

MathWorks **AUTOMOTIVE CONFERENCE 2022** North America

**Design of vehicle platooning controller
with V2V communication**

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Design of vehicle platooning controller with V2V communication

Platooning Controller example





Design Controller for Vehicle Platooning

Tune spacing controller for trailing vehicles in a platoon using PID Tuner.

[Open Live Script](#)

Simulink Control Design™
 Model-Based PID Controller Tuning
R2021b

V2V example



Point ID	Intersection Point (m)	Approx. Point Name (m)	Speed (m/s)
1	10.0, 10.0	1.02	6.02
2	10.0, 11.0	8.08	5.08
3	10.0, 12.0	9.09	7.47
4	10.0, 13.0	7.78	5.87



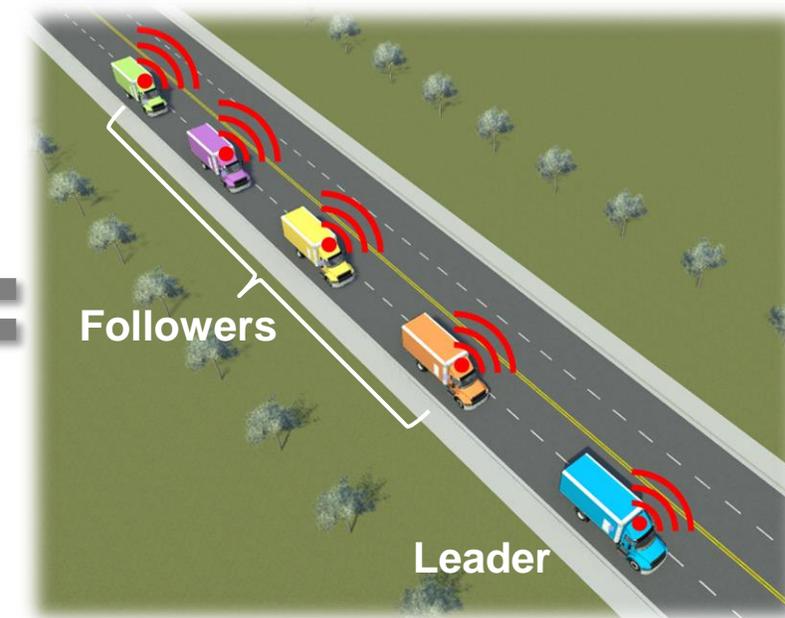
Intersection Movement Assist Using Vehicle-to-Vehicle Communication

Design intersection movement assist application using V2V communication.

[Open Example](#)

Automated Driving Toolbox™
R2022a

Platooning with V2V



Simulation for vehicle platooning controller with V2V communication

The image displays the MATLAB R2022a Simulink environment for a vehicle platooning simulation. The main workspace shows a Simulink model titled "FiveVehiclePlatoonTunedWithV2V". The model consists of a Leader vehicle and four Follower vehicles (Follower1 to Follower4). Each vehicle is represented by a block containing "Accel" and "ActorPose" sub-blocks. The Leader's "Accel" block receives input from a "double" signal source. The Follower vehicles receive "BusActorPose" signals from the Leader and other followers. Each Follower also has a "BSM" (Basic Safety Message) block that receives input from a "FIFO BSM" block (e.g., "FIFO BSM:1" for Follower1) and outputs "BusBSM" signals. The "PackAct" block is connected to the "ActorPose" outputs of all vehicles. The Simulink interface includes a toolbar with simulation controls (Run, Step Forward, Step Back, Stop) and a Property Inspector on the right.

The MATLAB R2022a interface shows the current folder "C:\06_Project\Platooning\PlatooningControlWithV2V". The file browser displays the following structure:

- Folder: .git
- Folder: AddVehicleDynamics
- Folder: bak
- Folder: doc
- Folder: resources
- Folder: slprj
- Folder: study
- Text Document: .gitattributes, .gitignore
- Class: HelperV2VReceiver.m, HelperV2VTransmitter.m, PackActorsInfo.m, VisualizePlatoon.m
- Function: helperActorInfo.m, plotPlatoonResults.m, setInitialBSM.m, stateFcnTruckTrailer.m
- Script: createBus.m, helperCreateV2VEnumDa..., helperFiveVehiclePlatoon..., helperFiveVehiclePlatoon..., helperFiveVehiclePlatoon..., helperFiveVehiclePlatoon...
- MAT-file: V2XChannellInfo.mat
- Project: PlatooningControlWithV...
- Simulink Model: dynamics.slx, dynamics_2.slx, fiveVehiclePlatoonDigital..., fiveVehiclePlatoonDigital..., fiveVehiclePlatoonInitial..., fiveVehiclePlatoonInitial..., fiveVehiclePlatoonTuned..., fiveVehiclePlatoonTuned...
- Simulink Cache: fiveVehiclePlatoon.slxc

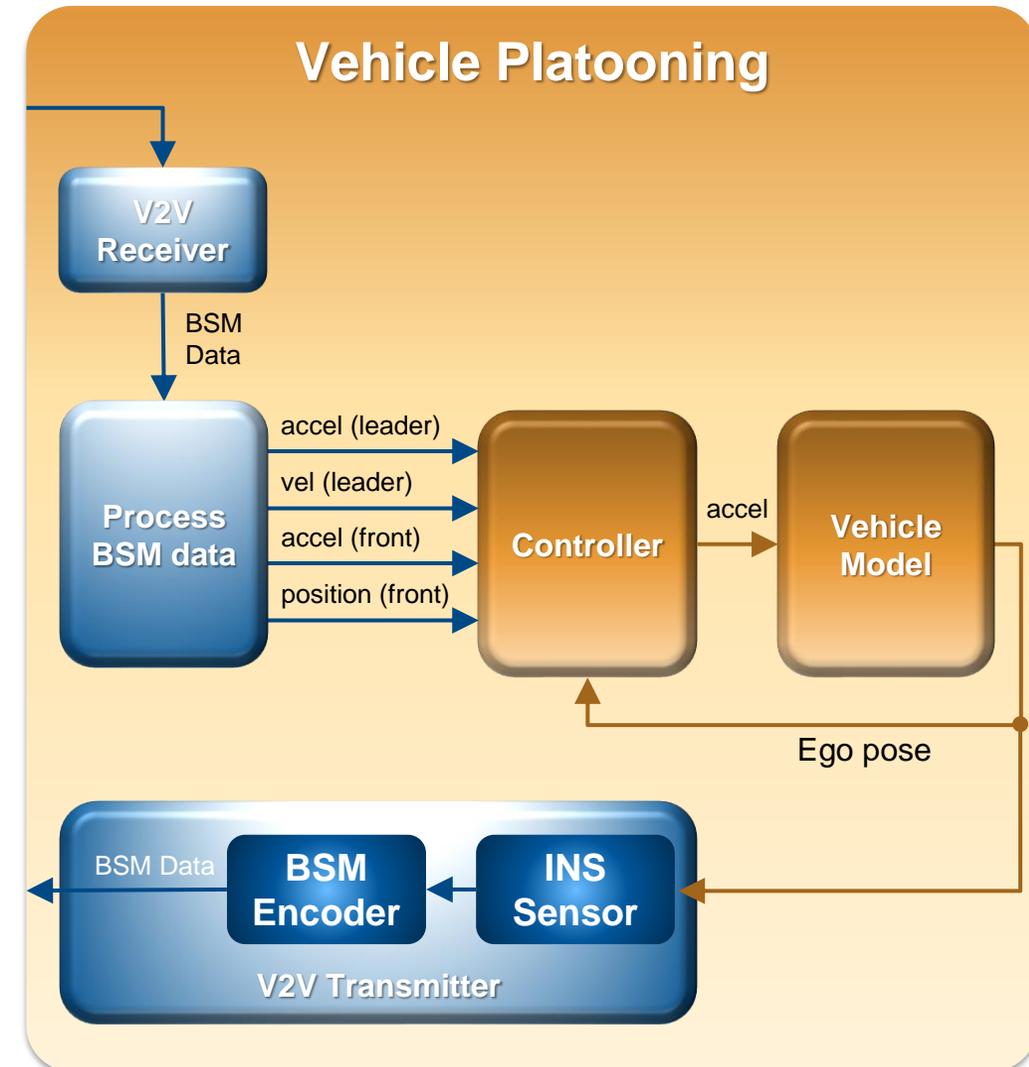
The Command Window shows the following MATLAB code:

```
fx >>
Figure = findobj(...
    Figure.Position
    screenSize = doub...
    1920/2
    1080-42
    [figureName = 'Pla...
    Figure = findobj(...
    Figure.Position
    clc
```

The Workspace pane on the right lists various variables and objects, including ActorPose, actorProfiles, ans, BusAccelerationSet4Way, BusActorInfo, BusActorsInfo, BusBrakeSystemStatus, BusBSM, BusBSMCoreData, BusPositionalAccuracy, BusVehicleSize, C1, channelAttributes, Cr, Figure, figureName, Gap, InitialBSM, Iz, K1, K2, K2tuned, L, L1, L2, lf, logstdout, lr, m, and ...

