

# SIMULATION FRAMEWORK FOR AUTONOMOUS TRUCKS

CASE STUDY: LOGISTICS CENTRE

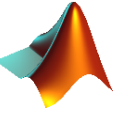
DR. SRIVATHSAN RAVI (BOSCH)

SHASHANK SHARMA (MATHWORKS)



# About Bosch Research and Technology Centre

## Mission and overview



“To conduct applied research for Bosch’s BUs that generates differentiating technologies and Innovative solutions for global and regional opportunities”



Intelligence for IoT



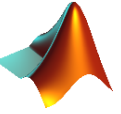
Computer Vision,  
Machine Learning



Numerical Methods and  
Algorithms



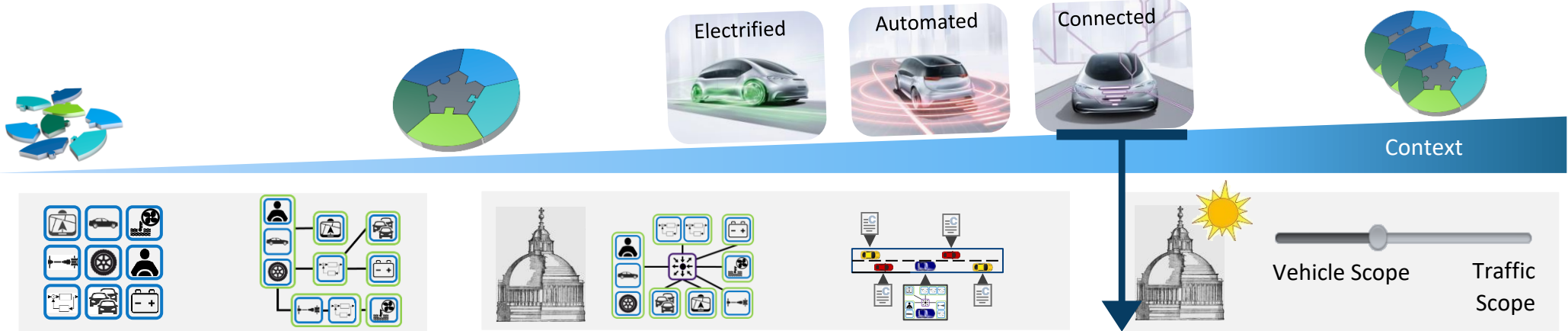
Bosch Center for AI - India



# Problem statement

## What do we want to achieve?

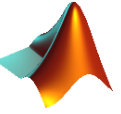
- ▶ Simulation framework for simulating multiple trucks in a logistics centre
  - ▶ Trucks drive to their loading docks to load and unload
- ▶ Use case a proof-of-concept for multi-ego simulation framework



Simulation framework for a **specific** virtual vehicle ✓

Simulation framework for a **generic virtual** vehicle for MiL/SiL. Single detailed ego vehicle with Bosch SW & components in a simple environment ✓

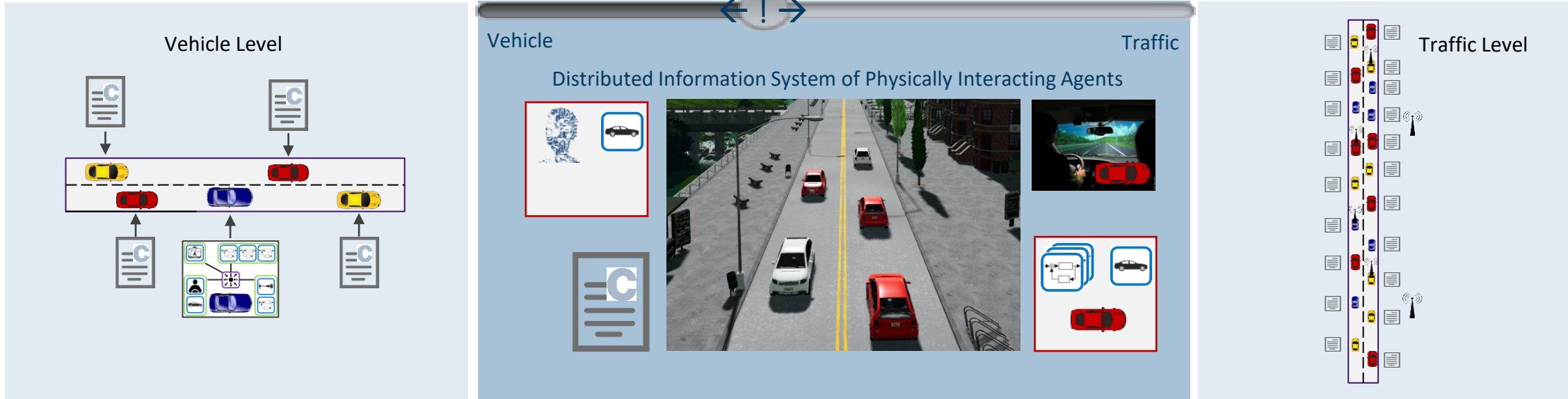
Simulation framework for a multi-agent simulations. Agents interact with each other and the infrastructure – trucks in a logistics centre ?

