MATLAB EXPO

November 13–14, 2024 | Online

Virtual Testing and Simulation to Automate Offroad Heavy Machinery Using MATLAB

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MathWorks

Offroad vehicle industries are adopting **autonomy** and **intelligence** for process optimization, safety, and sustainability

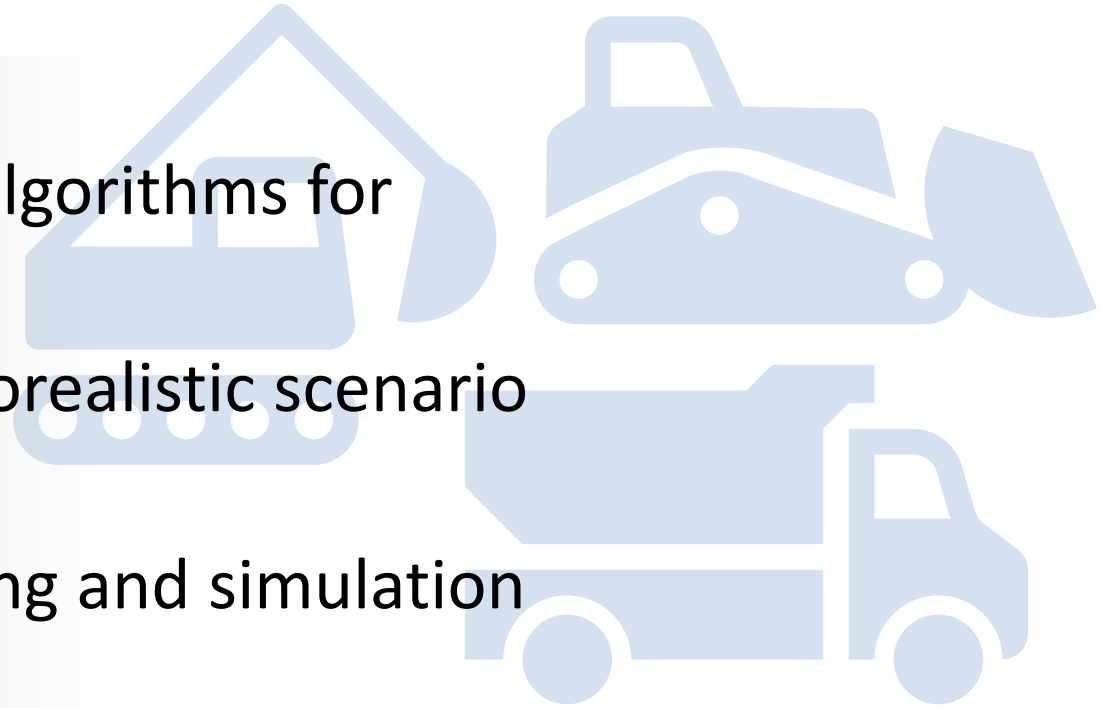
Construction

Agriculture

Mining

Key Takeaways - **Virtual testing** and **simulation** are essential for developing autonomous offroad heavy machinery

- Developing and validating autonomous algorithms for offroad heavy machinery in simulation
- Testing offroad heavy machinery in photorealistic scenario simulations
- Performing high-fidelity dynamic modeling and simulation



What are the key drivers behind interest in **autonomy** and **intelligence** for offroad heavy machinery?

Workforce

- Widespread skilled operator shortage
- Aging workforce

Tasks

- Inherently high-fatality tasks
- Precision and accuracy

Technology

- Perceived successes of autonomy in automotive industry
- The rise of the Internet of Things (IoT) and better connectivity

Economics

- ROI despite high initial costs
- Competitive advantage via operational efficiency, cost reduction, and improved quality and safety

Industry examples transforming offroad vehicle operations include …

Construction

Sumitomo Heavy Industries Speeds Development of Embedded Model Predictive Control Software for Hydraulic Excavators