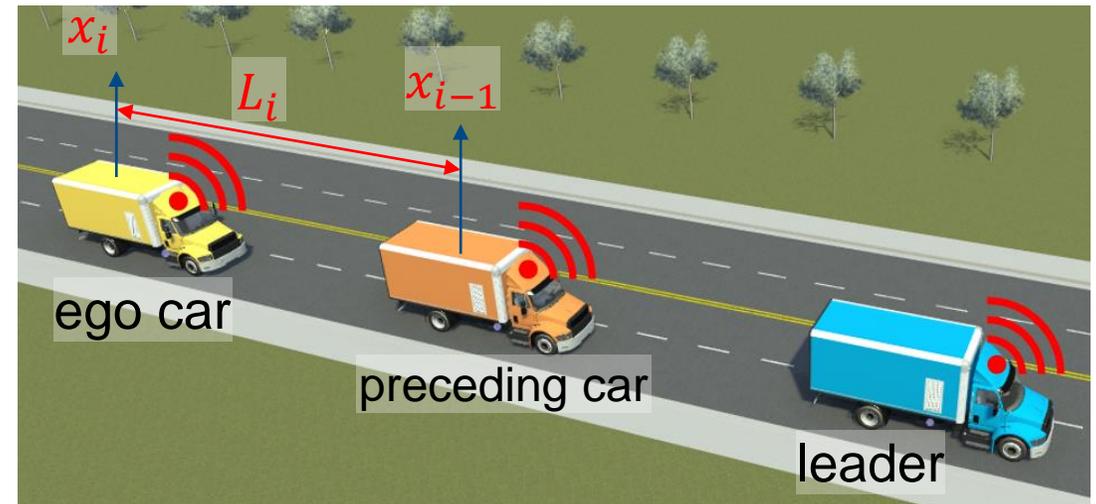
Platooning: components

- Information flow via V2V
 - Obtains the position and movement information of the other vehicles in the platoon via V2V
- Distributed controller
 - Sliding mode control: every controller share the same structure and parameters
 - Constant spacing: every car maintains a constant spacing from the preceding car
- Vehicle model
 - Truck-trailer kinematic model
 - A single track 3DOF rigid vehicle body (bicycle model)



Platooning: problem statement

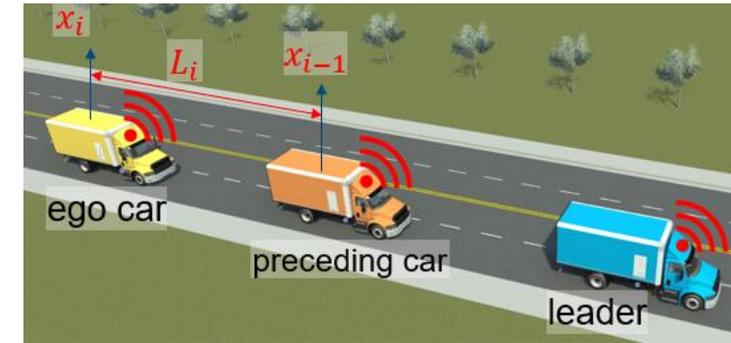
- Problem setup:
 - A given acceleration profile drives the lead vehicle
 - Every trailing vehicle is controlled by a controller based on the position and motion information of the other vehicles in the platoon
- Requirement:
 - Define spacing error: $\varepsilon_i = L_i - (x_{i-1} - x_i)$
 - Individual stability
 - $\varepsilon_i \rightarrow 0$: spacing error goes to zero if predecessor maintains constant speed.
 - String stability
 - spacing error does not amplify downstream.



where L_i is the desired spacing that includes the vehicle length.

Controller with sliding mode control

$$a_{ego} = C_1 a_{lead} + (1 - C_1) a_{front} - K_1 (v_{ego} - v_{lead}) - K_2 (x_{ego} - x_{front} + L)$$