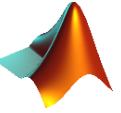


# Simulation framework

## Solution proposition - Architecture

- ▶ Design of a modular and scalable simulation framework that enables
  - ▶ Separation of truck vehicle dynamics from the environment
  - ▶ Simulating truck models with varying levels of fidelity and composition
  - ▶ Interaction of several agents in a shared environment





# Simulation framework for highly autonomous trucks

## Simulink as the simulation integration platform

➤ Simulink offers a modular simulation framework with clear separation of vehicle from environment

**Modularity**



➤ Many ego vehicles share the same environment making the framework scalable

**Scalability**



➤ Offers 3D scenario creation through RoadRunner and Unreal Engine

**Visualization**



➤ Planners, controllers and semi-trailer models readily available for fast framework prototyping

**Out of the box**



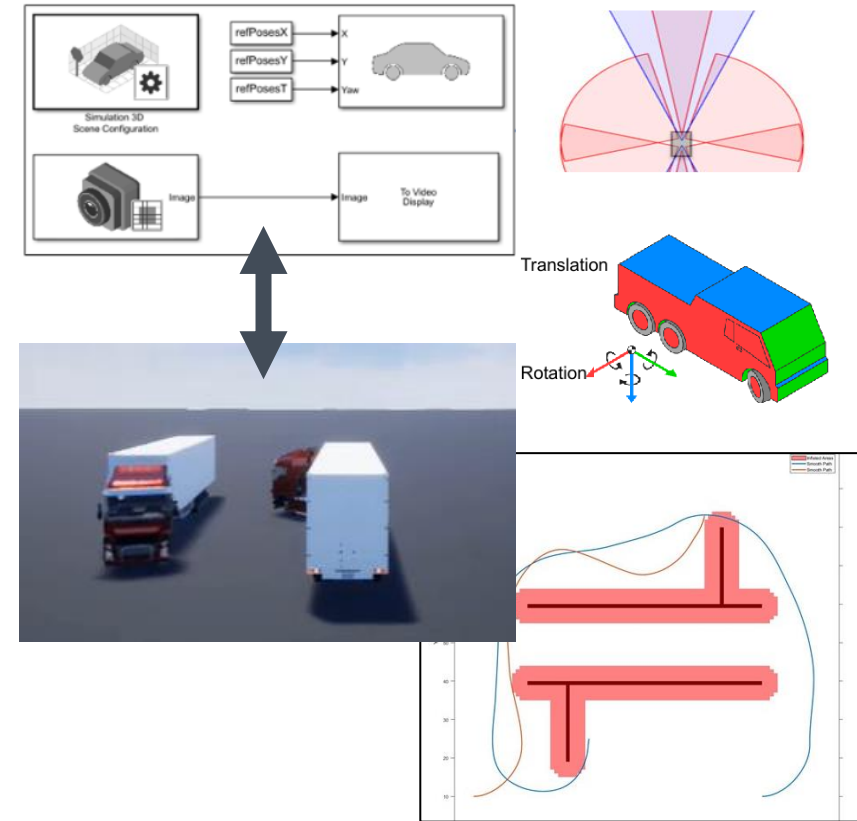
➤ Tool familiarity and ready-to-use reference examples

**Tooling**



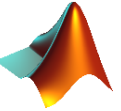
➤ Ongoing collaboration with MathWorks and technical advisory

**Collaboration**



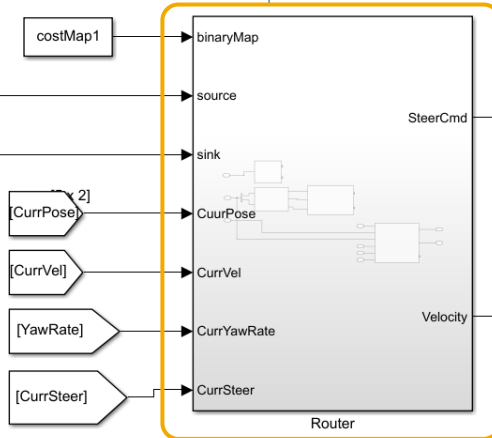
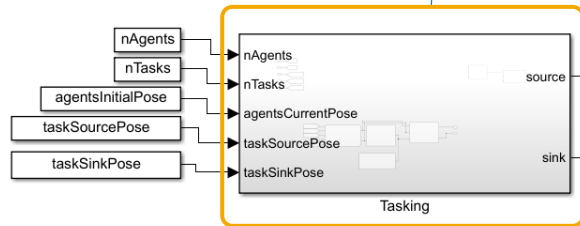
# Simulation framework for a multi-ego workflow

