Development of an Enhanced Heavy Duty Truck Autonomous Driving Simulation Environment

Bibin Pattel

Jairo Sandoval

Hoseinali Borhan

[Accelerated Technology Center – Cummins R&T]

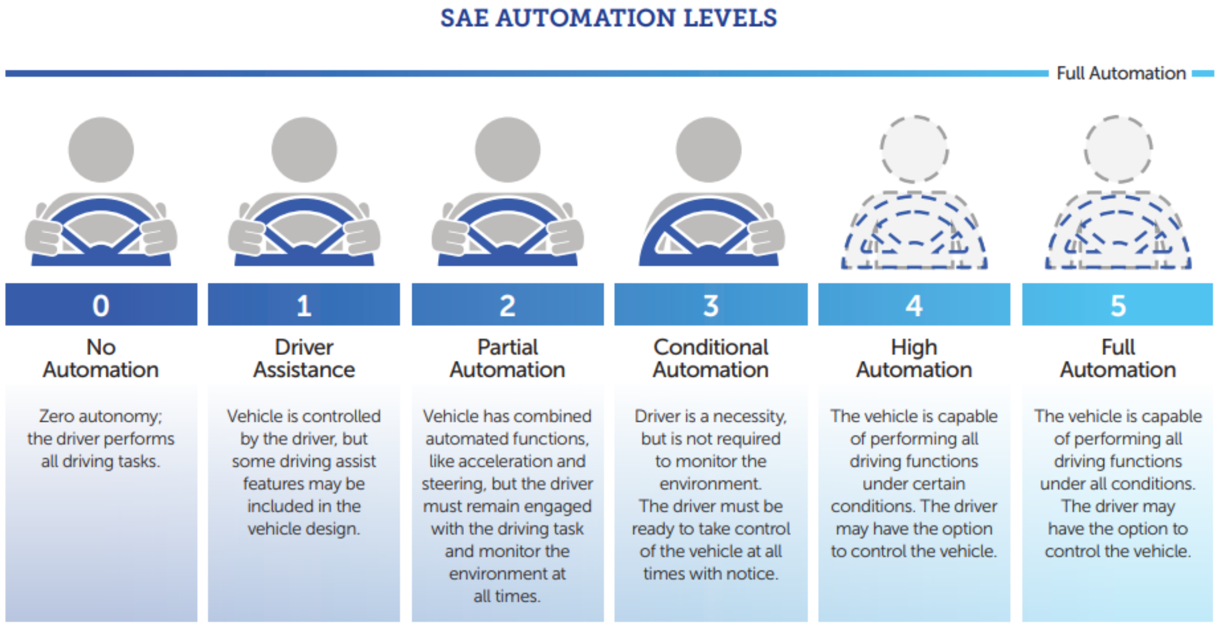
May 5, 2021

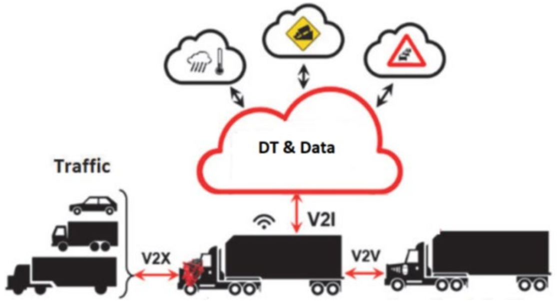
Outline

- Motivation: Connectivity and Advanced Driver Assist Systems (ADAS) and Automated Driving Systems (ADS) for Transportation
- Interaction of ADAS and ADS with the Powertrain Systems
- Need for Simulation Framework
- Simulation Framework Overview
  - Collaboration with MathWorks and integration of Mathworks Automated Driving Toolbox Motion Planning and Motion Control Features
- Identify Improvement Opportunities and Simulate Advanced Solutions on Different Scenarios

Motivation: Connectivity and ADAS/ADS for Transportation

- Only limited research/solutions available combining autonomous driving with Fuel/Energy Efficiency
- Extend our core competency and expertise in Powertrain controls development to help in system integration and automation
- Goal is to provide interface for ADAS/ADS solutions considering Powertrain Efficiency and Fuel/Energy Optimization
- Deep integration requirements between our powertrain, ADAS and ADS Suppliers and OEM





Cruise Control (CC)

Predictive Cruise Control (PCC)

Adaptive Cruise Control (ACC)

Co-Operative Adaptive Cruise Control (CACC)