Trade off between lead car and preceding car

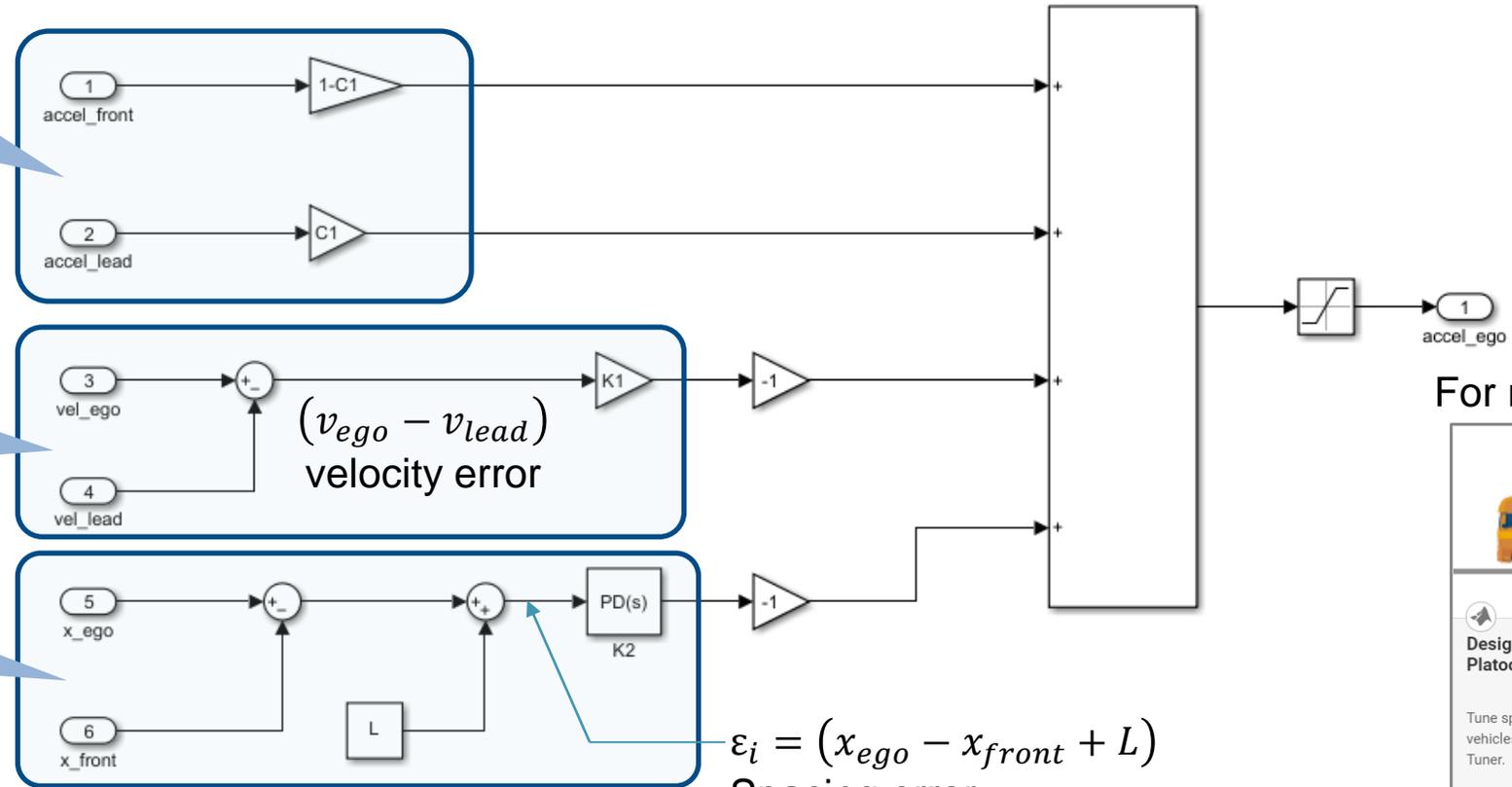
$$C_1 a_{lead} + (1 - C_1) a_{front}$$

Ego velocity will converge to lead velocity

$$-K_1 (v_{ego} - v_{lead})$$

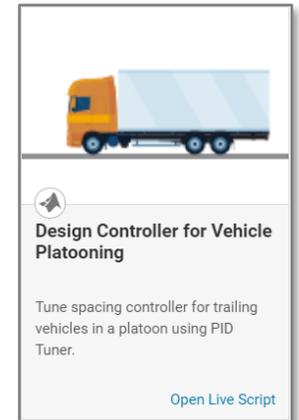
Spacing error will converge to zero

$$-K_2 (x_{ego} - x_{front} + L)$$



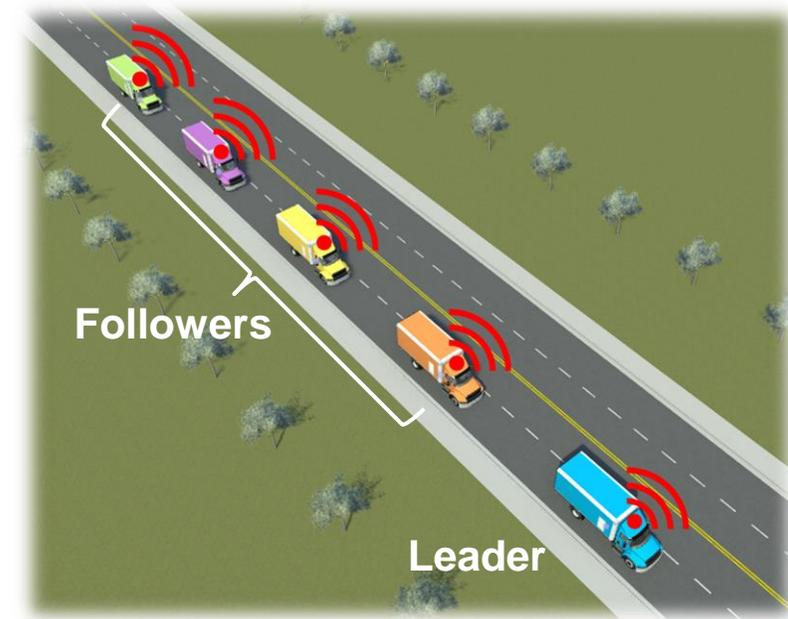
$\epsilon_i = (x_{ego} - x_{front} + L)$
Spacing error
= ego - preceding car position

For more details



What is V2V? How does V2V work?

- **Vehicle-to-vehicle (V2V) communication**
 - enables vehicles to wirelessly exchange safety information of surrounding vehicles and provides the vehicles with a 360-degree awareness of other vehicles in proximity.
- **V2V communications systems**
 - use **dedicated short-range radio communication (DSRC) or cellular network** to exchange messages containing vehicle information (e.g., vehicle's speed, heading, braking status).



Basic Safety Message (BSM) by SAE J2735

- SAE J2735 – Data and message set dictionary
- Defines the **Basic Safety Message (BSM)**
