



YOUR DEVELOPMENT PARTNER



## Lane change assist development with Simulink

Thaddäus Menzel 

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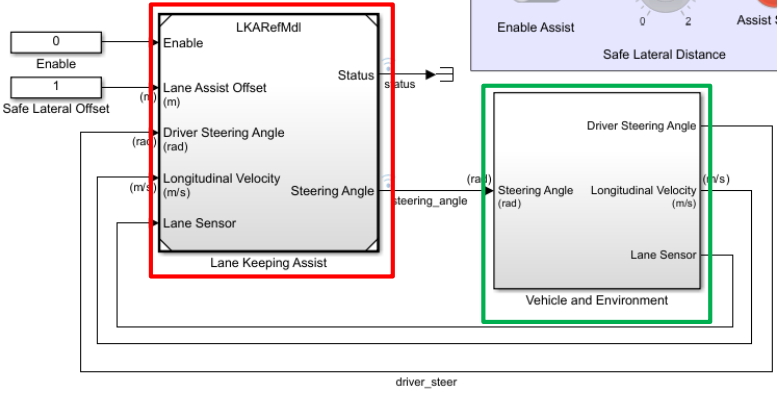
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# Agenda

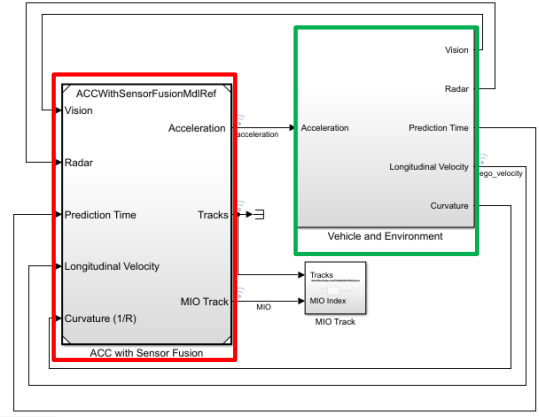
- ⊕ Tutorial for design of a lane change assist by using the default ADAS examples
- ⊕ Challenges solved on the way
- ⊕ Future challenges for the usage in driving simulator or real car
- ⊕ Visualization of the lane change assist
- ⊕ Why Simulink and the Automated Driving Toolbox?



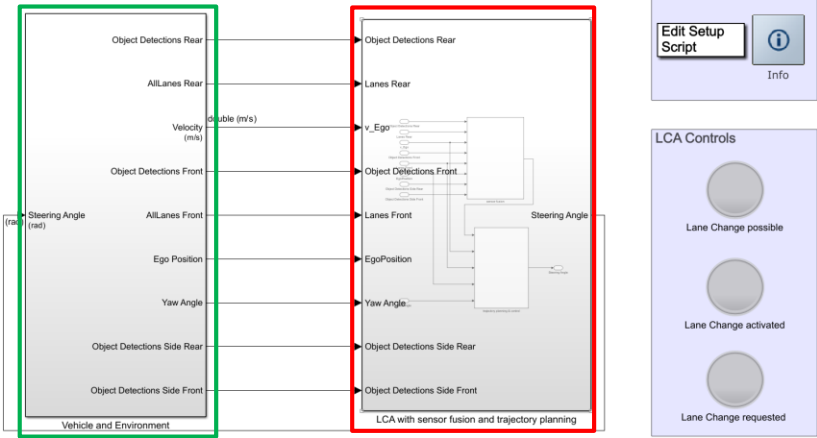
**Lane Keeping Assist Test Bench**



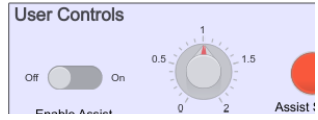
**Adaptive Cruise Control Using Sensor Fusion Test Bench**



**Lane Change Assist Test Bench**

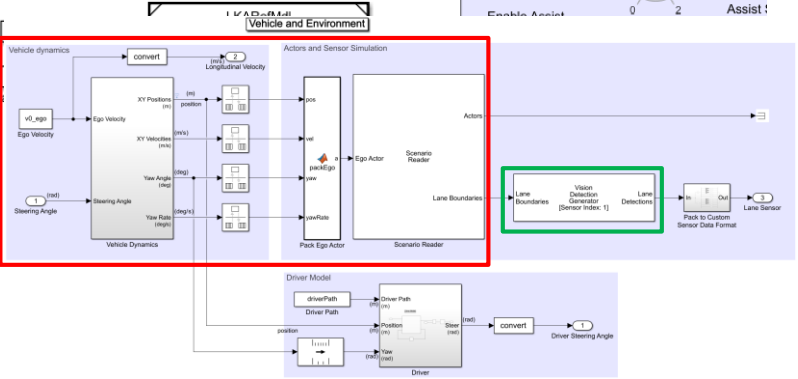
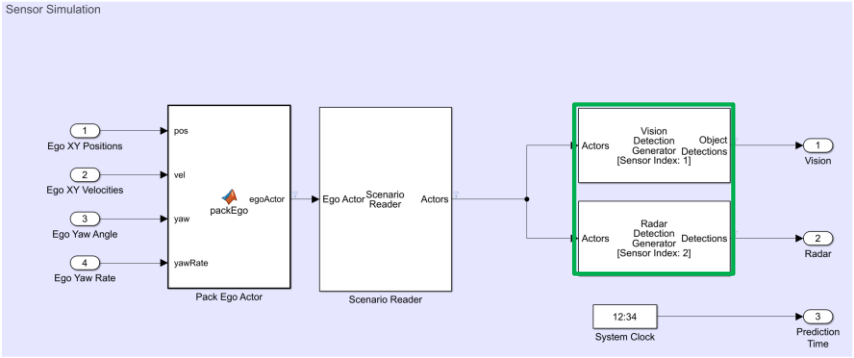


Lane Keeping Assist Test Bench



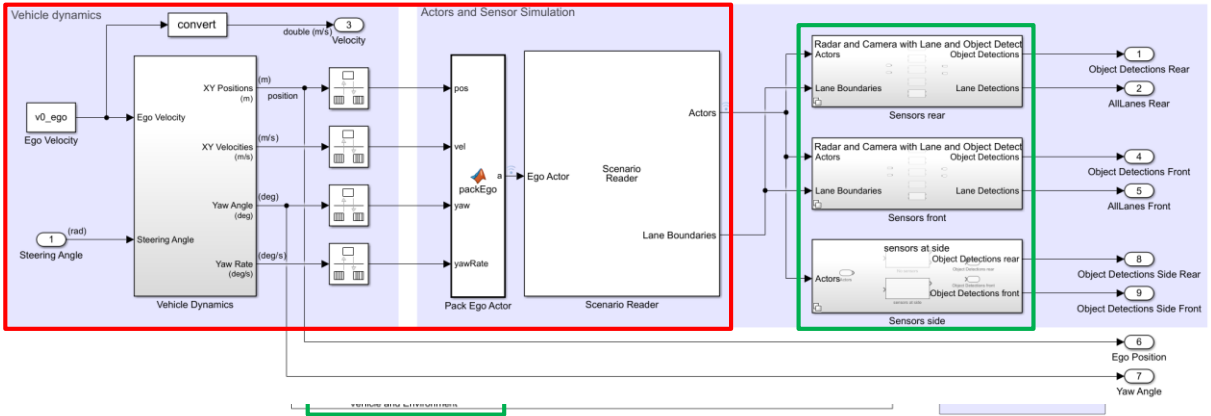
Adaptive Cruise Control Using Sensor Fusion Test Bench