## Proof of concept

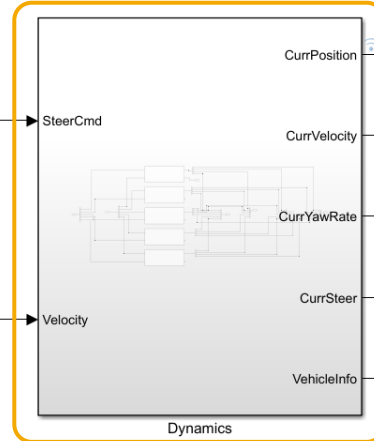


- ▶ Case study focus
  - ▶ Feasibility & modularity
  - ▶ 2D & 3D visualization

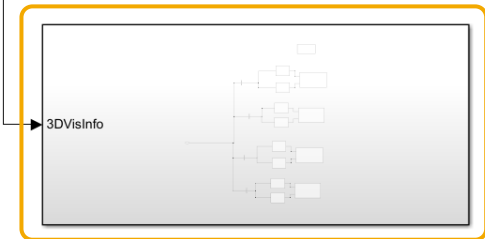
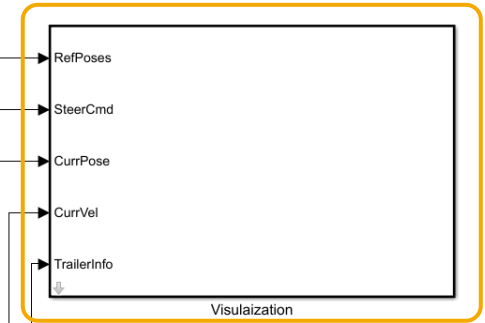
**1. Supervisory Control:**  
 Tasking multiple agents  
 Route optimization for multiple agents



**2. Path Planning:**  
 RRT\* planner  
 Dubins path segment



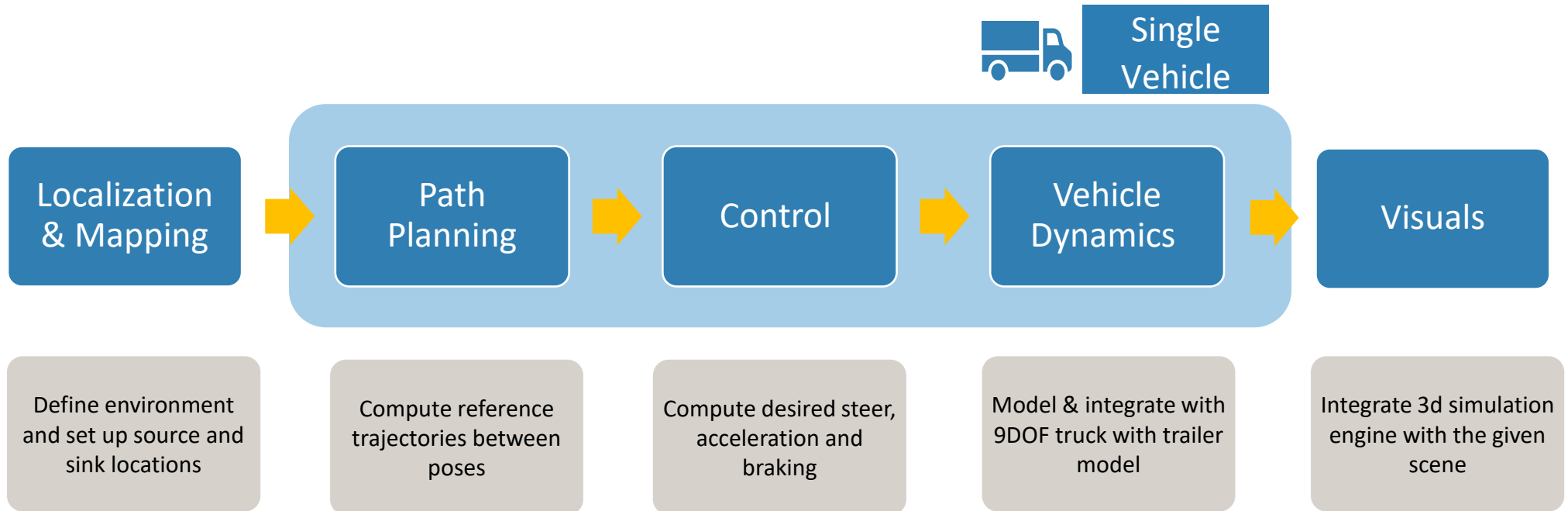
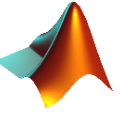
**3. Vehicle Dynamics:**  
 Adapted an existing example using in-built blocks