 - Latitude, longitude, Elev
 - Speed
 - Heading angle
 - Steering wheel angle
 - Lat, long acceleration
 - Vehicle length, width

	SURFACE VEHICLE STANDARD		J2735®	JUL2020
	Issued	2006-12		
	Revised	2020-07		
Superseding J2735 MAR2016				
(R) V2X Communications Message Set Dictionary				

```
BSMcoreData ::= SEQUENCE {
  msgCnt          MsgCount,
  id              TemporaryID,
  secMark        DSecond,
  lat             Latitude,
  long           Longitude,
  elev           Elevation,
  accuracy       PositionalAccuracy,
  transmission   TransmissionState,
  speed          Speed,
  heading        Heading,
  angle          SteeringWheelAngle,
  accelSet       AccelerationSet4Way,
  brakes         BrakeSystemStatus,
  size           VehicleSize
}
```

For more details



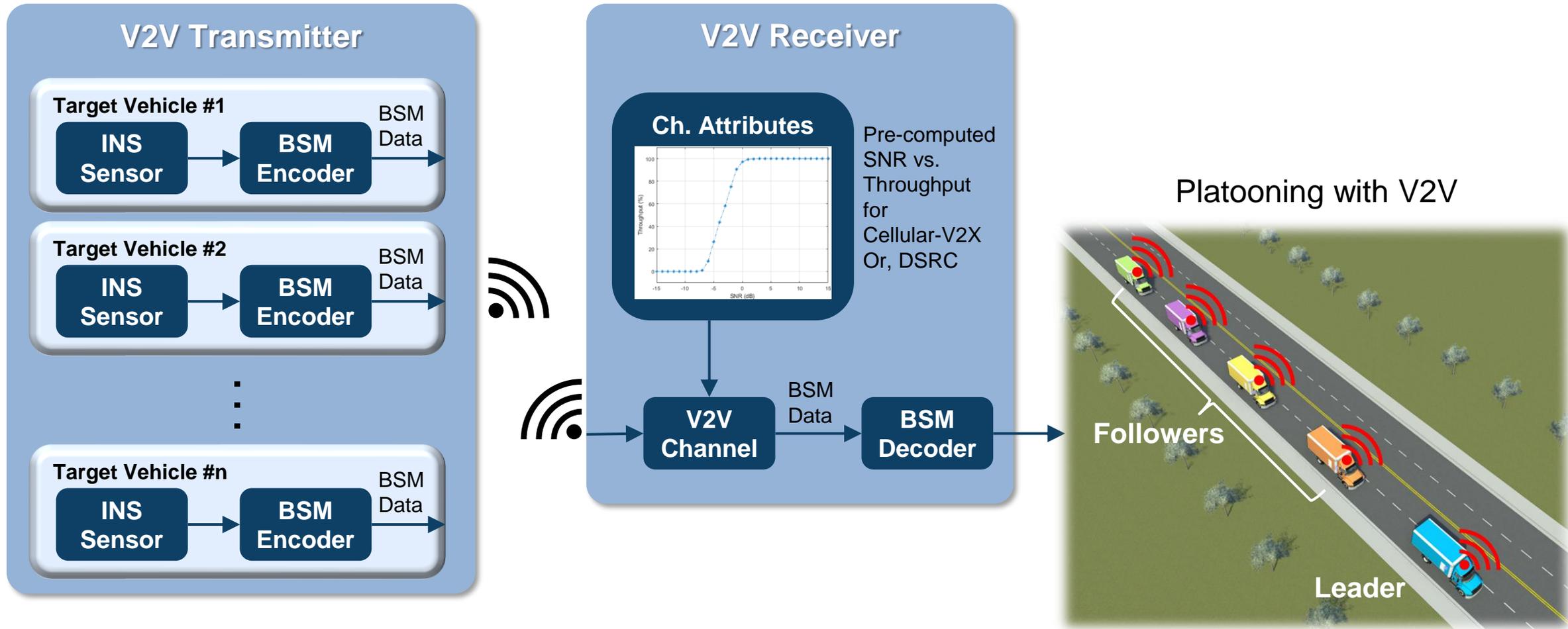
Intersection Movement Assist Using Vehicle-to-Vehicle Communication

Design intersection movement assist application using V2V communication.

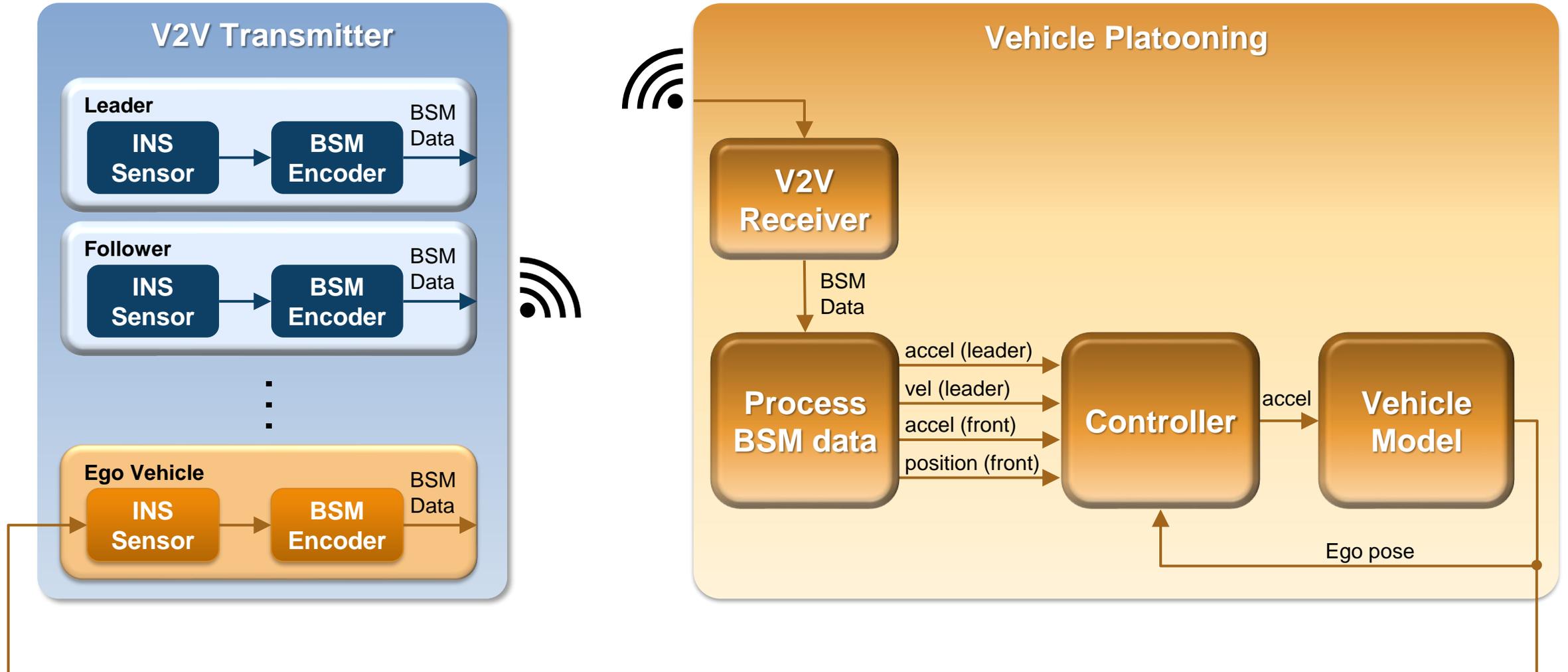
[Open Example](#)