Actors and Sensor Simulation

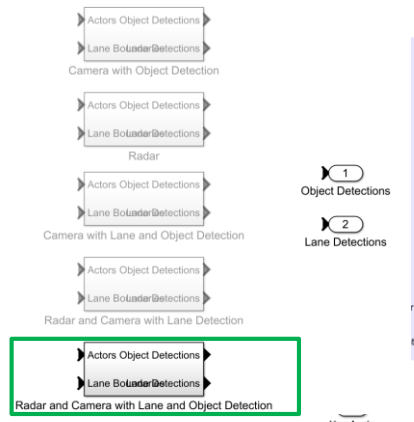
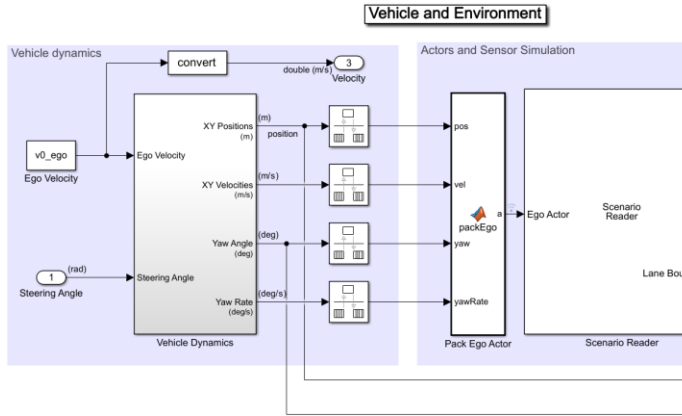
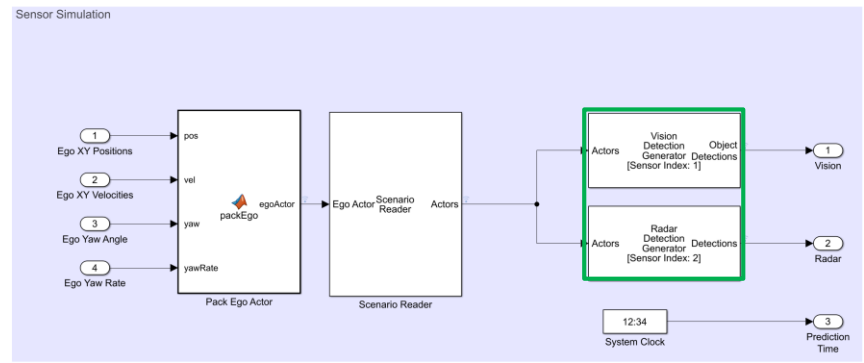
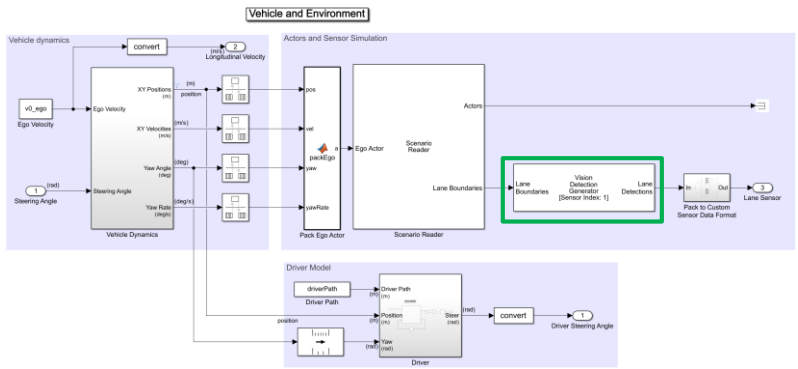


Lane Change Assist Test Bench

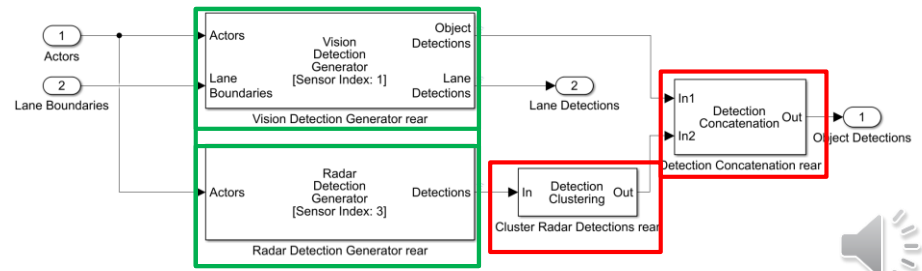
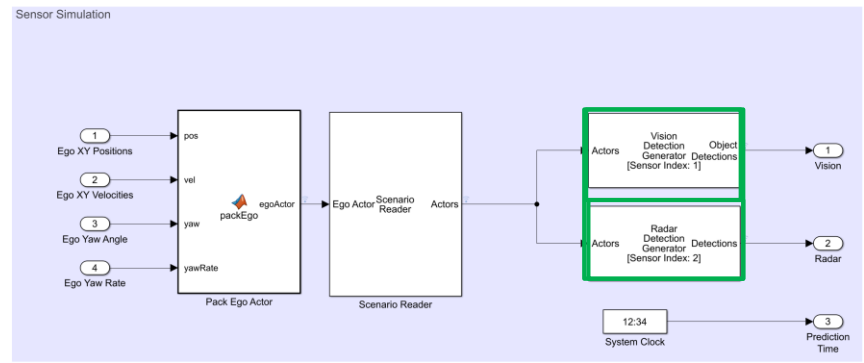
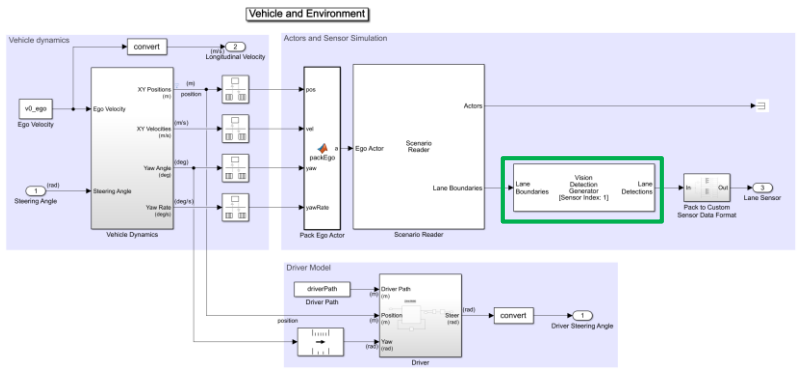
Vehicle and Environment