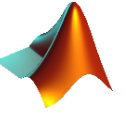


4. 2D & 3D Visualization

# Simulation framework for a single vehicle workflow

## Workflow overview

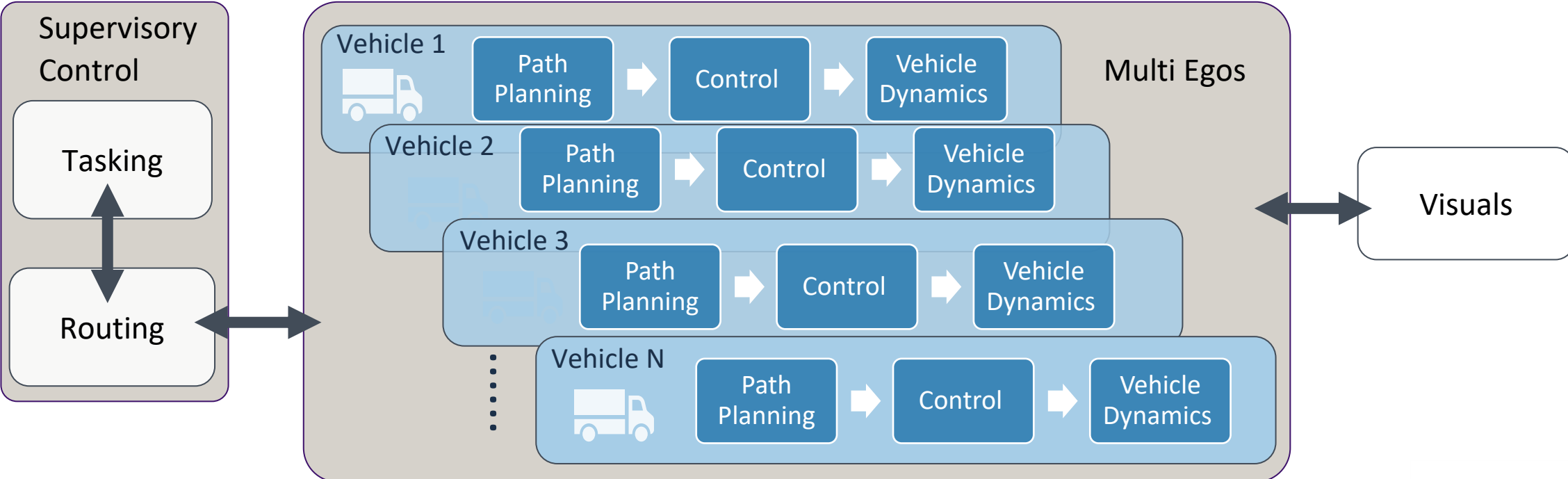




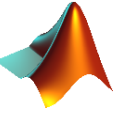
# Simulation framework for a multi-ego workflow

## Workflow overview

### Mapping & Environment Modeling







# Simulation framework for a multi-ego workflow

## Supervisory control

Challenge:

How can the trucks complete trips without colliding with each other?