Automated Driving Toolbox™
R2022a

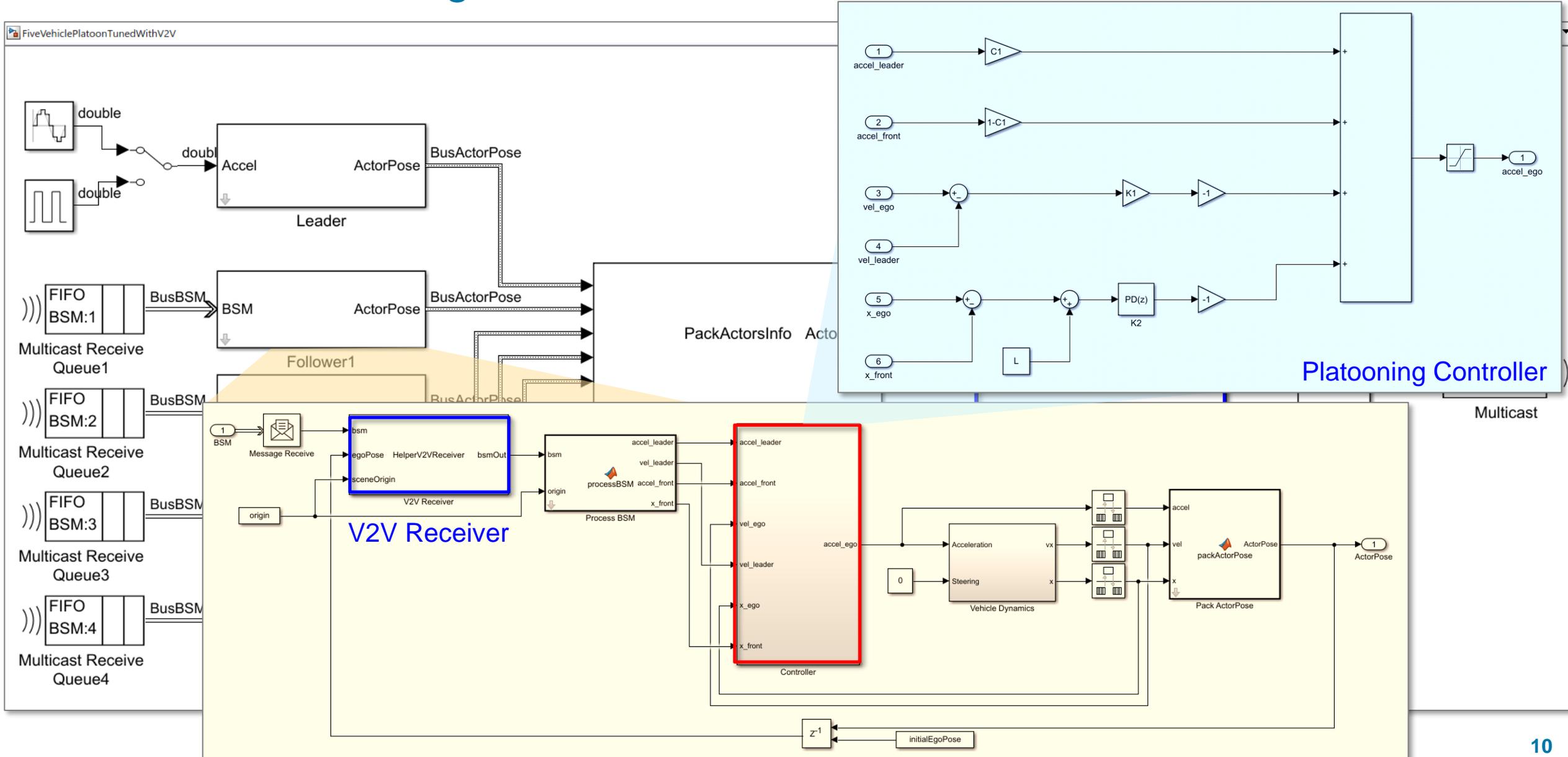
Design V2V Transmitter and Receiver



Vehicle Platooning Controller with V2V Communication

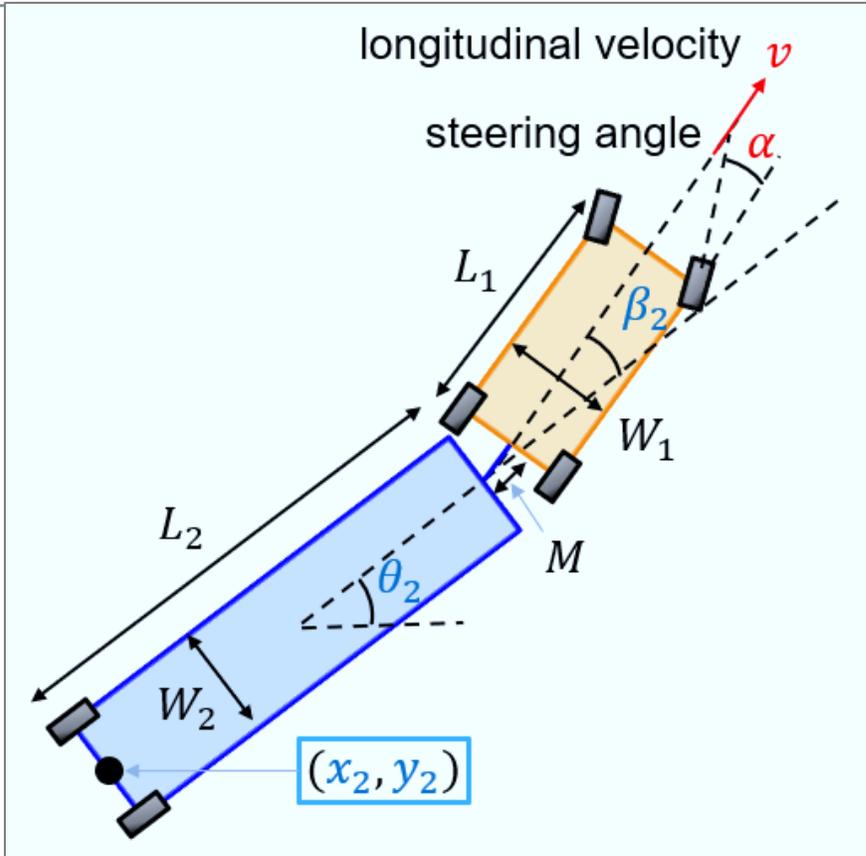


Vehicle Platooning Controller with V2V Communication

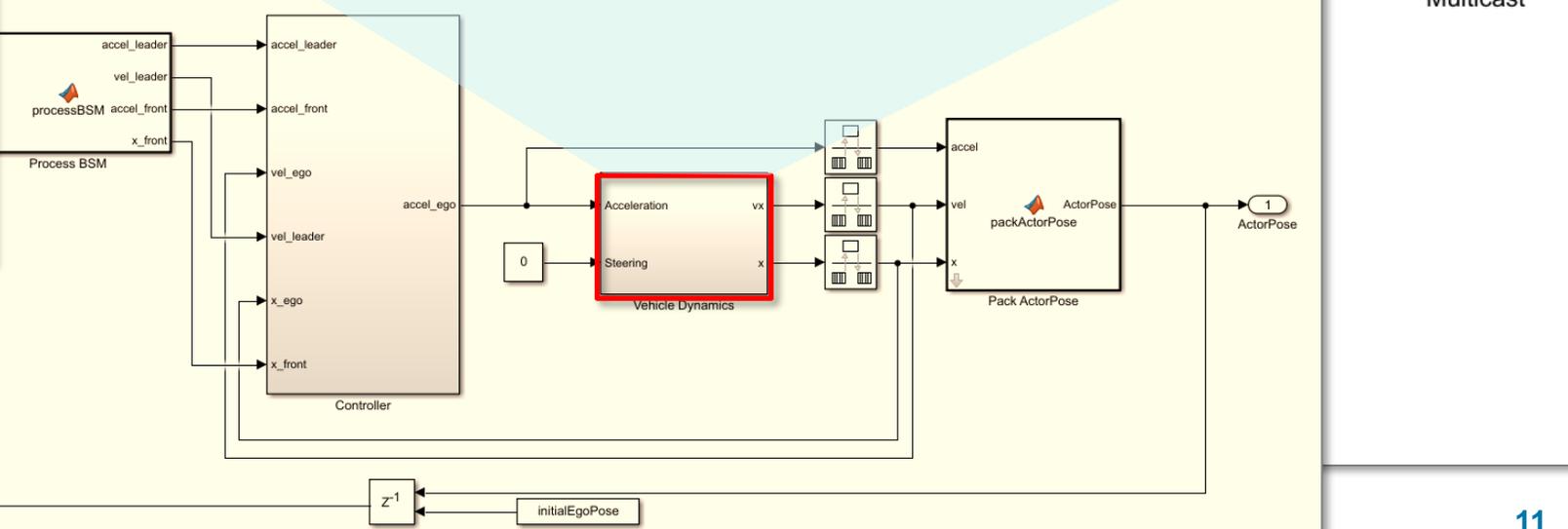
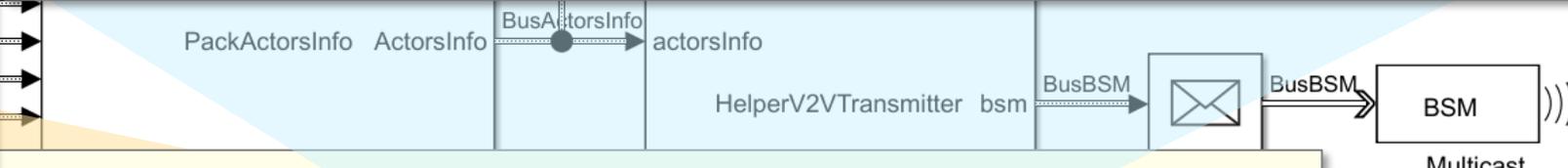
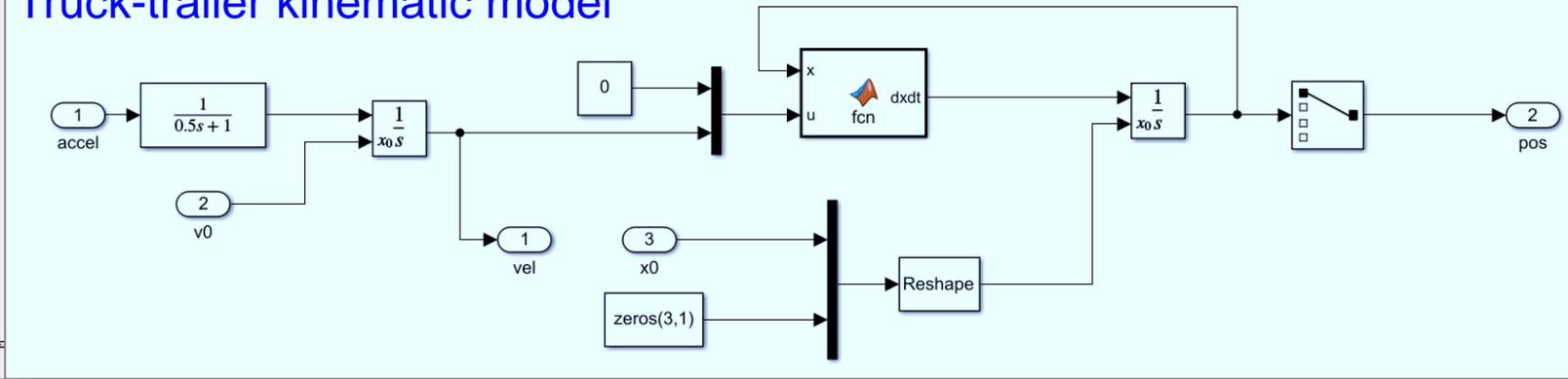