Lane Keep Assist

Forward Collision Warning/Avoidance

More Longitudinal and **Less** Lateral Control

Path Planning

Behavior Planning

Perception

Trajectory Generation

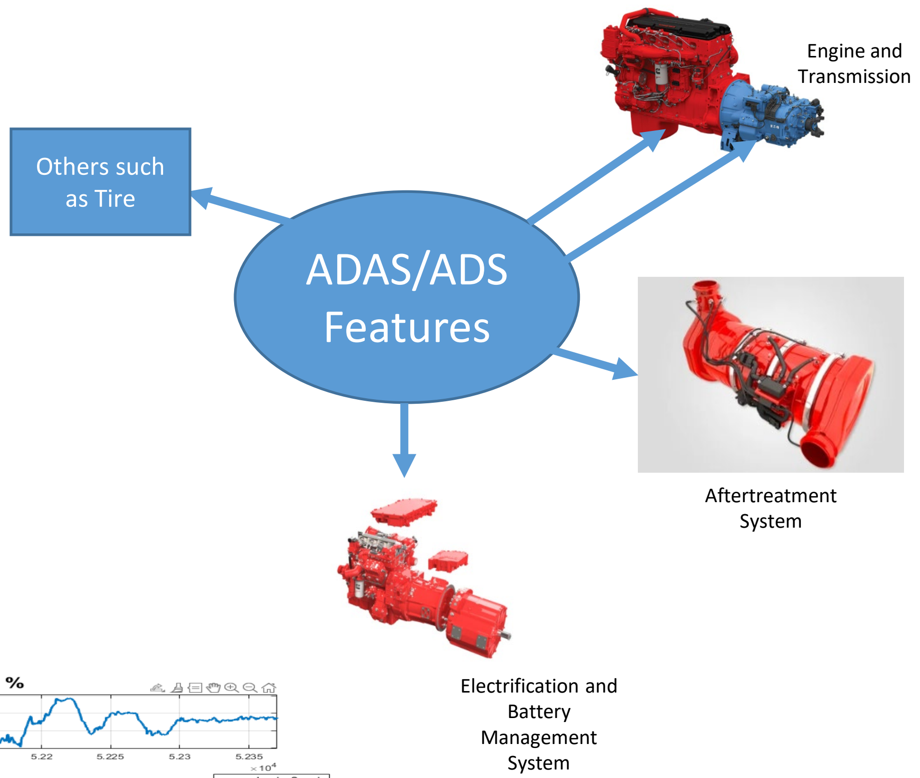
Motion Control

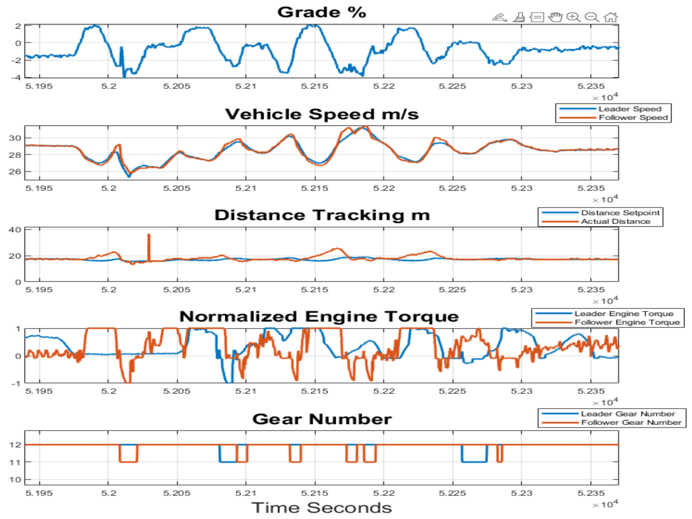
Longitudinal and Lateral Control

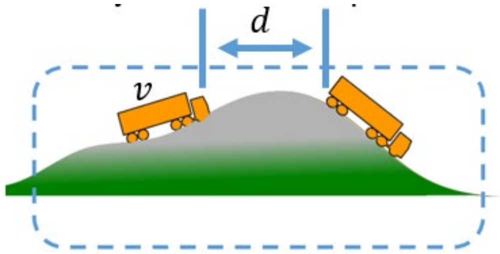
https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/automated-vehicles/320711/preparing-future-transportation-automated-vehicle-30.pdf

Interaction of ADAS and ADS with the Powertrain Systems

- Important to understand the interaction between the components and features: CACC Example
- Typically path planning/motion planning does not consider optimizing energy utilization of the powertrain system
  - Mostly considers start/end locations and trip time for global path planning
- Global path/speed profile can be optimized considering powertrain, road grade profiles, traffic etc.
- Local optimization during short horizon trajectory generation for
  - Lane change decisions
  - Opportunistic platooning