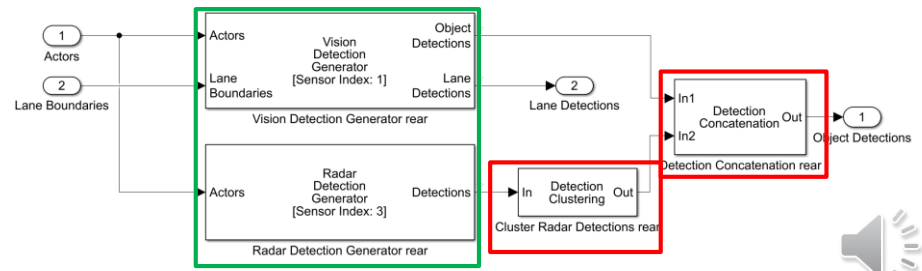
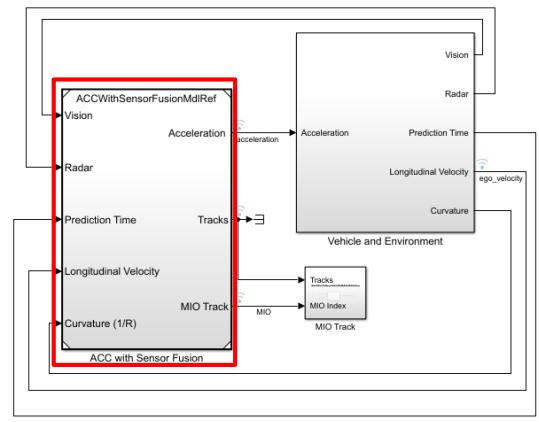
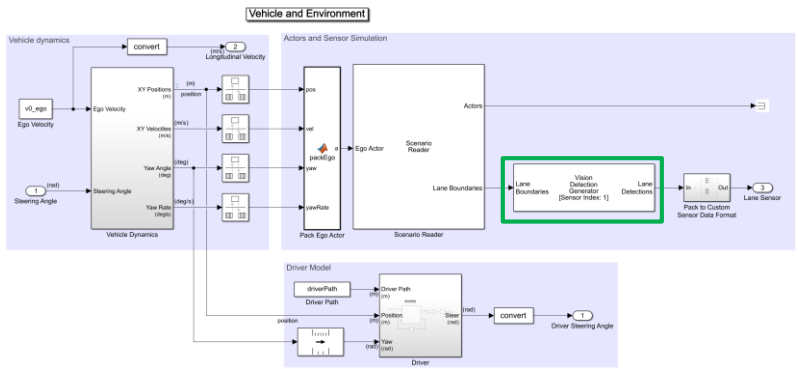
Actors and Sensor Simulation



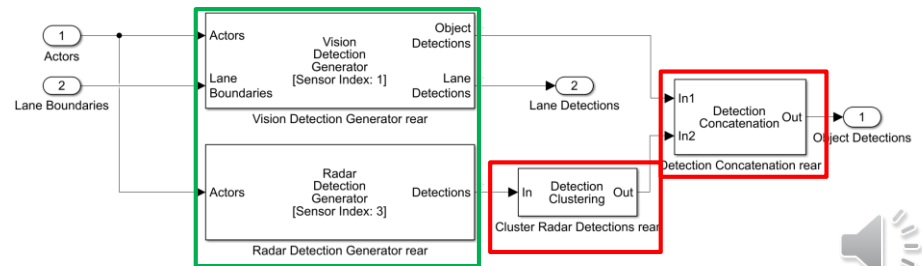
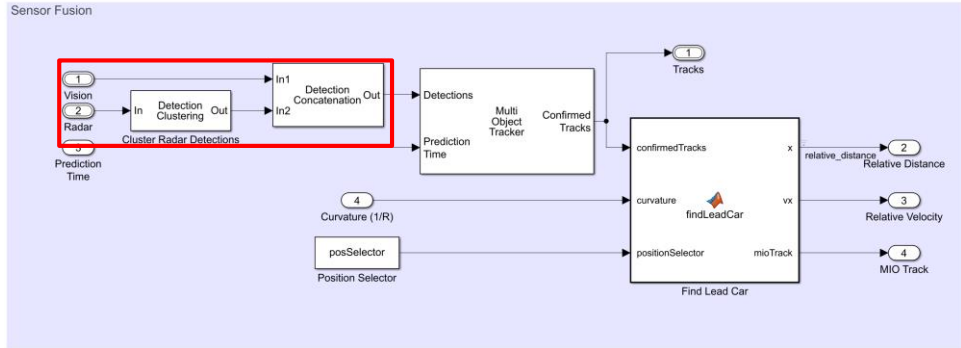
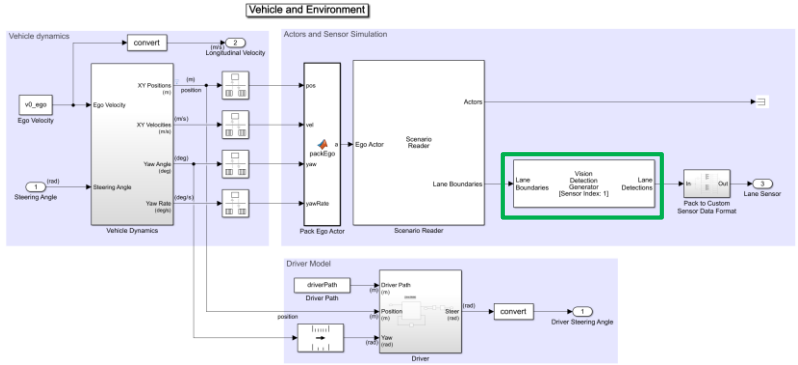
Actors and Sensor Simulation



Adaptive Cruise Control Using Sensor Fusion Test Bench

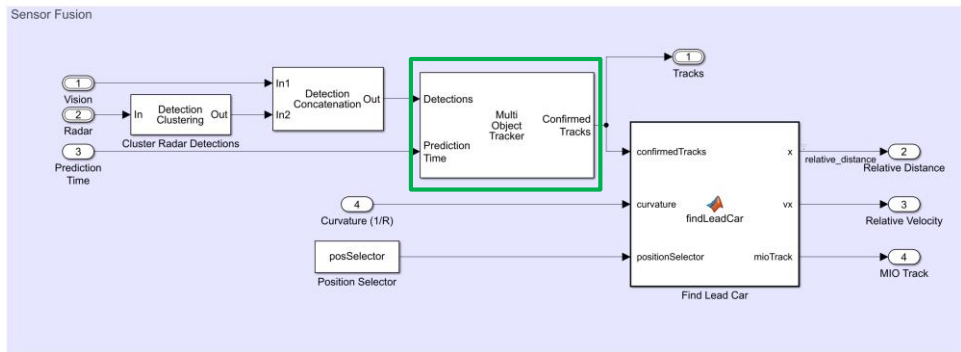
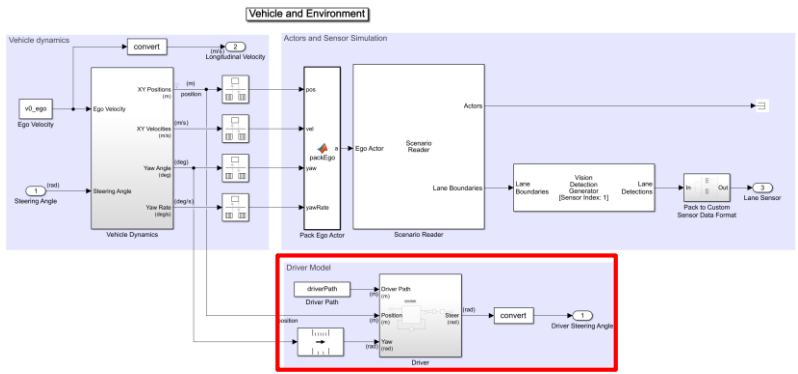