LINK

Agriculture

CNH Industry Develops Intelligent Filling System for Forage Harvesters

LINK

Mining

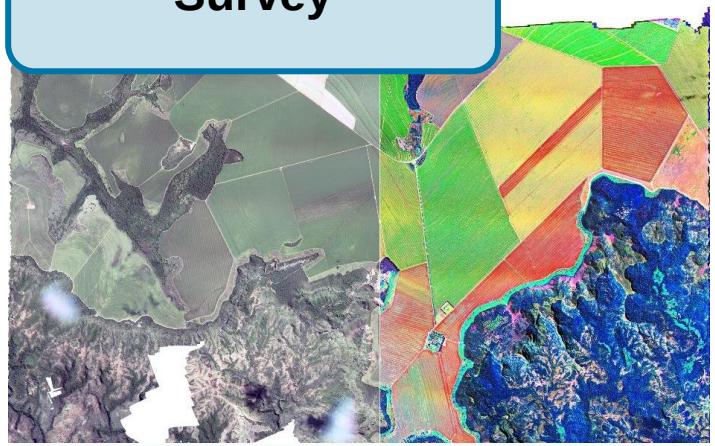
Caterpillar Uses Machine and Deep Learning to Build Ground-Truth for Training, Validation, and Deploying Classifiers

LINK

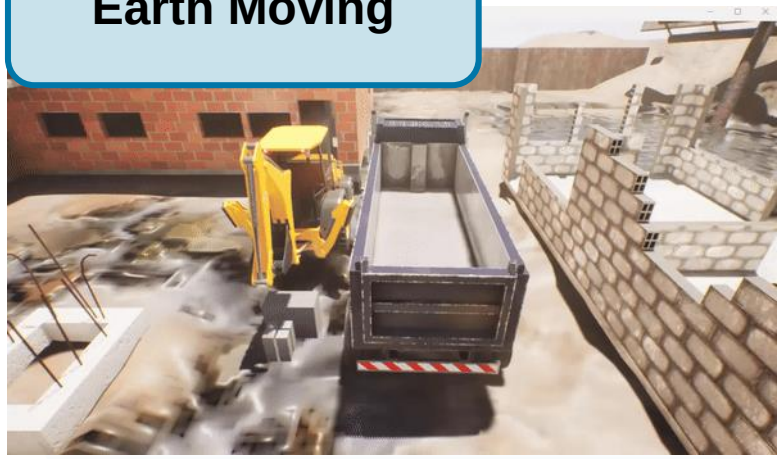
The core elements of **Autonomy** – perception, planning, and control – are powering offroad vehicles on all terrains