Vehicle Platooning Controller with V2V Communication

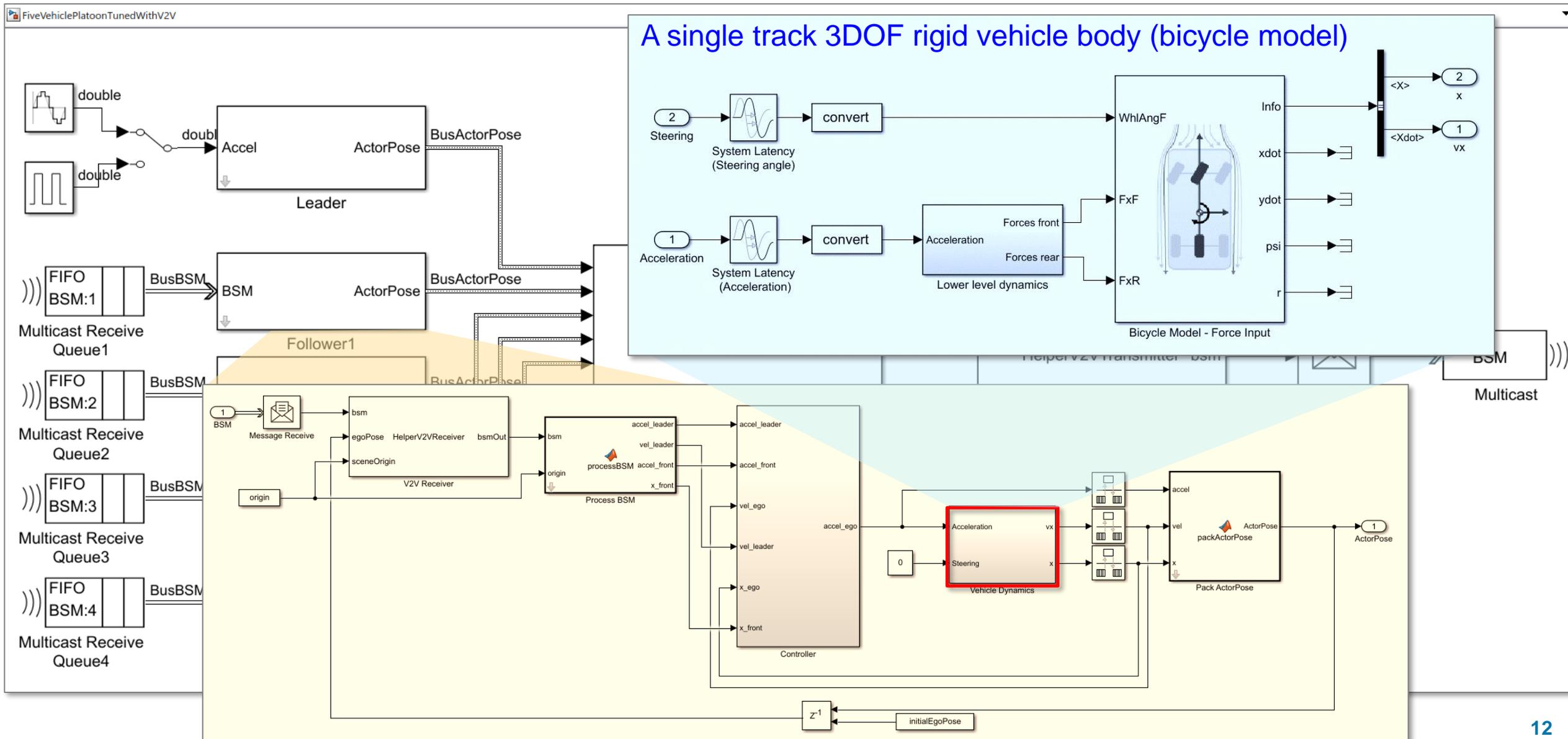
FiveVehiclePlatoonTunedWithV2V



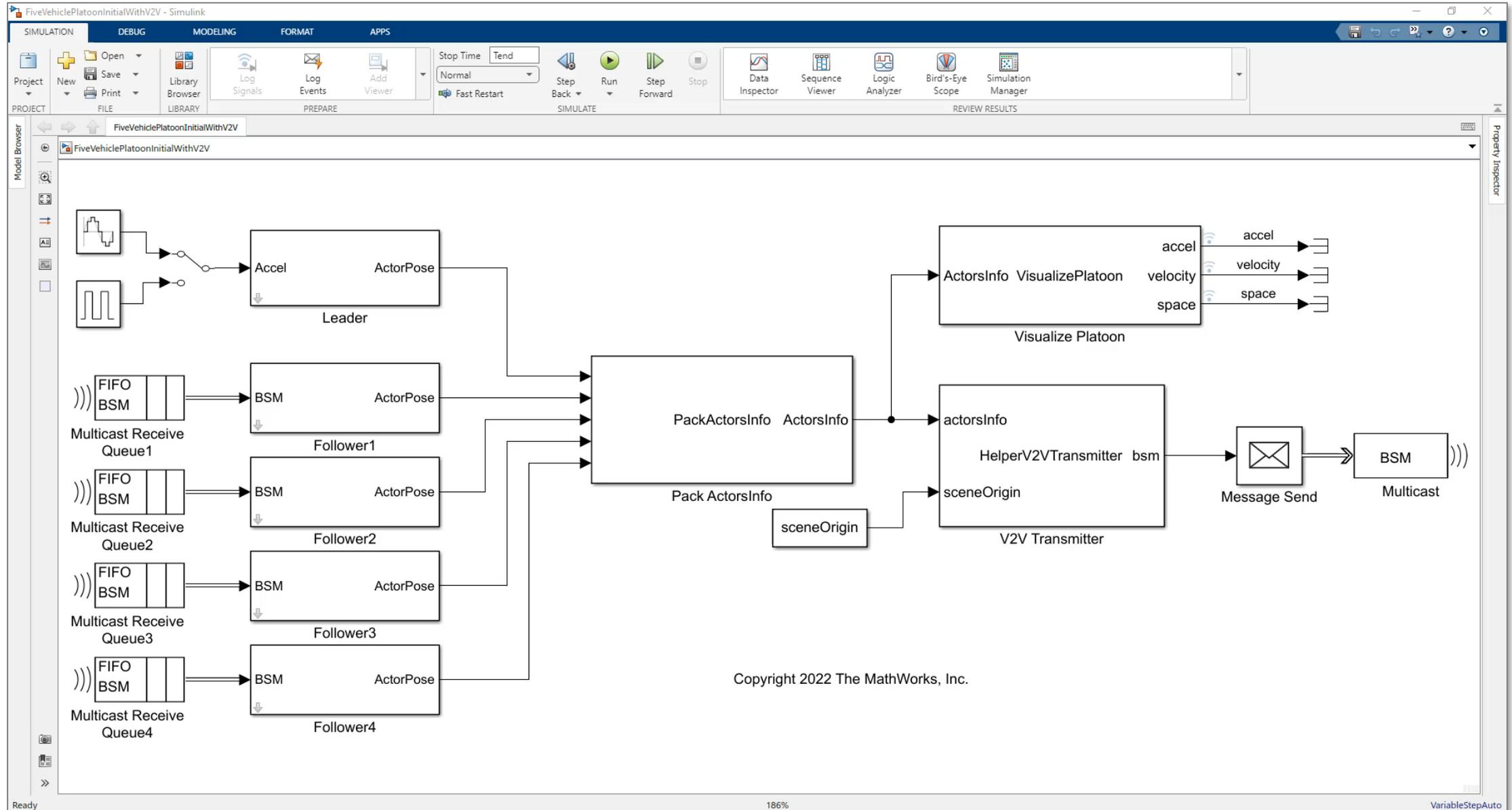
Truck-trailer kinematic model



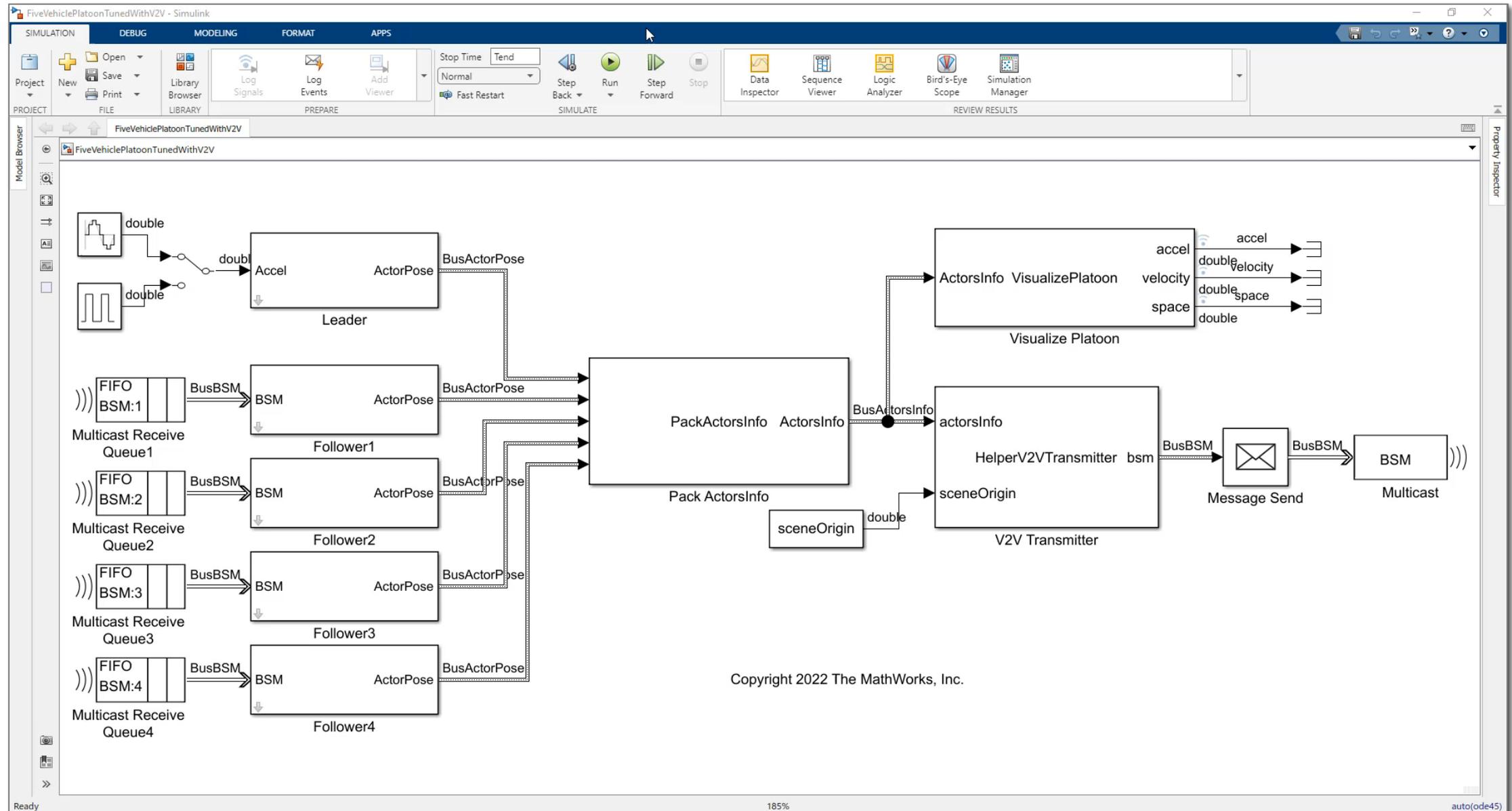
Vehicle Platooning Controller with V2V Communication



Simulation result (with initial setting of controller gains)