Tracking and Sensor Fusion

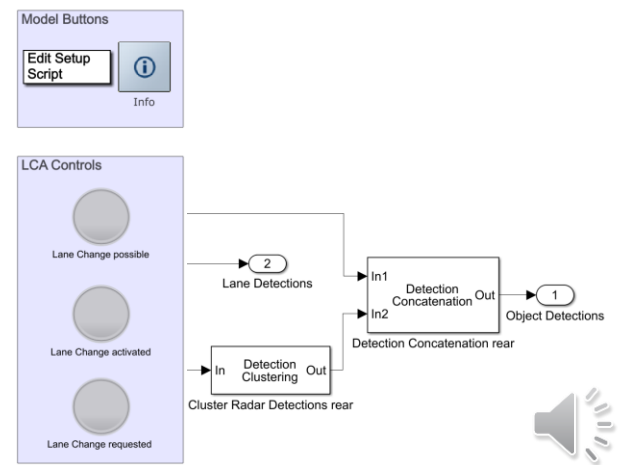
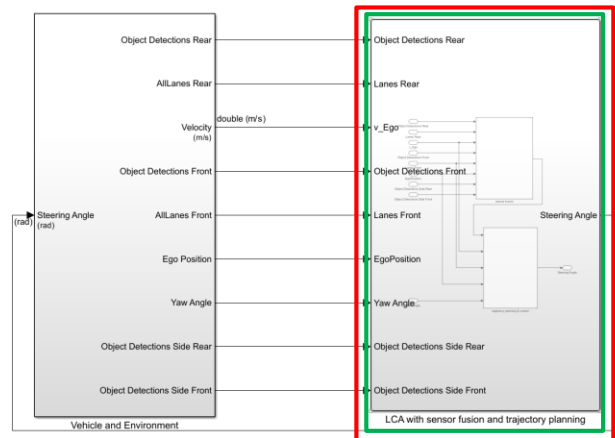




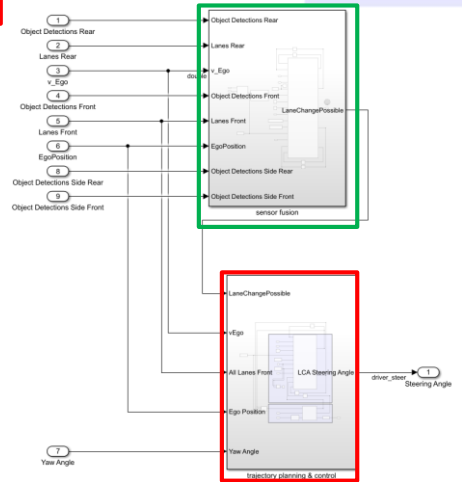
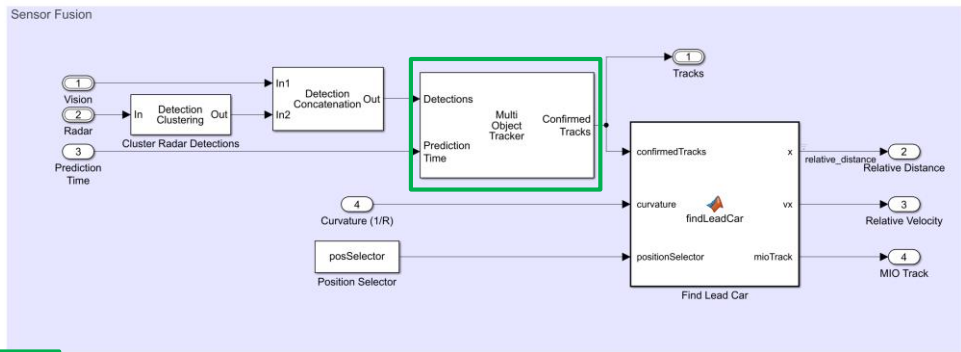
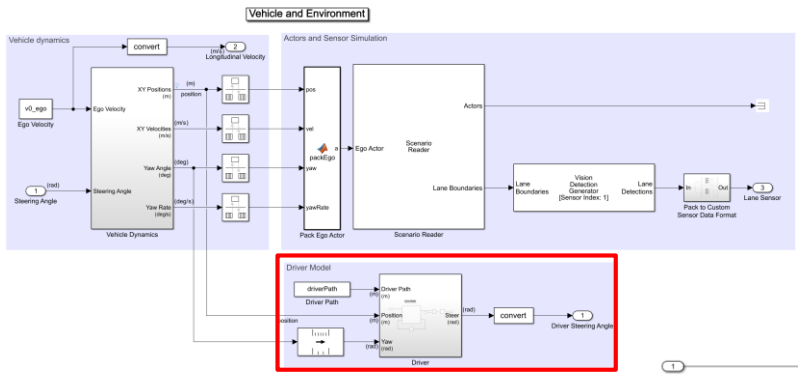
Tracking and Sensor Fusion



