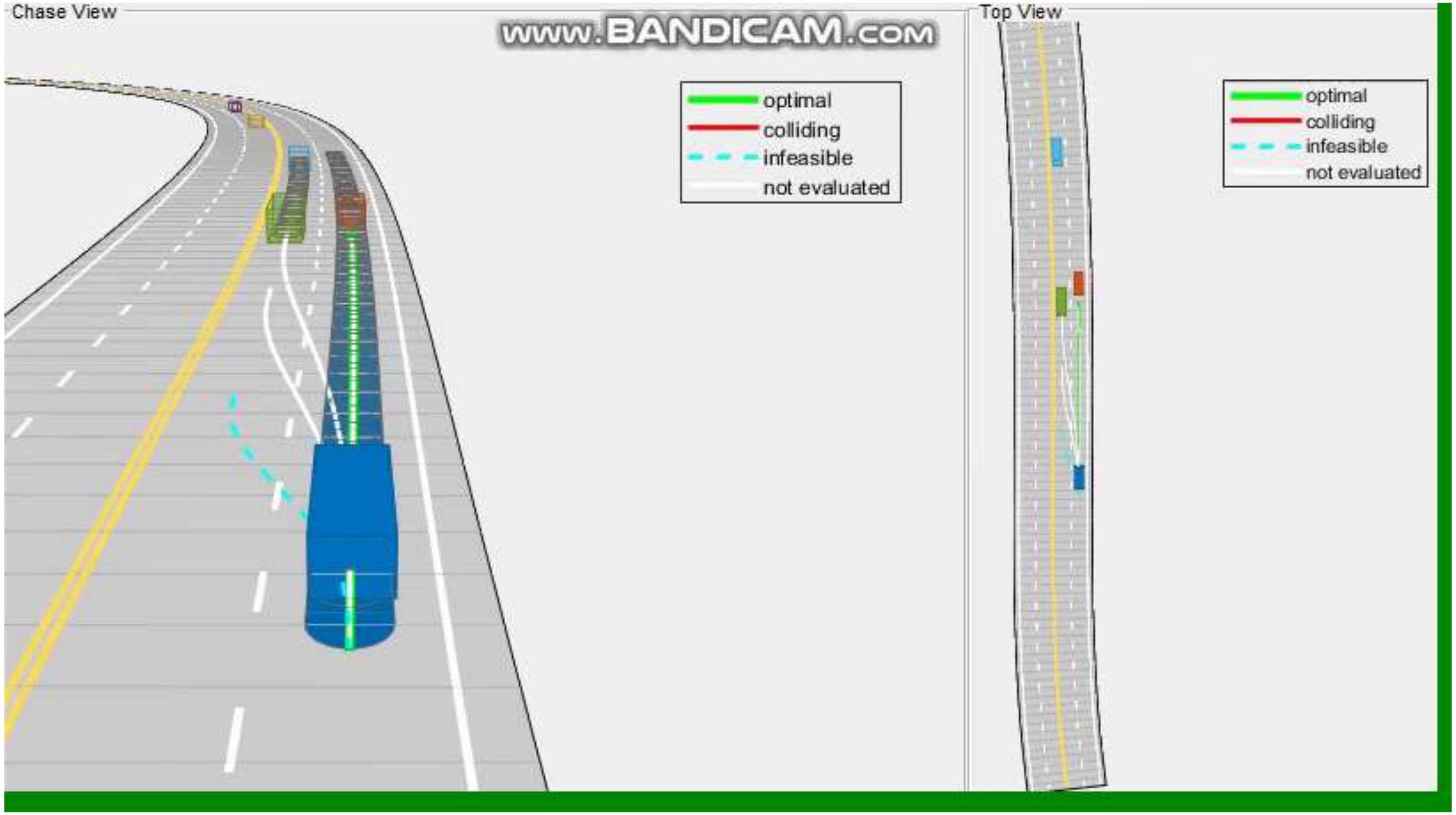


Velocity
20
15
10
5
0
0
2
4
6
8
10
12
14
16
18
20



Deceleration m/s^2
0
-2
-4
-6
-8
-10
0
2
4
6
8
10
12
14
16
18
20

Lane Change


Chase View
www.BANDICAM.com
optimal
colliding
infeasible
not evaluated
Top View
optimal
colliding
infeasible
not evaluated

Lane Change