Tasks

Survey



Earth Moving



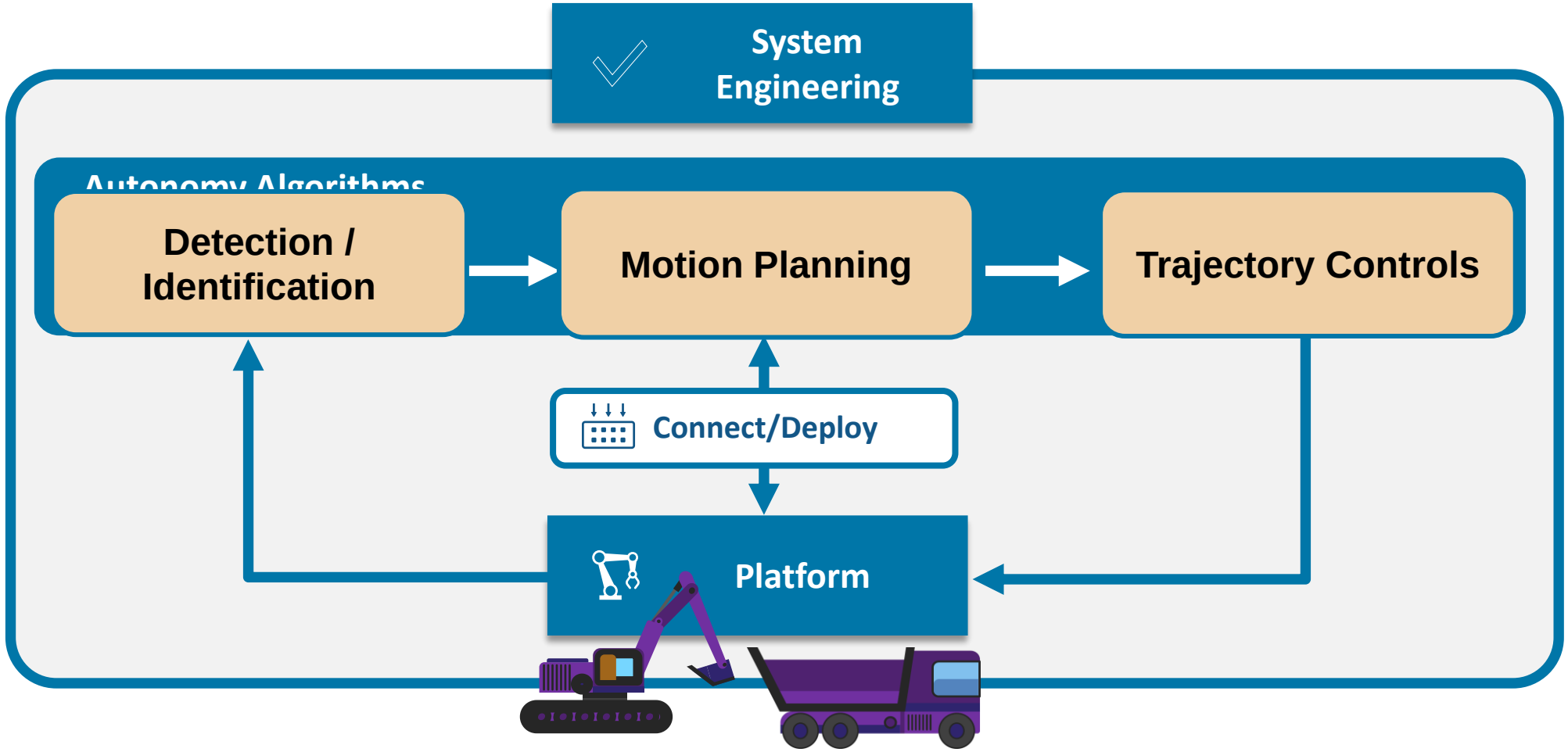
Transport

Detection / Identification

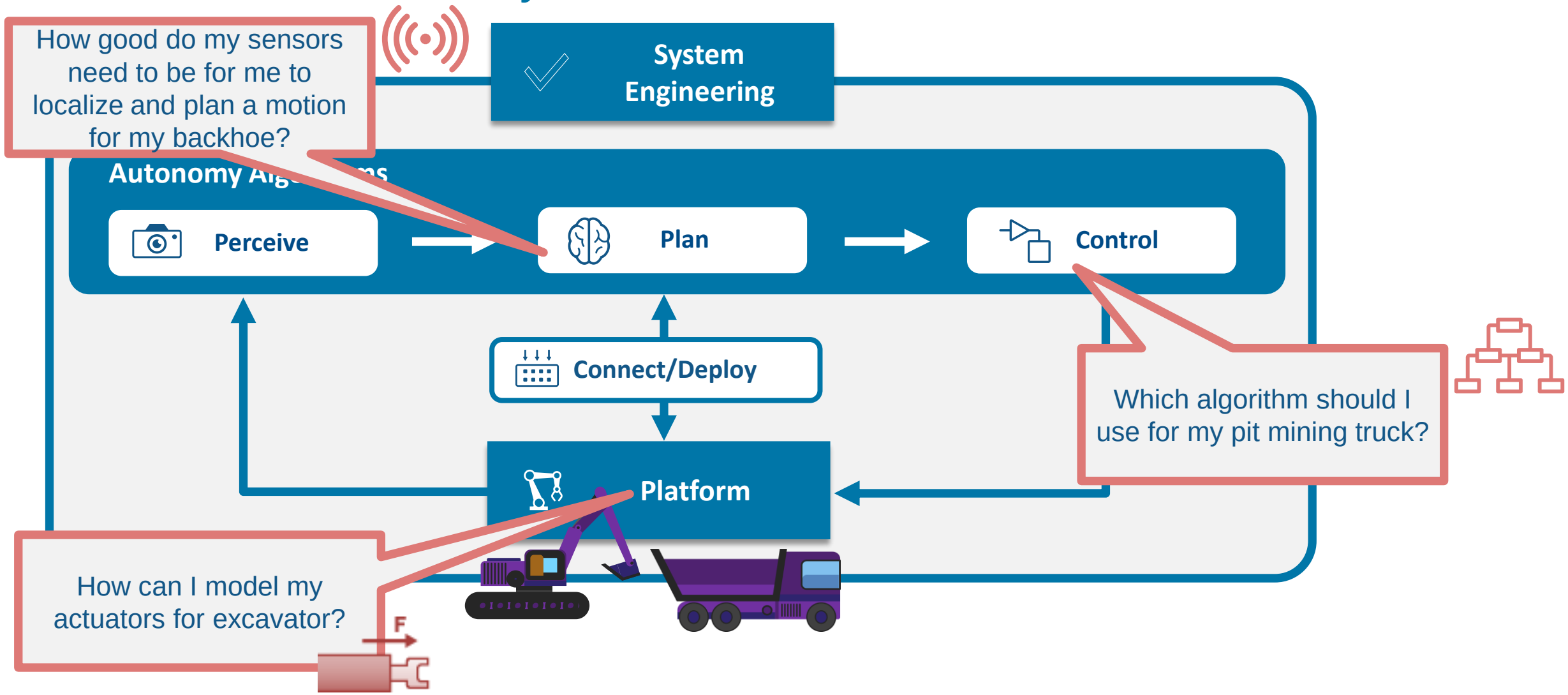
Motion Planning