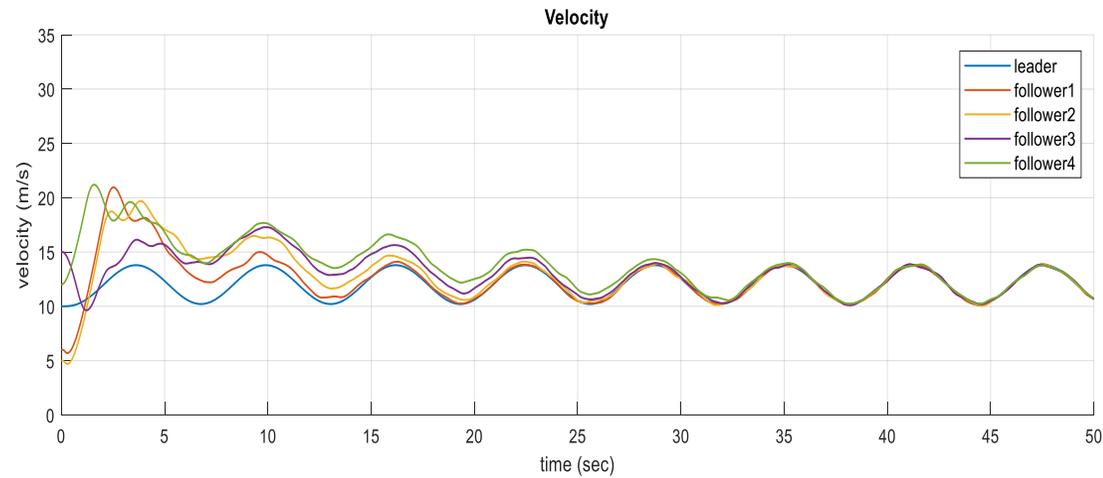


Simulation result (after tuning K2 for faster response)

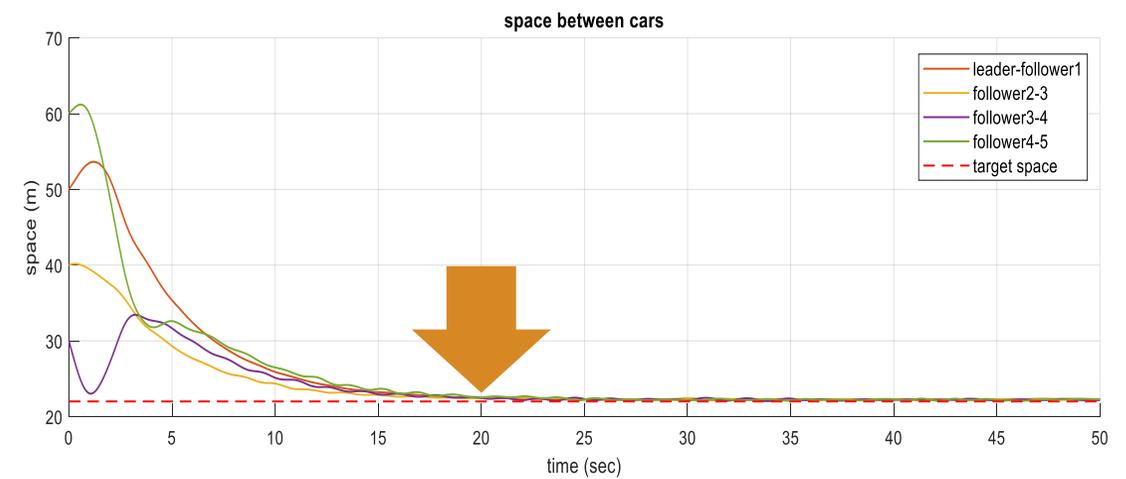
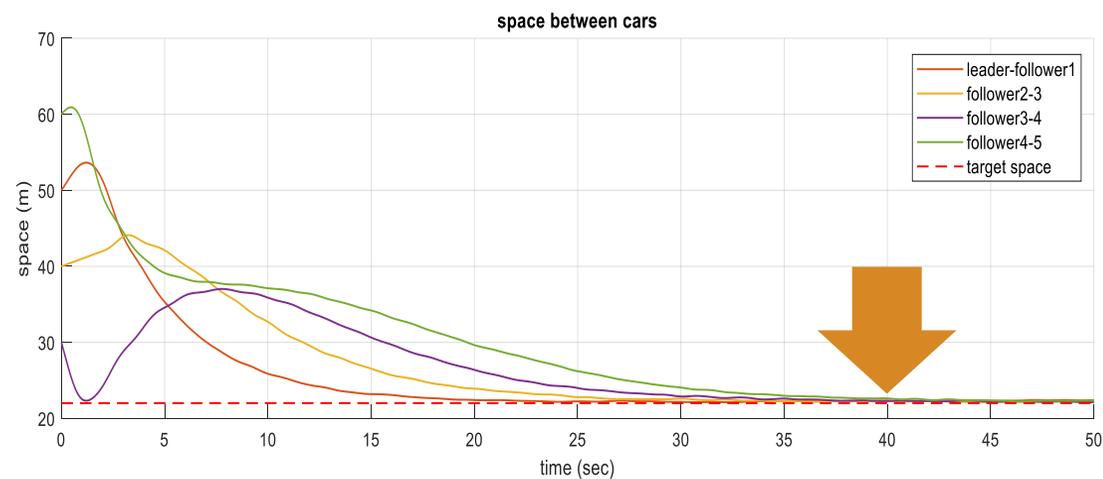
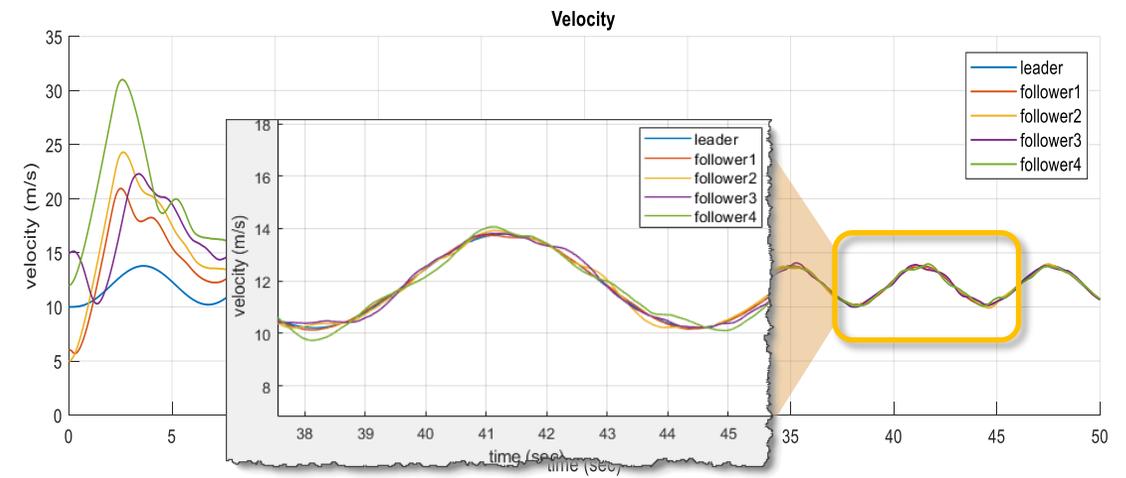


Simulation result (before vs. after tuning K2 for faster response)