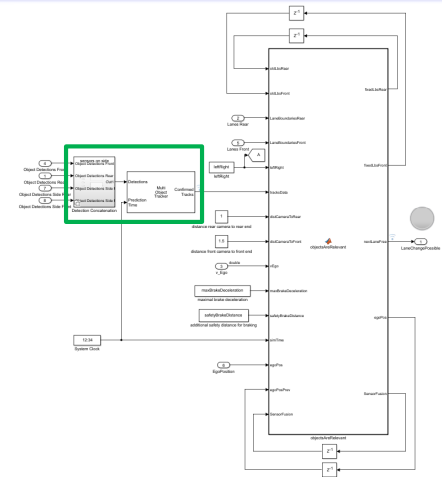
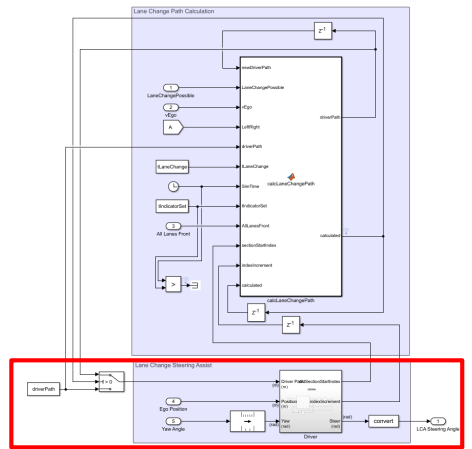
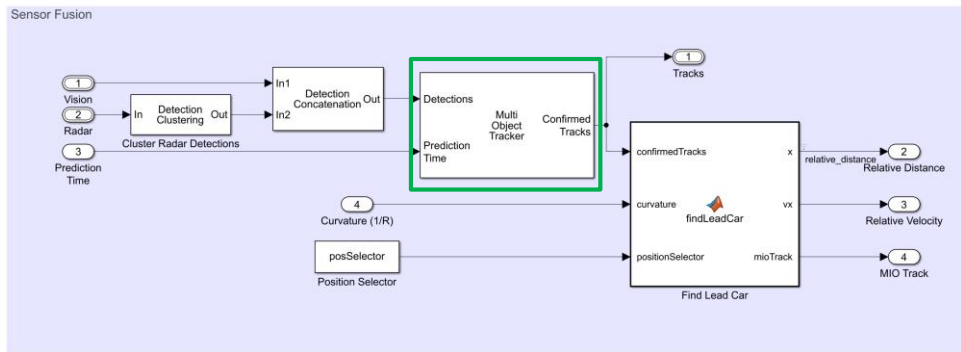
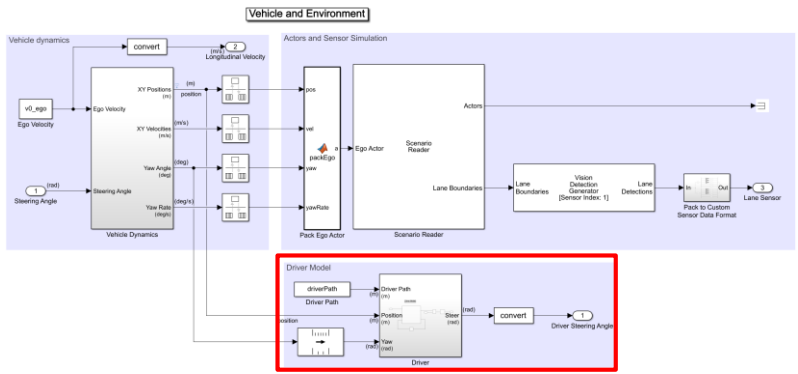
Lane Change Assist Test Bench

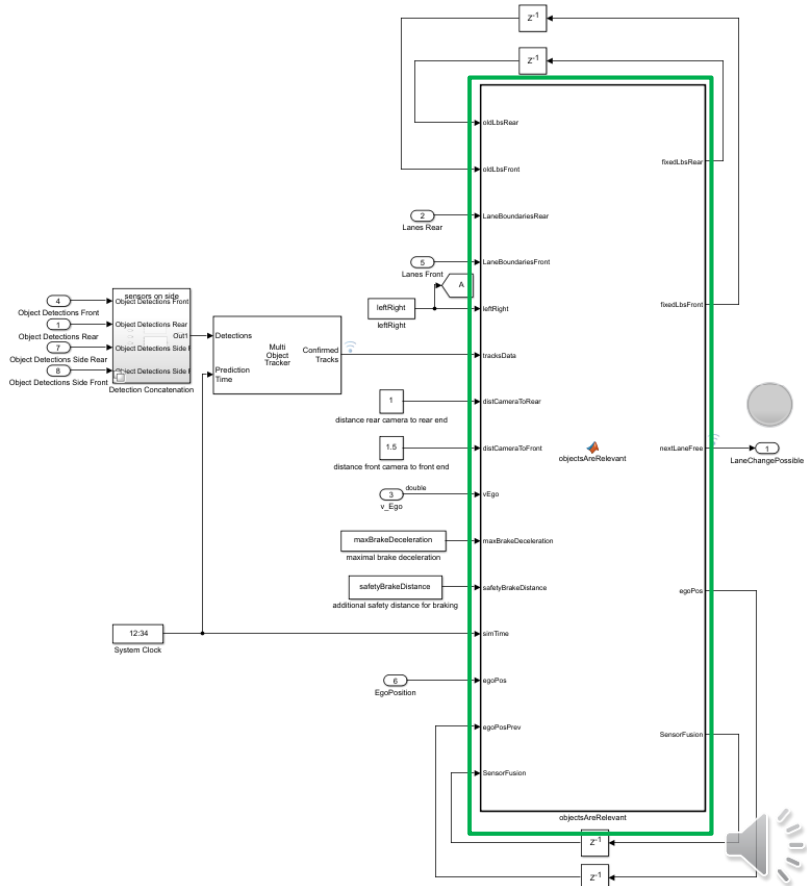
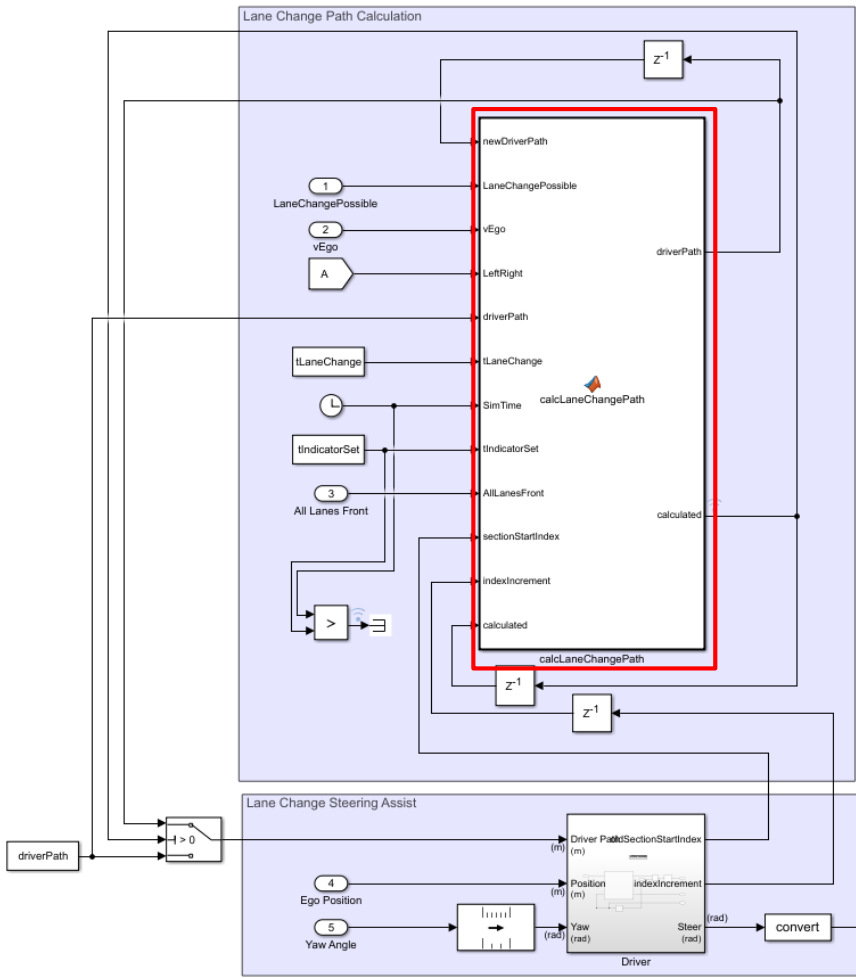