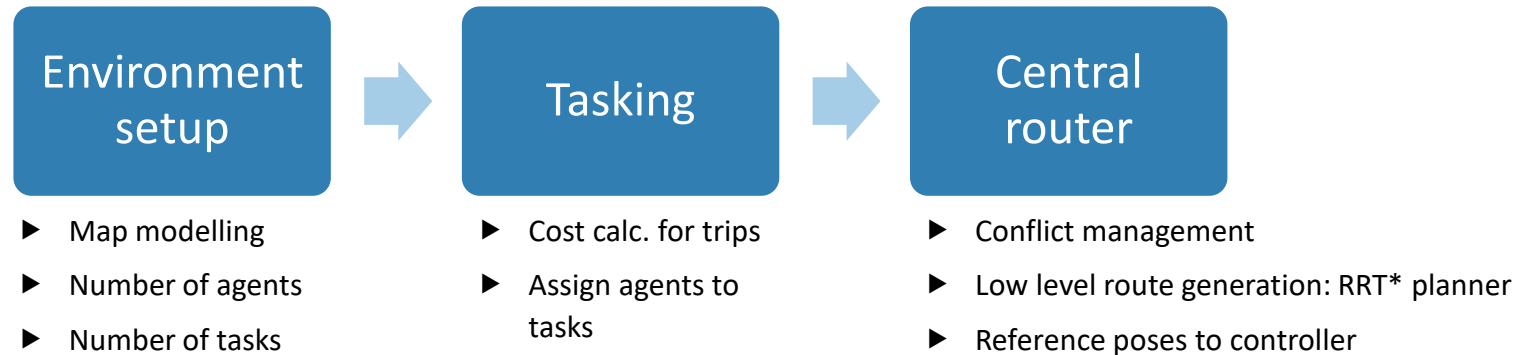
Solution:

Task assignment & route optimization for multiple agents

Assumptions:

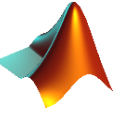
All agents communicate via one central server

Only 1 trip can be assigned to 1 agent at a given point in time



# Simulation framework for a multi-ego workflow

## Path planning & controls



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In-built planner RRT\* to generate trajectories

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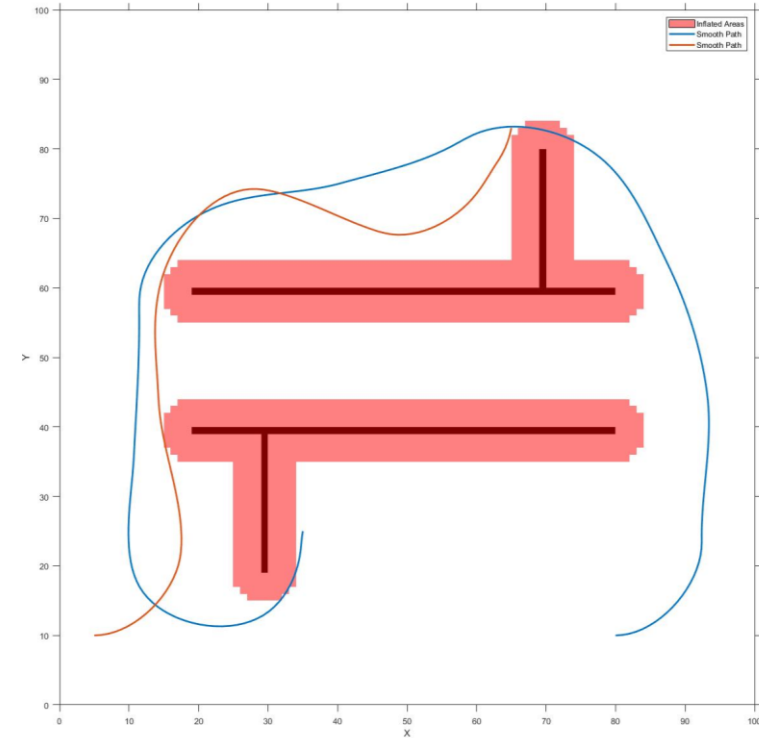
Reference path generated composed of Dubins segments

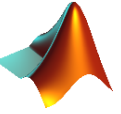
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Trajectory generation by computing a smooth path & velocity profile

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Planning output fed into a Stanley lateral and longitudinal controller