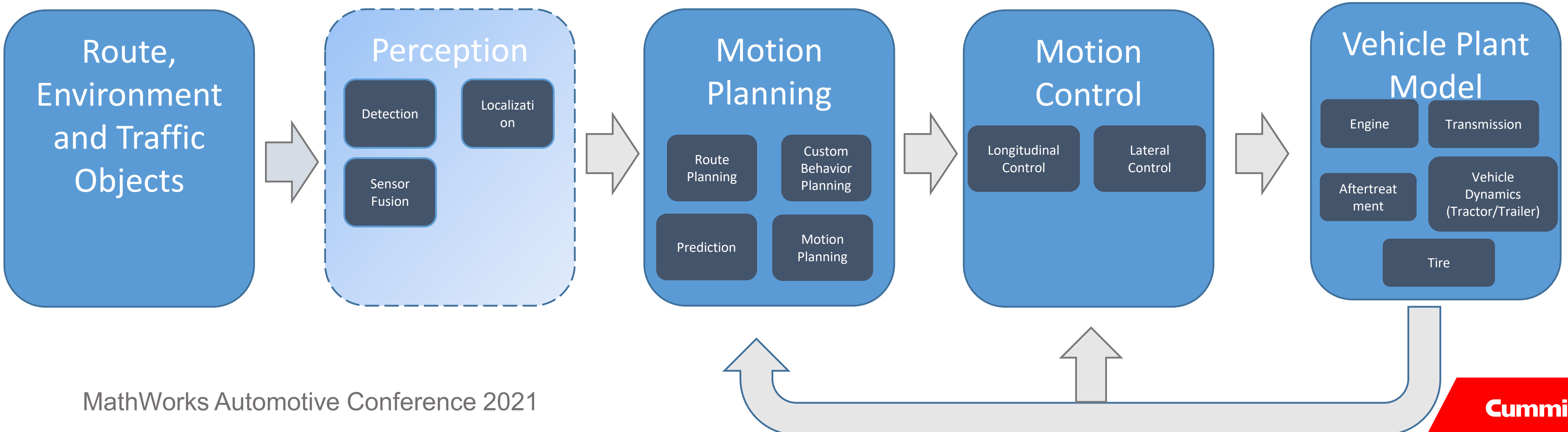


Need for Simulation Framework

- Plug and play interface for components and ADAS options for longitudinal and lateral control
- Assess existing and new controls
- Simulink as integration platform
  - Engine, Transmission, Aftertreatment
  - Different levels of fidelity of components

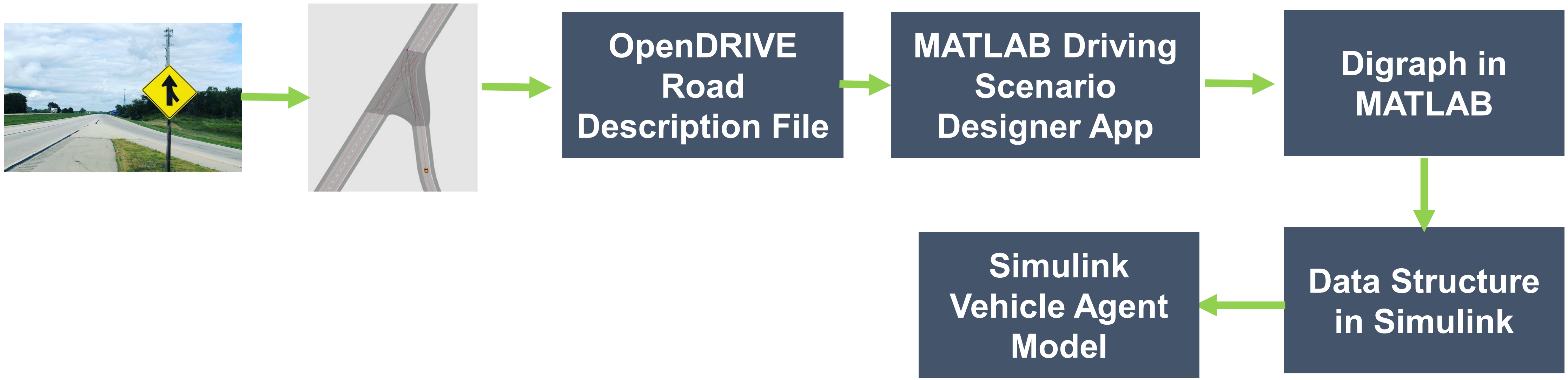
- Motion Planner and Motion Controller from Mathworks Automated Driving Toolbox
- IPG Truckmaker
  - Longitudinal and lateral vehicle dynamics
  - Tractor/Trailer/Tire models
  - Visualization