Tracking and Sensor Fusion

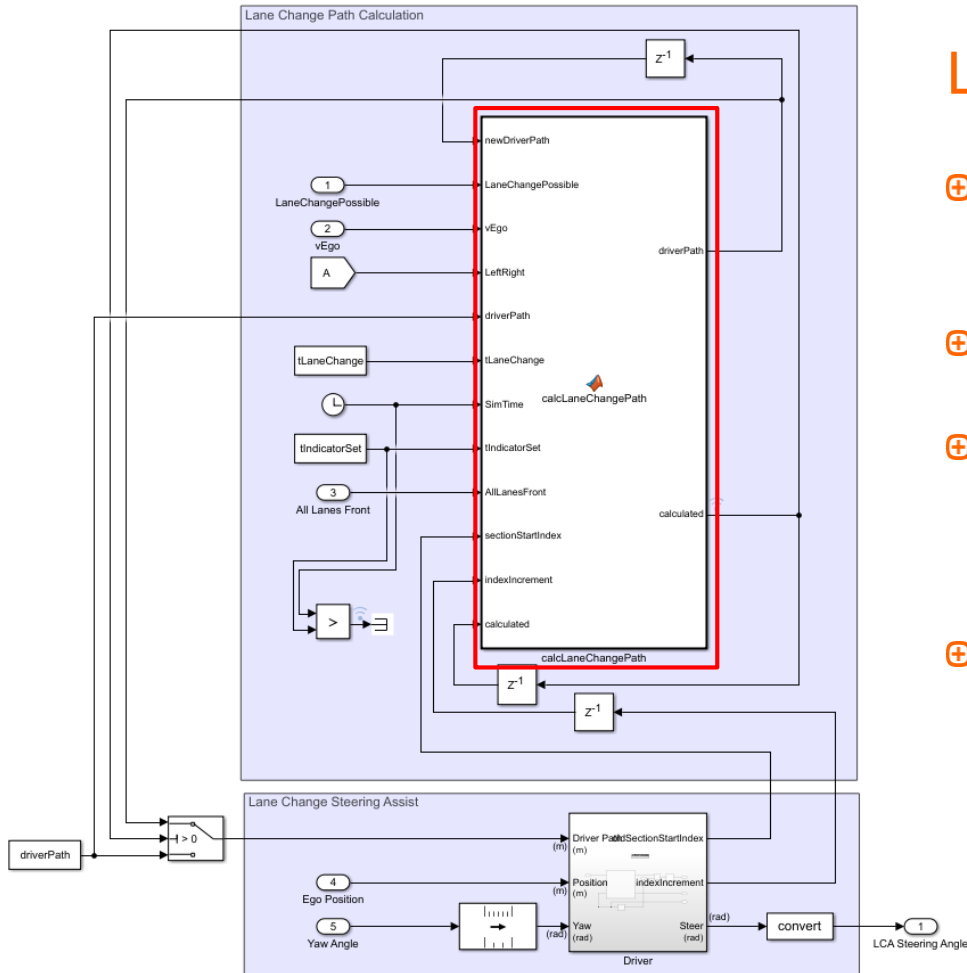


Tracking and Sensor Fusion





## LCA: Trajectory planning

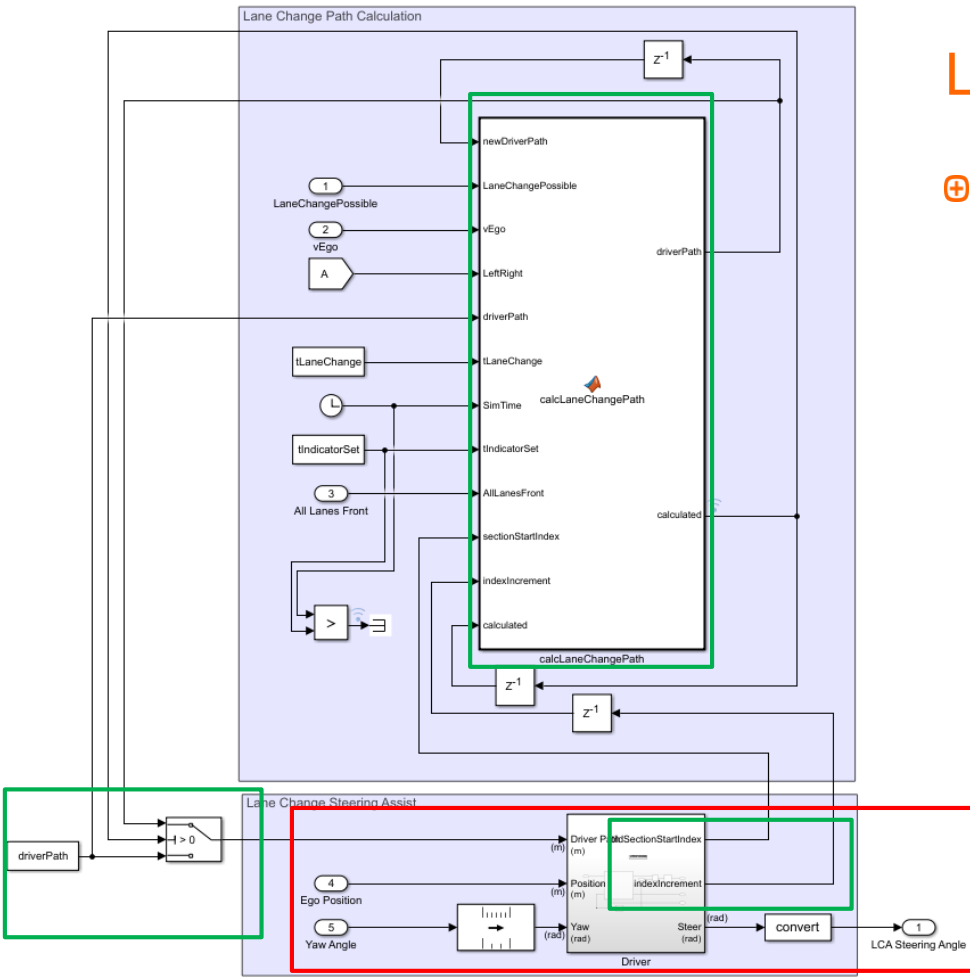


- ⊕ Works similar to driver model from lane keeping assist: Section of driver path identified by the “sectionStartIndex”
- ⊕ Lane width and the lateral offset to target lane identified by lane boundaries ahead
- ⊕ Calculation of lane change path by using clothoids (similar the calculation of the clothoids of the single tracks inside MultiObjectTracker)
- ⊕ Same lateral offset executed on the rest of the driver path after the lane change curve (works not in curves and only needed for the simulation, after lane change the lane keeping assist would be active or the driver would steer)