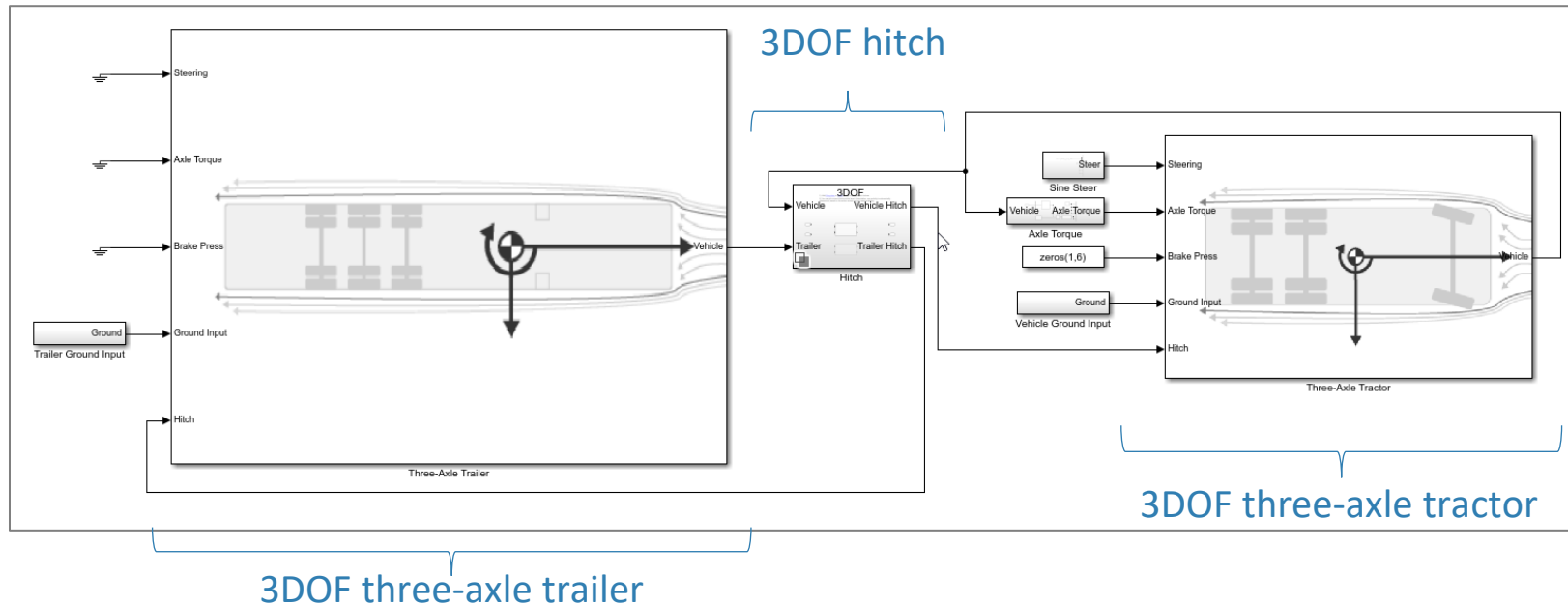
# Simulation framework for a multi-ego workflow

## Vehicle dynamics

Reference application “Three-Axle Tractor Towing a Three-Axle Trailer”

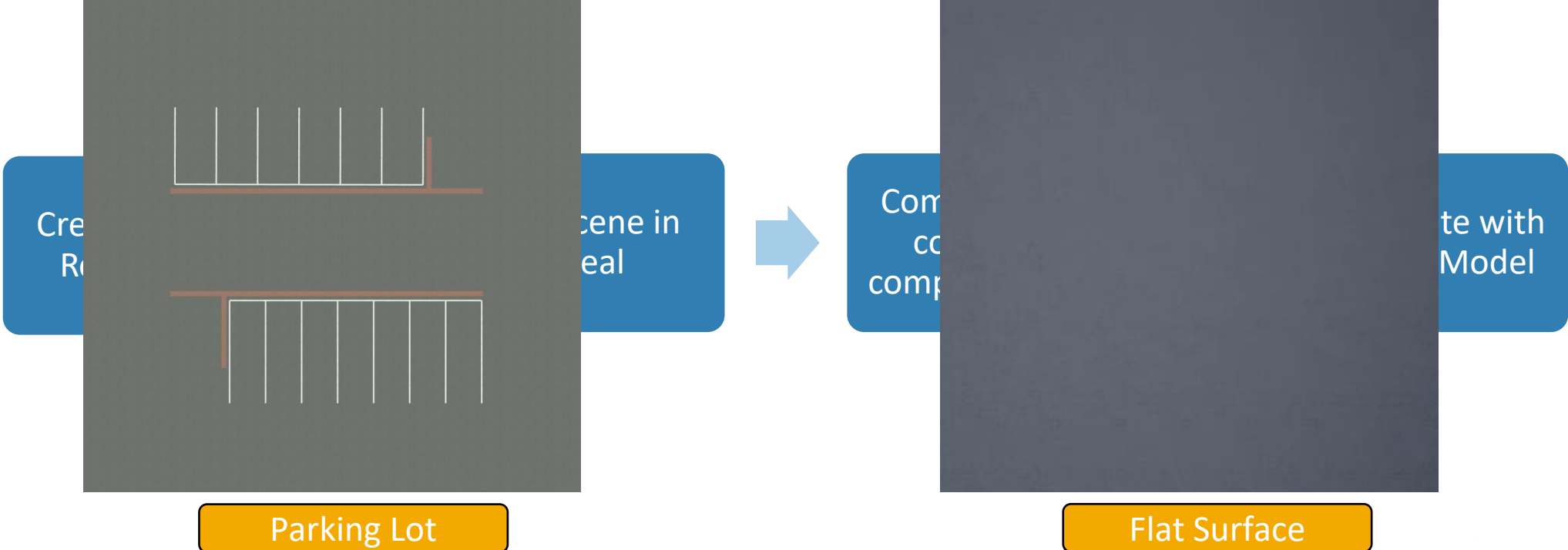
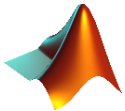
Rigid vehicle body models to calculate longitudinal, lateral, and yaw motion