MATLAB + SIMULINK®

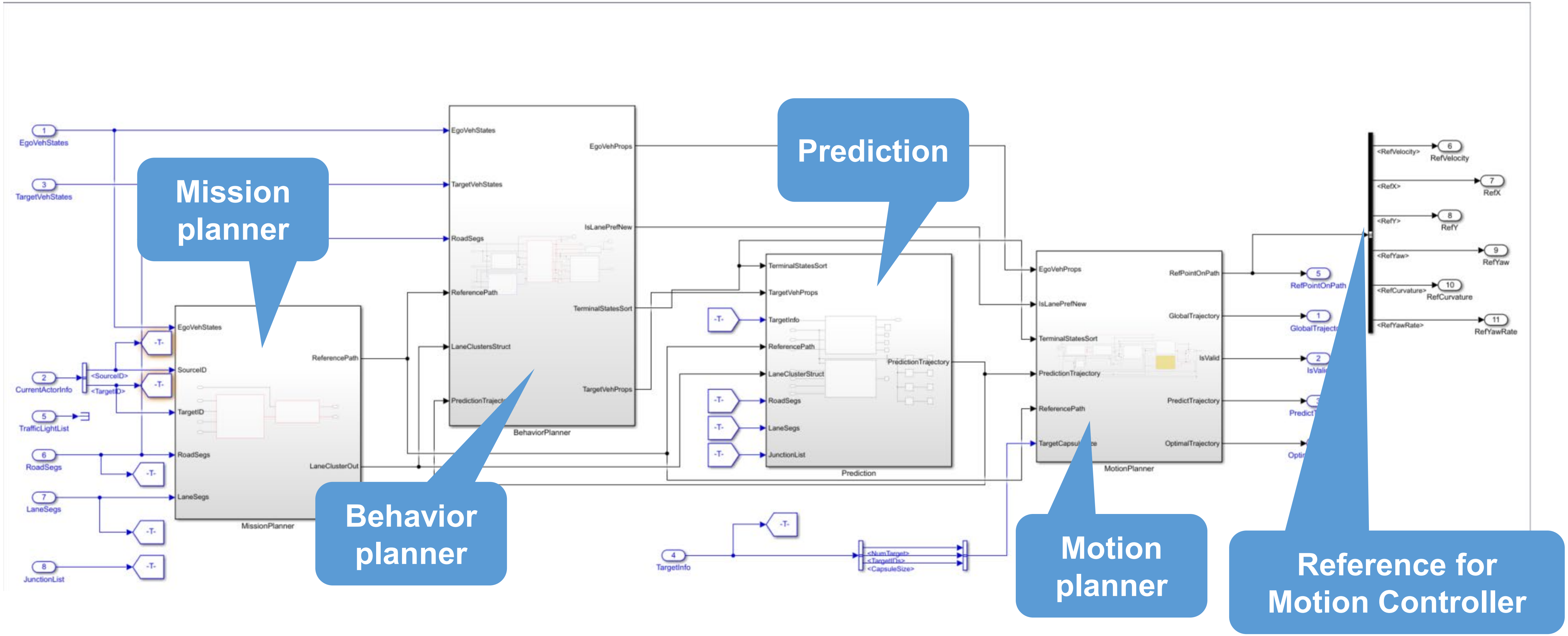


Importing Real World Routes/Scenarios

- Import real world road networks into the simulation framework using the OpenDrive file support
  - Elevation and Speed limit required
- OpenDrive is a standard open format specification for describing road networks

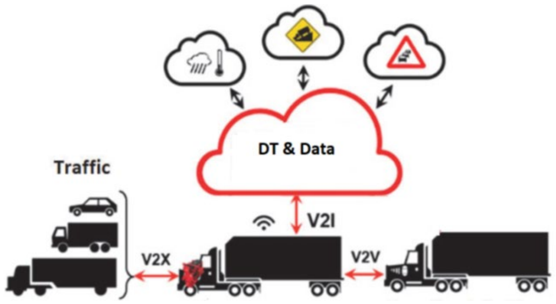


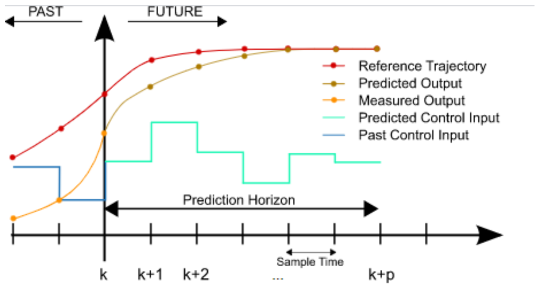
Motion Planning from Automated Driving Toolbox (Customized)



Custom Behavior Layer

- Customizable behavior layer for
  - Optimal speed target, preferred lane, target gaps to the front and rear vehicles
  - For example inhibit lane change under certain conditions
- Can interface advanced control methodologies to utilize connectivity, and look ahead information
  - Model Predictive Control (Online)
  - Dynamic Programming for global optimization (Offline + Cloud connectivity)