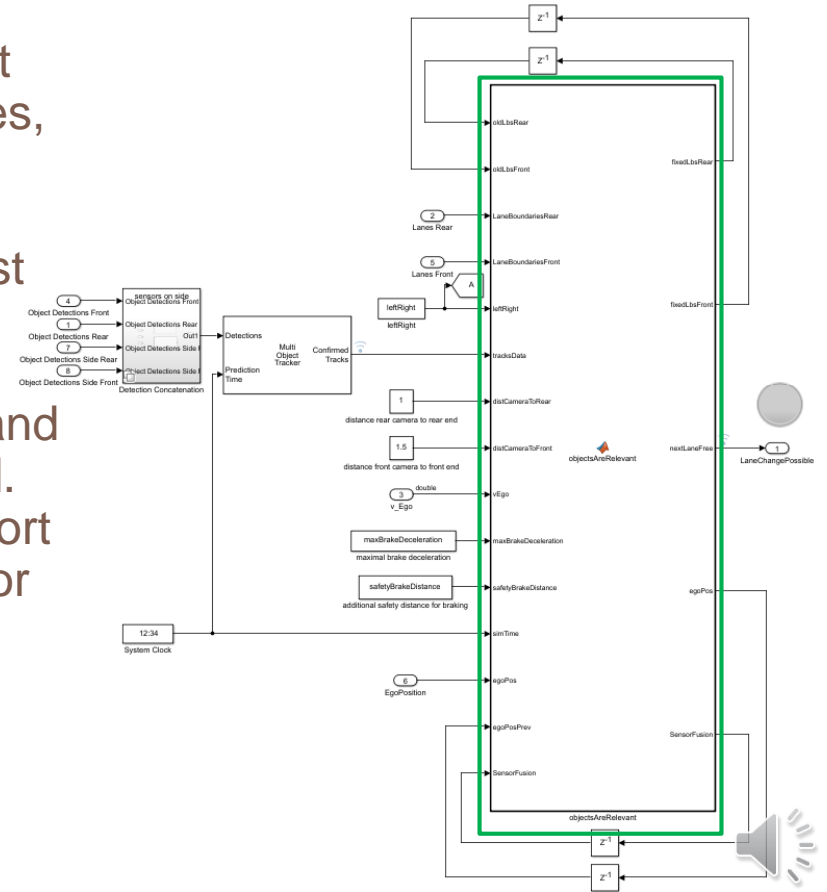
# LCA: Trajectory control

- ⊕ Works similar to driver model or trajectory control from lane keeping assist



# LCA: Sensor fusion and check for free lane

- ⊕ Do a sensor fusion from rear sensors and front sensors and the corresponding lane boundaries, by using the lateral position of the detected objects. If there is a slow object on target lane ahead, wait until it was passed. If there is a fast object coming from behind, wait until it has passed.
- ⊕ Check for slow objects on target lane in front and fast objects on target lane coming from behind.
- ⊕ Calculate all braking distances based on comfort braking and decide if lane change is possible or not.
- ⊕ In case of no camera with lane detection a corridor is used, which comes from the default ACC example in the “findLeadCar” block



## Particular challenges solved

- ⊕ No detection of lanes behind ego vehicle with default camera sensor model
  - ⊕ Modify scenario reader: Points of lanes from real world sent to output not only from ego vehicle's front, also from its rear.
  - ⊕ Modify camera sensor model: Calculated clothoid of lane boundary points at the rear has a mirrored offset (whole clothoid is mirrored) and reversed tolerance values (smallest x-value is now negative, thus has the largest distance to sensor and gets the largest tolerance value for interpolation).
- ⊕ Visualization of detected lane boundaries behind ego vehicle is still not possible (Bird's Eye Scope for visualization cannot be modified, but correct values seen in Bird's Eye Plot).
- ⊕ Sensor fusion of lanes (lane boundaries) and the detected objects.
- ⊕ Sensor fusion of detected objects coming from behind and detected objects ahead (especially needed, if there are no sensors on the side of ego vehicle). Based on constant velocities and works actually not for long vehicles like trucks or busses (sensor models are at moment too simple: Rear objects can only be seen, if their frontal surface can be seen and vice versa).
- ⊕ Trajectory planning or modification in real-time.





# Future challenges to get this LCA into driving simulator

- ⊕ Another trajectory planning for lane change:
  - ⊕ No more based on a given driving path, which must also be modified after the lane change.
- ⊕ Maybe another trajectory control for lane change:
  - ⊕ Maybe steering signal has to be used instead of trajectory coordinates and a corresponding driver model.
- ⊕ Maybe another sensor models must be used:
  - ⊕ First option is to link the scenario from driving simulator with the input of the all knowing sensor models from Simulink.
  - ⊕ Second option is to link other sensor models (maybe more real) with the driving simulator and its scenario reader and the LCA.
- ⊕ The model must be compiled (Co-simulation works not in real-time).

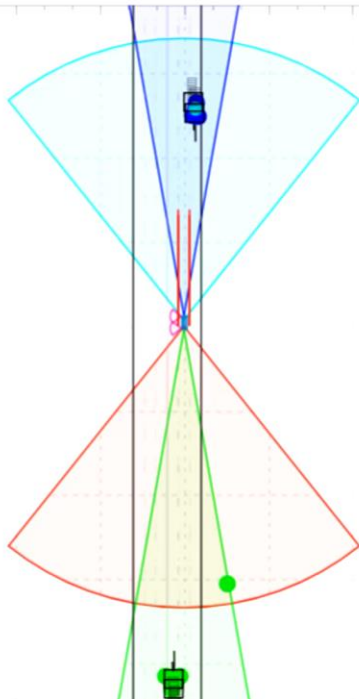


# Future challenges to get this LCA into IDAPT

- ⊕ Another trajectory planning for lane change:
  - ⊕ No more based on a given driving path, which must also be modified after the lane change.
- ⊕ Maybe another trajectory control for lane change:
  - ⊕ Maybe steering signal has to be used instead of trajectory coordinates and a corresponding driver model.
- ⊕ Another sensor models must be used:
  - ⊕ Real sensor models of the car must be linked to the LCA.
- ⊕ The model must be compiled (Co-simulation works not in real-time).