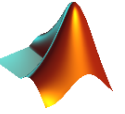
Hitch subsystem allows relative longitudinal, lateral, and yaw motion between tractor and trailer



# Vehicle simulation

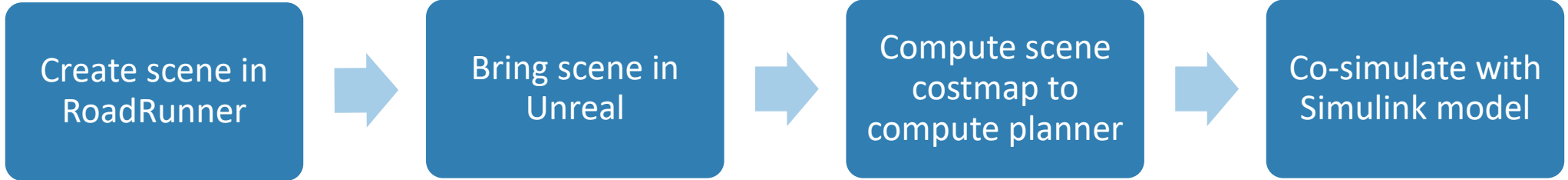
## Co-simulation workflow





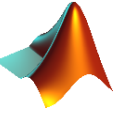
# Vehicle simulation

## Co-simulation using a default Unreal scene



Flat surface

The screenshot displays a Simulink workspace with a 3D Unreal scene window titled 'AutoVirtEnv (64-bit Development PCD3D\_SM5)'. The scene shows a white vehicle on a flat surface under a blue sky. To the right, a 'Figure 2' window shows a 2D plot of a path with a cyan outline and a blue box containing '8X'. The plot has axes labeled 'X' and 'Y' ranging from 0 to 100. The Simulink interface includes a 'REVIEW RESULTS' section and a 'Running' status indicator at the bottom.