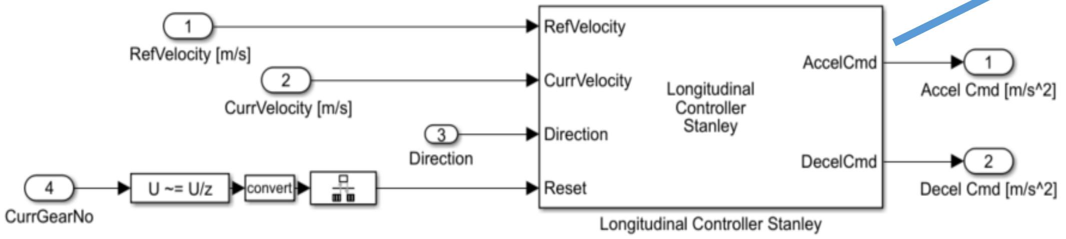


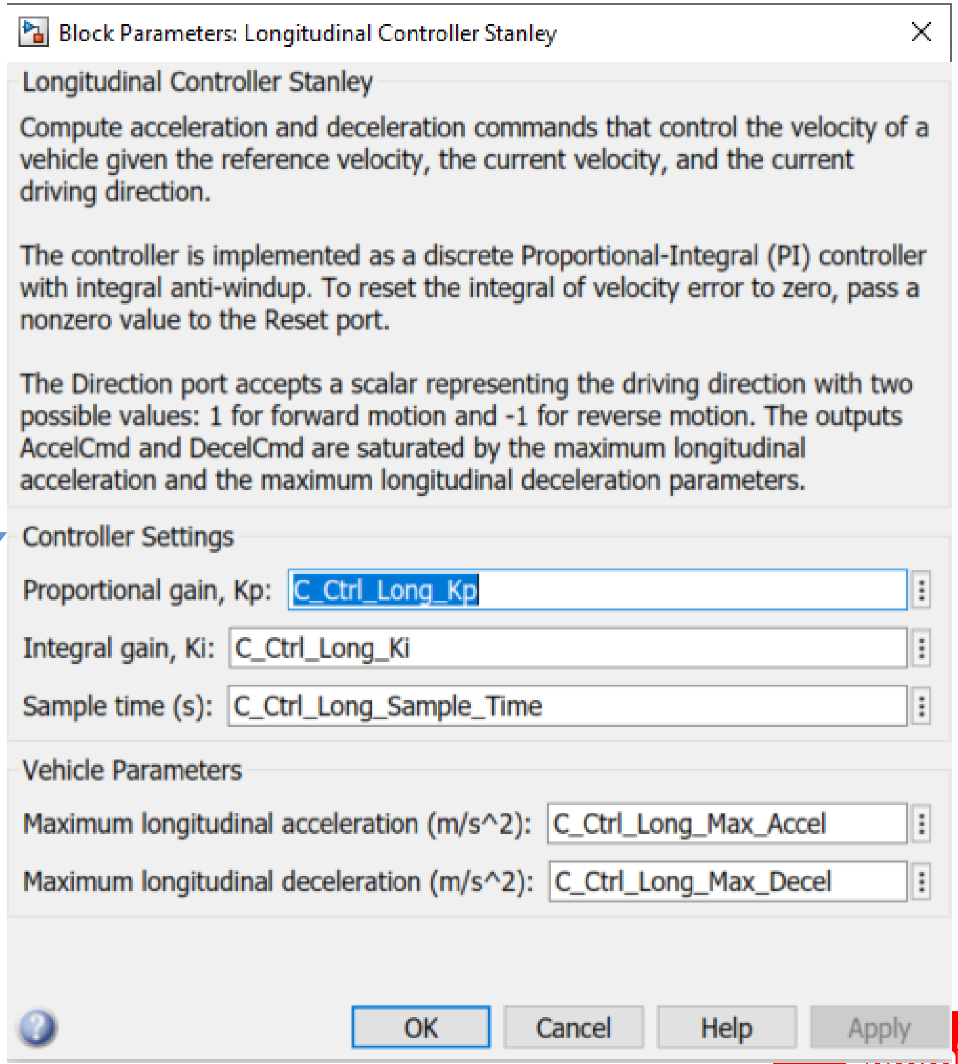


Motion Tracking Controllers from Automated Driving Toolbox

- Longitudinal and Lateral Stanley controllers from Automated Driving System toolbox
- Tunable controller parameters makes it easy to adapt these controllers for different class of vehicles
  - Gains
  - Acceleration/Deceleration Limits
  - Mass
  - Steering Angle