□ Vision Coverage   □ Radar Coverage   ● Vision Detections   ● Radar Detections   — Lane Detections   □ Tracks



### LCA Controls



Lane Change possible



Lane Change activated



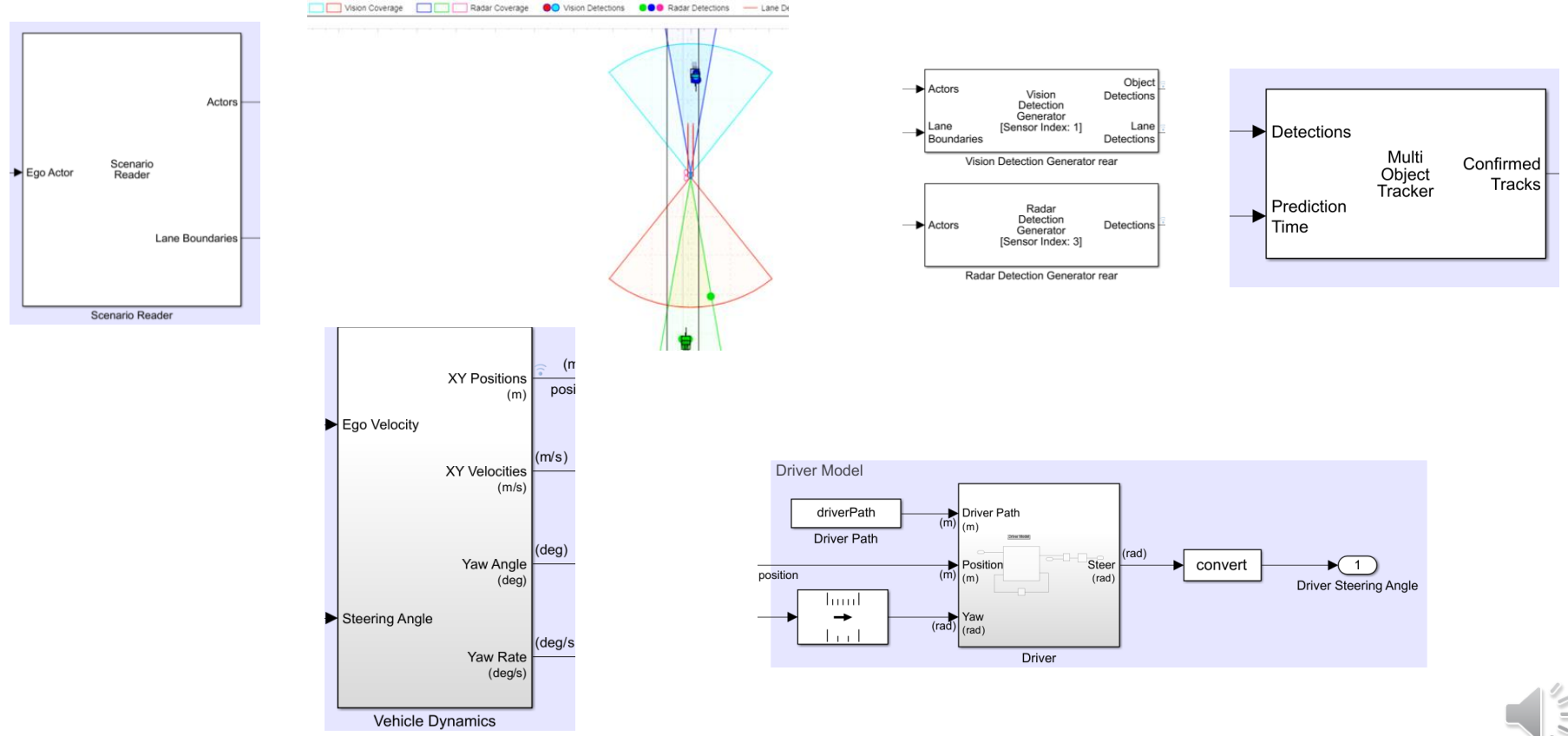
Lane Change requested

T=2.100

5%

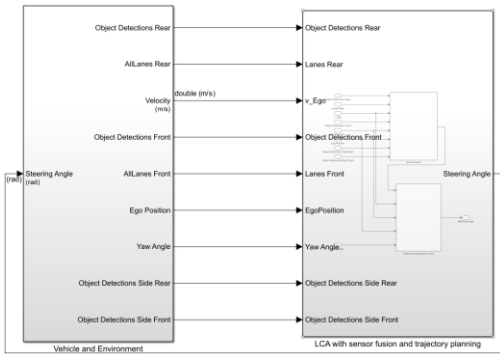


# Why Simulink and Automated Driving Toolbox?



# Summary

Lane Change Assist Test Bench



Model Buttons

Edit Setup Script

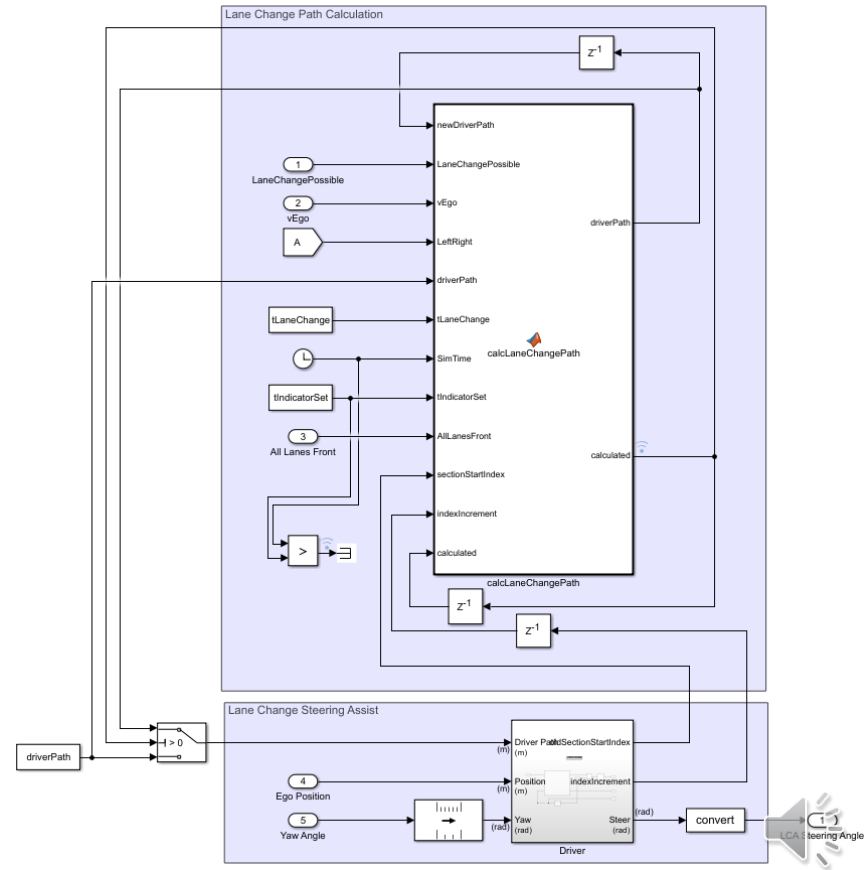
Info

LCA Controls

Lane Change possible

Lane Change activated

Lane Change requested



# Applus<sup>+</sup> IDIADA

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Q & A

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