# Vehicle simulation

## Co-simulation using a custom RoadRunner scene

Create scene in RoadRunner



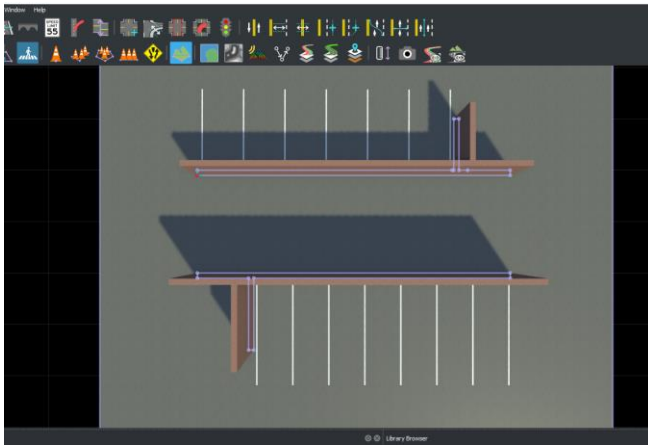
Bring scene in Unreal



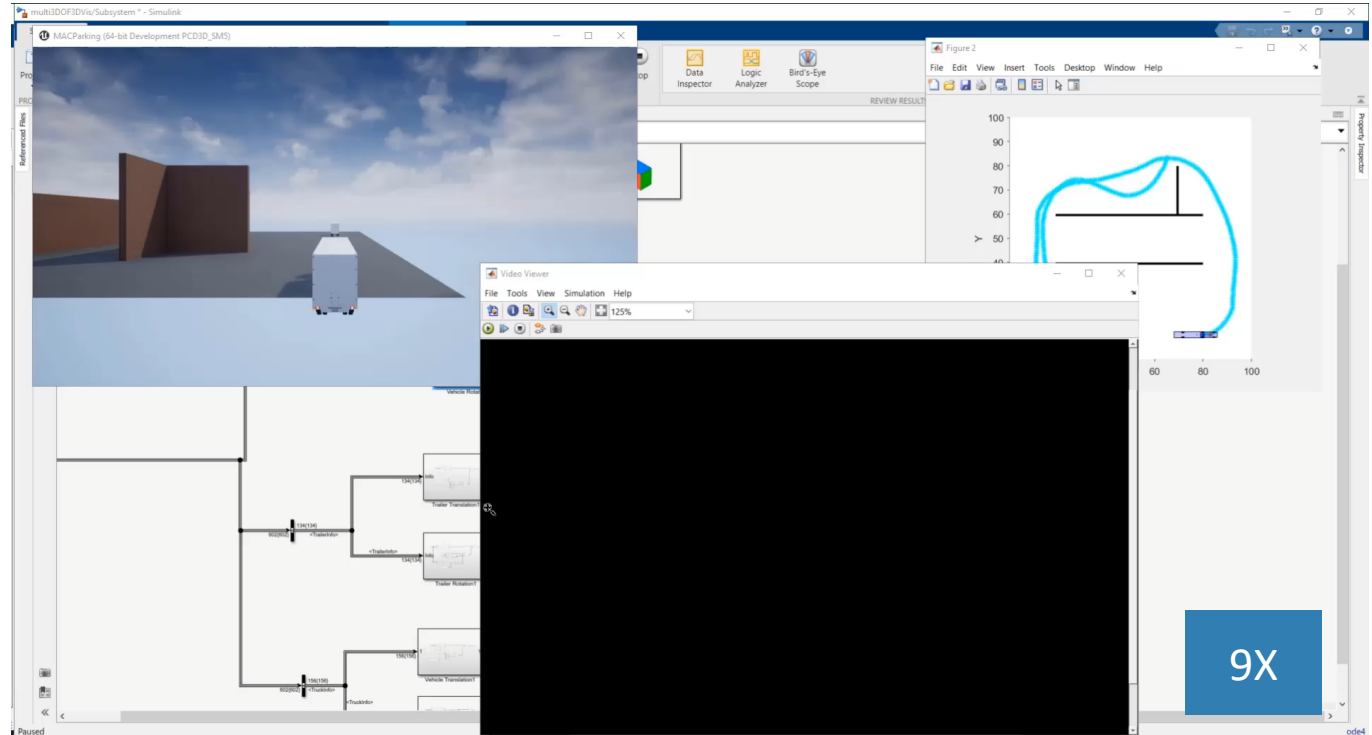
Compute scene costmap to compute planner



Co-simulate with Simulink model



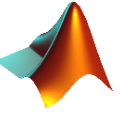
Parking lot



9X

# Concluding remarks

## Summary



### 01

Initial framework prototype demonstrated simulation of two autonomous trucks

- Out of the box functions and reference examples

### 02

Single development environment for vehicle model, planning, scene simulation and visualization

- Separation of environment and vehicle models

### 03

The initial framework will serve as proof-of-concept for modular and scalable simulation framework for multi-ego simulations

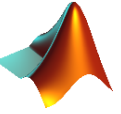
### 04

Framework will help function developers at to test and validate functions for autonomous driving.

### 05

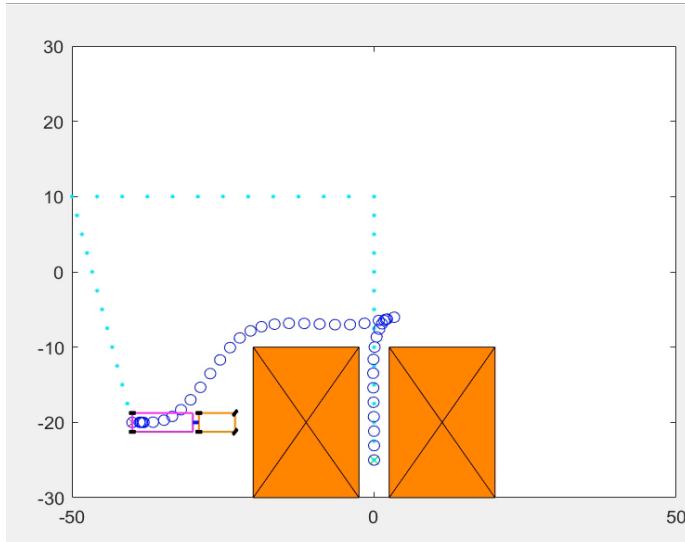
Simulation strategy will change depending on the number of actors (< 10 or >10 )

- different solution approach from MathWorks for more than 10 actors.



# Concluding remarks

## Future outlook



Truck and Trailer Automatic Parking  
Using Multistage Nonlinear MPC  
*Robotics System Toolbox™*  
*Model Predictive Control Toolbox™*  
*Optimization Toolbox™*  
**R2021a**



Path planning with reverse manoeuvre is work in progress



MathWorks is also investing in Reverse planning



Generalized communication platform for multi-agent simulation



# THANK YOU