Longitudinal Motion Tracking Controller

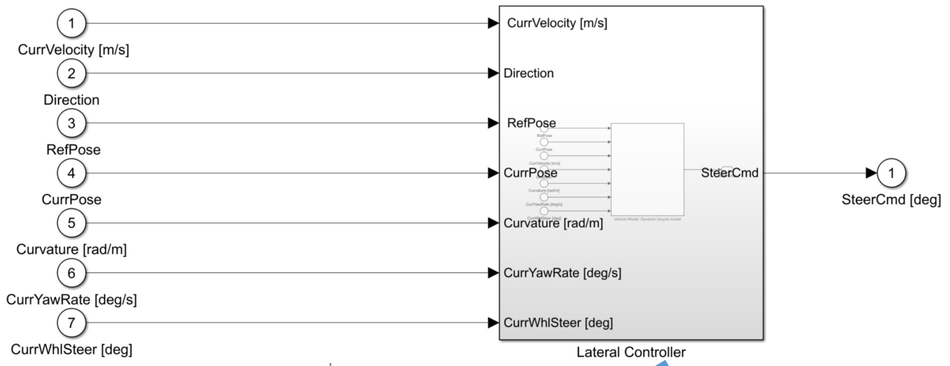


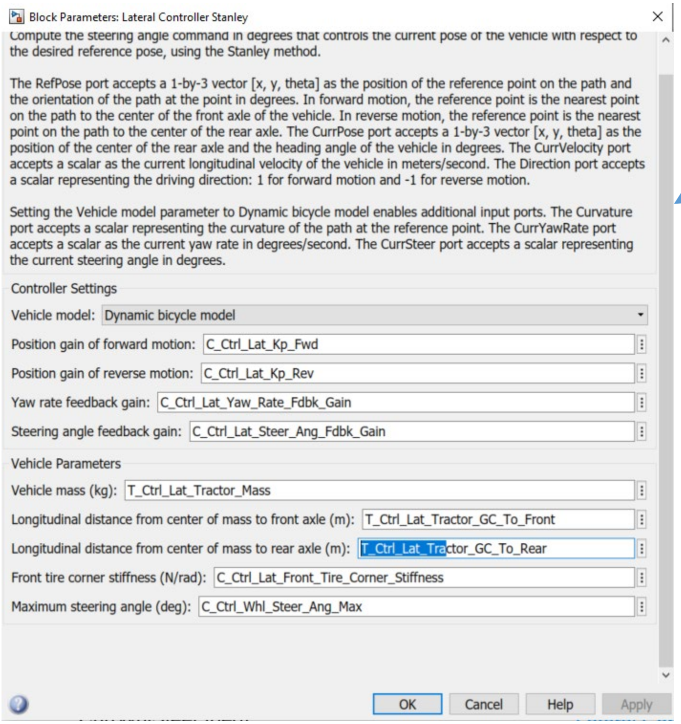


Motion Tracking Controllers from Automated Driving Toolbox

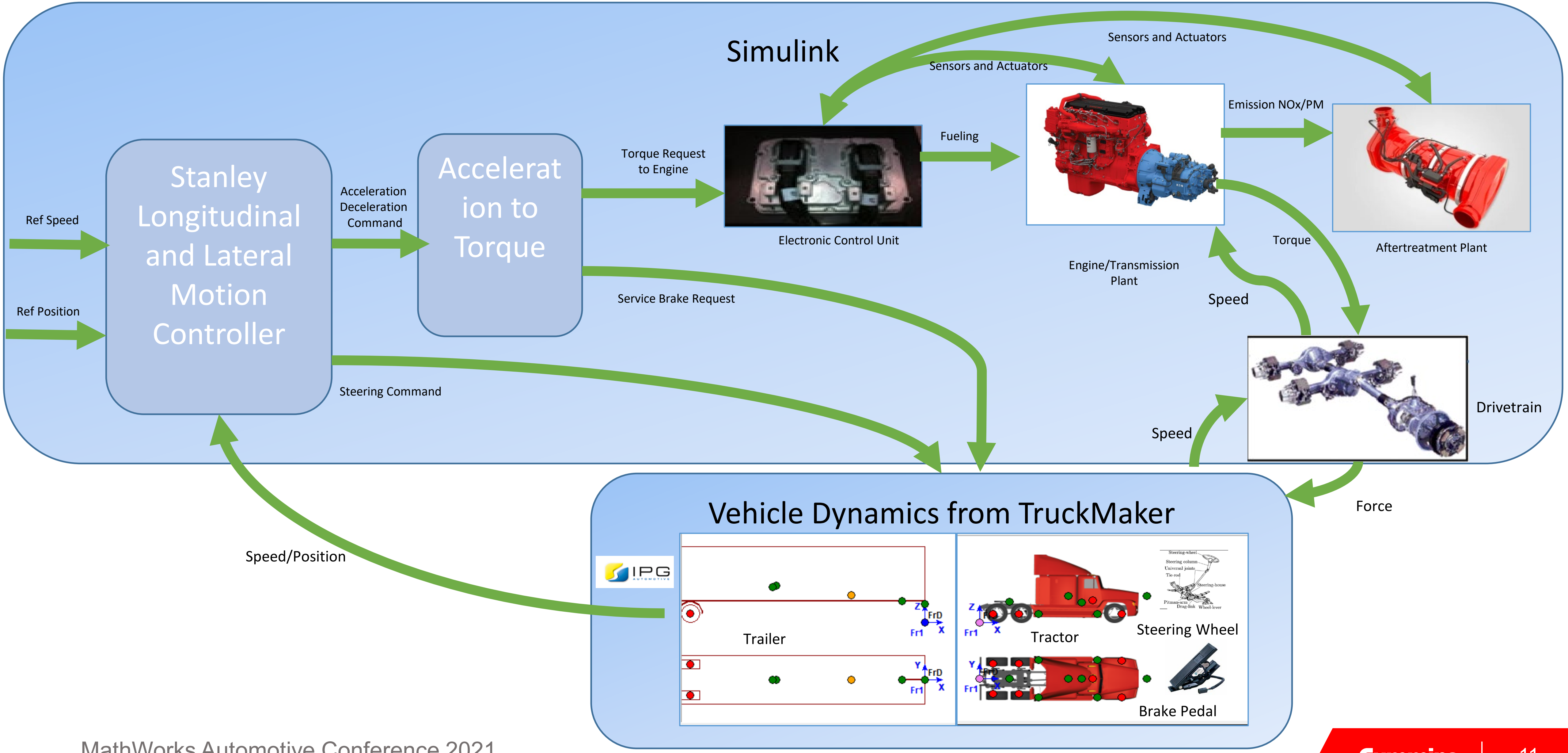
- Longitudinal and Lateral Stanley controllers from Automated Driving System toolbox
- Tunable controller parameters makes it easy to adapt these controllers for different class of vehicles
  - Gains
  - Acceleration/Deceleration Limits
  - Mass
  - Steering Angle