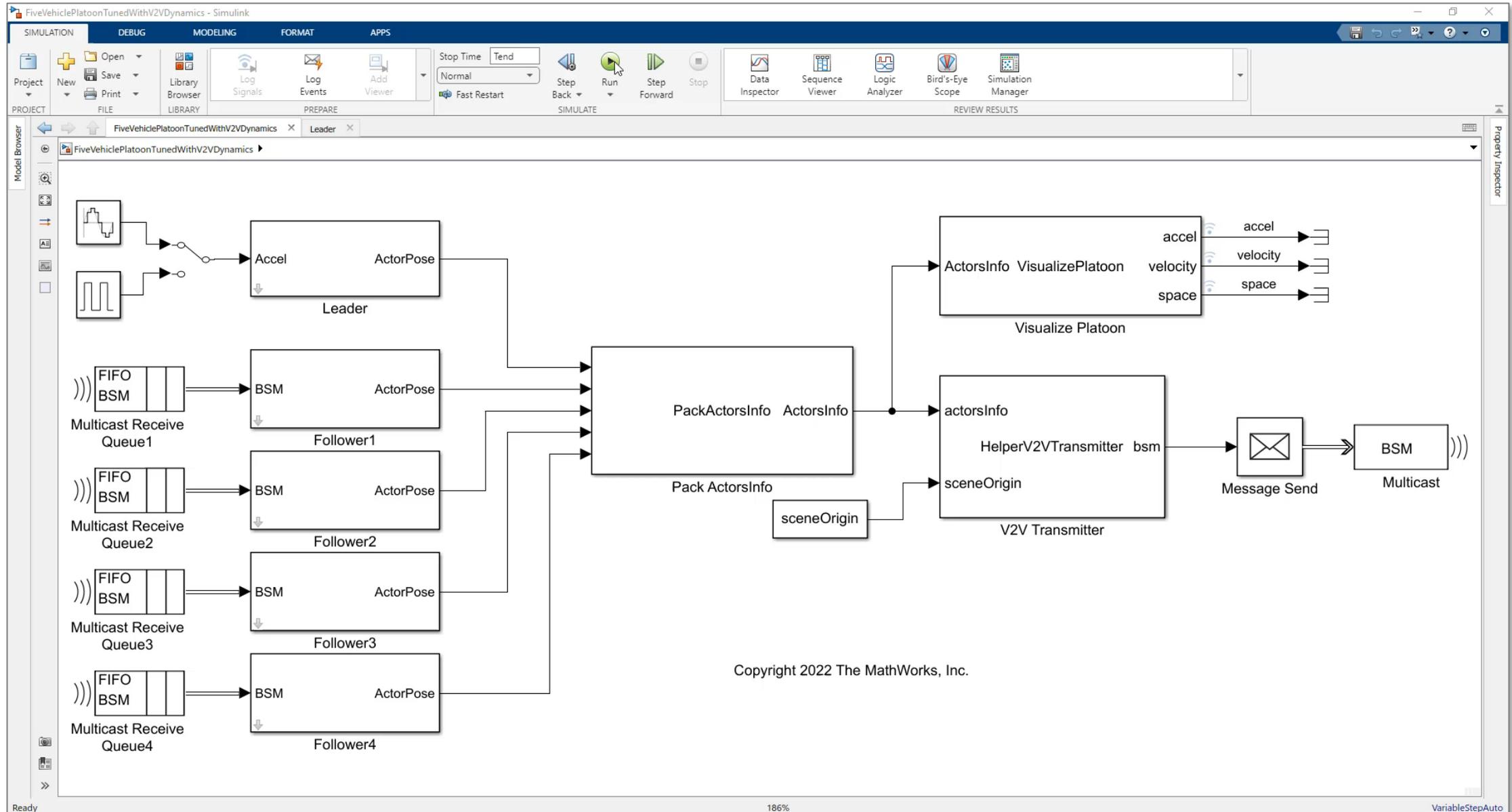
Before



After



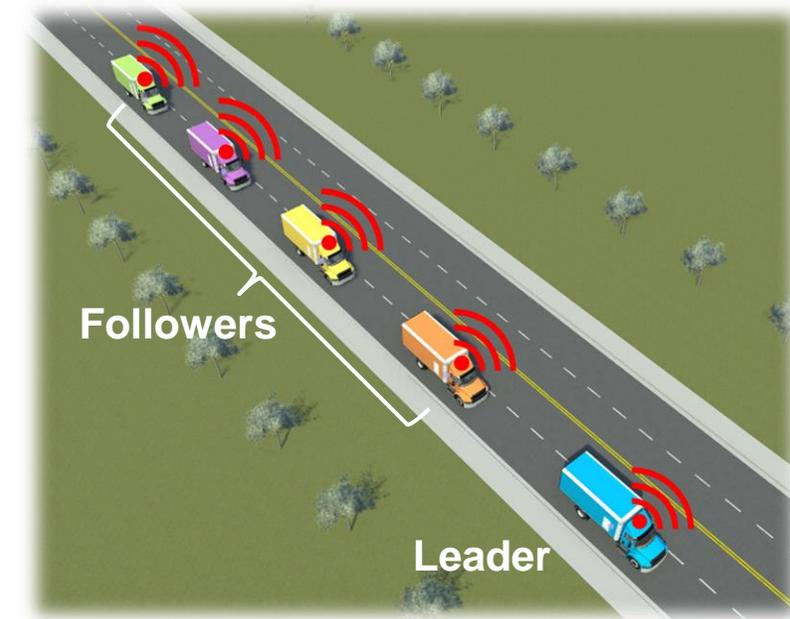
Simulation result (With a single track 3DOF rigid vehicle body - bicycle model)



Key takeaways:

Design of vehicle platooning controller with V2V communication

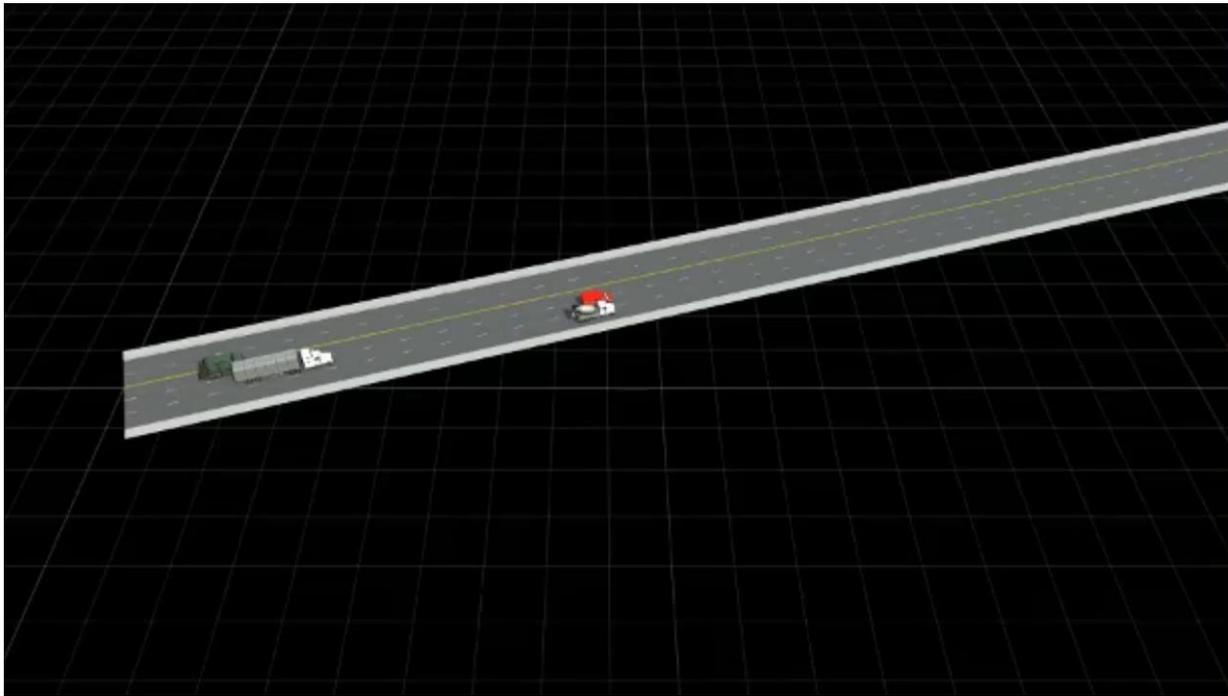
- Demonstrated how to design a controller for vehicle platooning controller with V2V communication using
 - Simulink Control Design™
 - Automated Driving Toolbox™
- The test bench model consists of
 - V2V communication
 - Model characteristics of the V2V communication channel
 - Implement BSM defined by SAE J2735
 - Vehicle model
 - Truck-trailer kinematic model
 - A single track 3DOF rigid vehicle body (bicycle model)
 - Distributed controller implementing sliding mode control



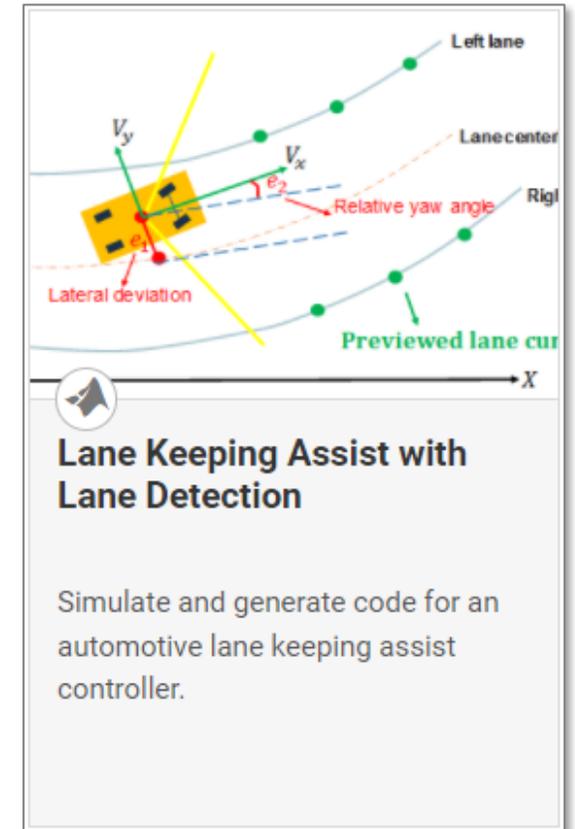
Simulink Control Design™
Automated Driving Toolbox™
R2022a

Further studies

- Scenario authoring using RoadRunner Scenario with truck and trailer meshes



- Platooning system requires a lateral control for curved roads.
 - Lateral control by Lane keeping control



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Thank you

Please contact me at spark@mathworks.com
with questions