Lateral Motion Tracking Controller

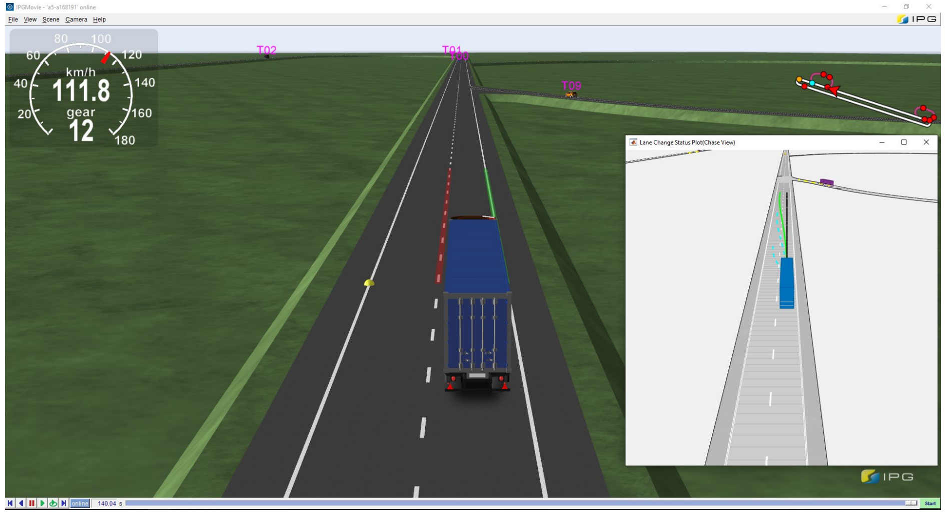


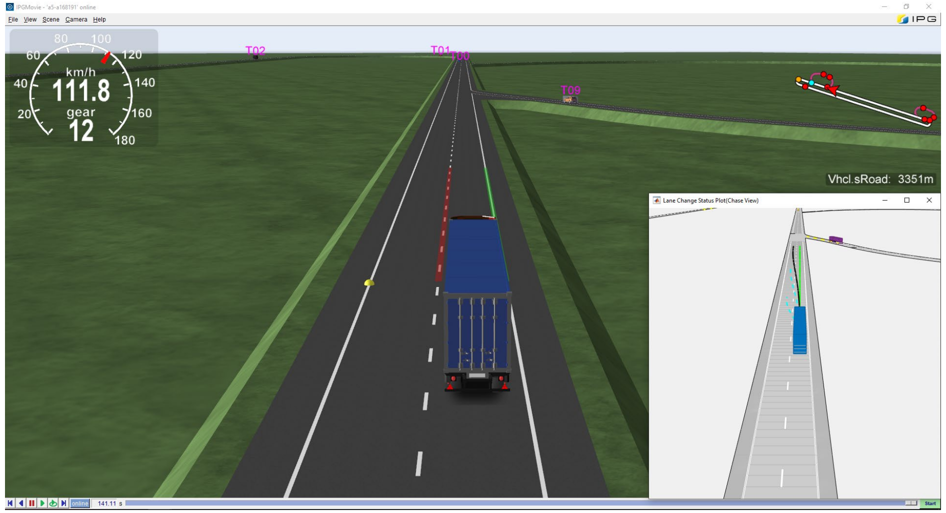


Motion Controller and Vehicle Dynamics

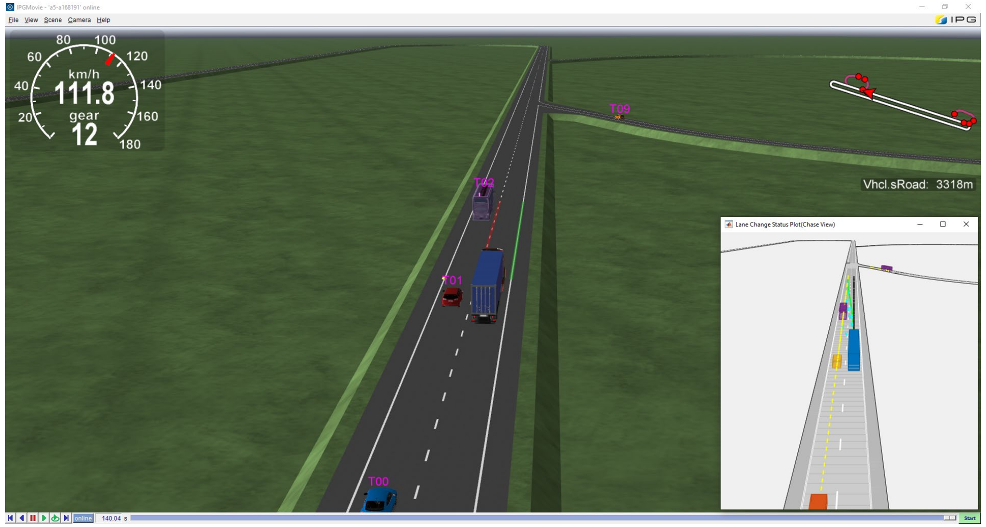


Scenario 1.1: Highway Passenger Car Merging



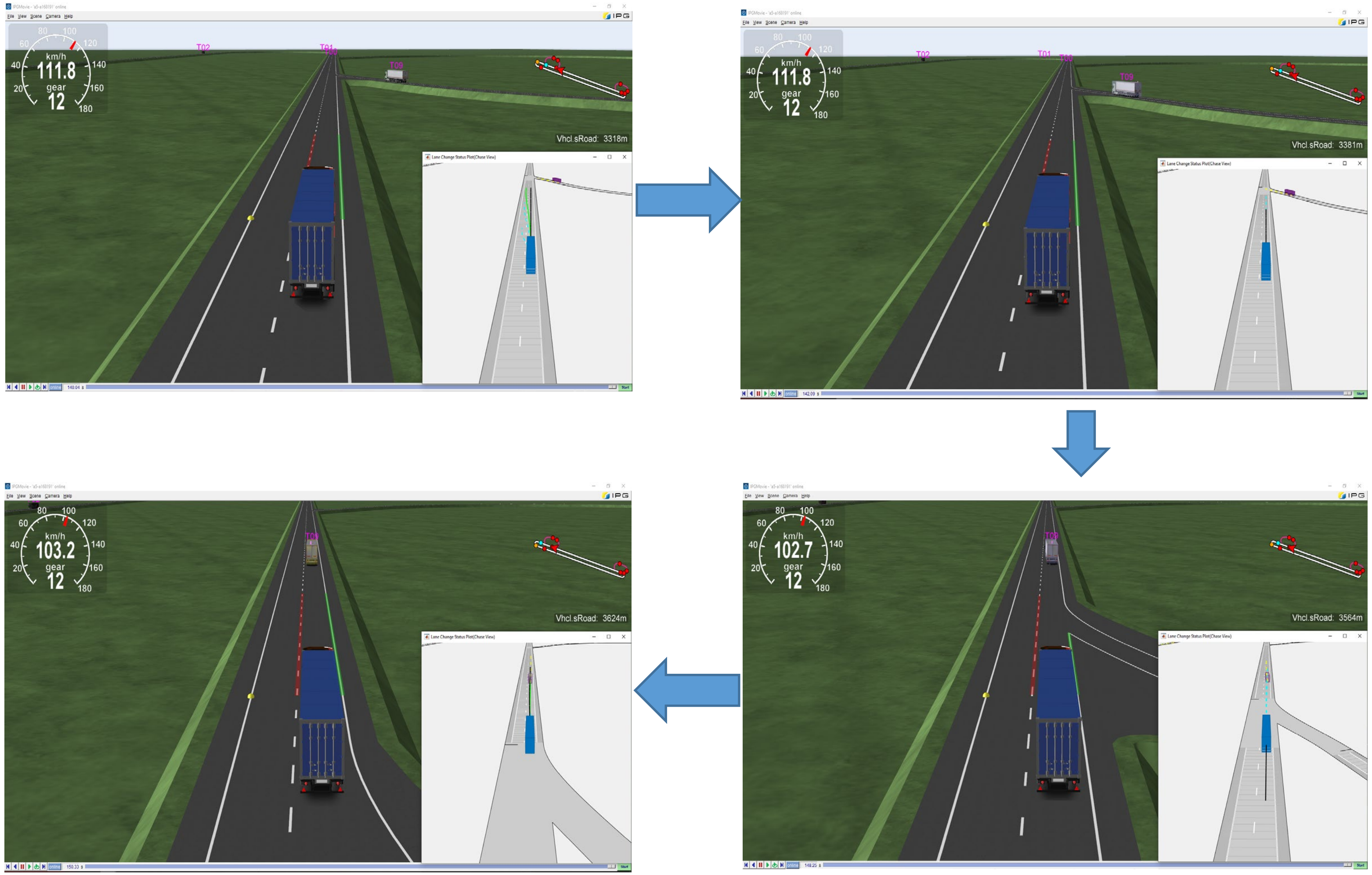


- Merging scenario with left lane occupied
  - Option 1: Go with the target speed and at the merge apply deceleration or brake => Energy Loss
  - Option 2: Coast down to the merge (Zero Fueling) , and then change to left lane => Energy Efficient



Scenario 1.2: Highway Truck Merging Opportunity for Platooning

- If the truck which is merging is equipped with V2V / DSRC communication and exchange information such as the destinations, planned paths, trip times, their weights etc. and decide to form platoon instead of changing lane and trying to overtake
- Drag reduction benefits



Concluding remarks

- Used MATLAB, Simulink as a plug and play simulation integration platform for evaluating existing and new control strategies for ADAS features
- With MathWorks collaboration and support, blocks and algorithms from Automated Driving Toolbox are used for Motion Planning and Motion Control, with customized behavior planner
- Integrated with IPG Truckmaker for detailed vehicle dynamics, visualization, and Traffic objects interaction
- Developed plug and play interface ready to be used with Motion planning/control features from different ADAS suppliers

Cummins®

www.cummins.com

Email: bibin.n.pattel@cummins.com