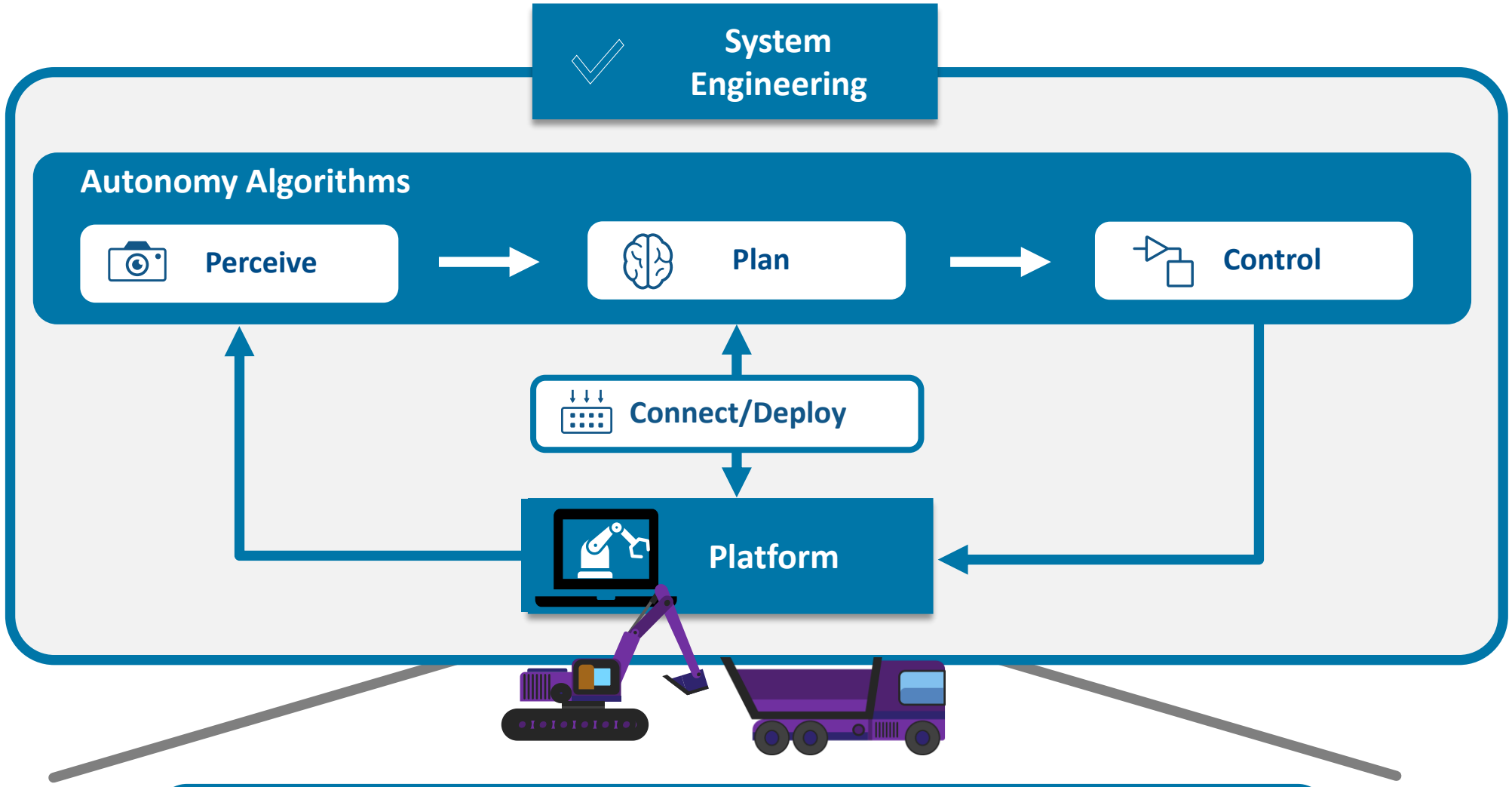
Trajectory Controls

Autonomy

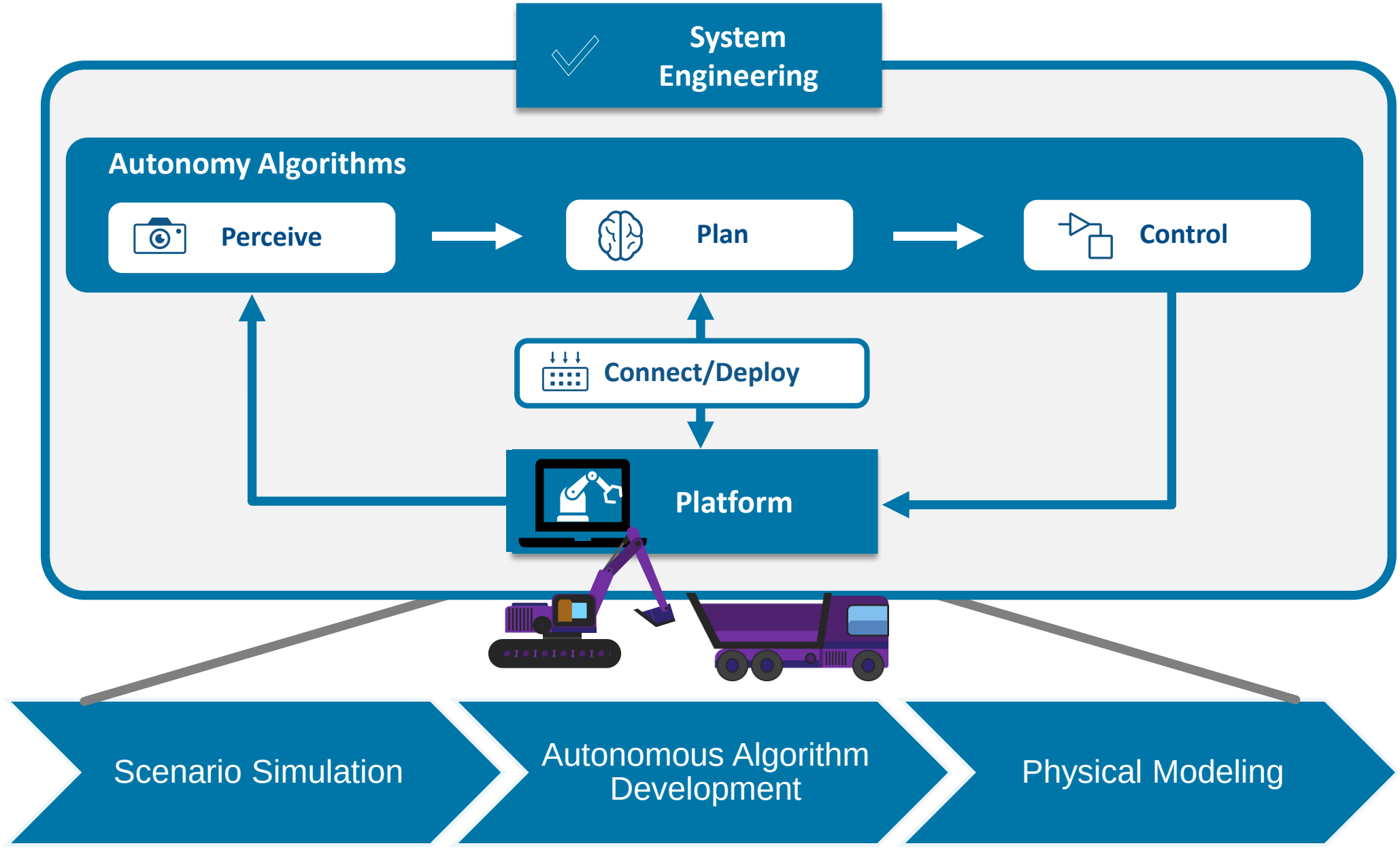

System Engineering
Autonomy Algorithms
Detection / Identification
Motion Planning
Trajectory Controls
Connect/Deploy
Platform

There are a variety of challenges in developing autonomous offroad systems



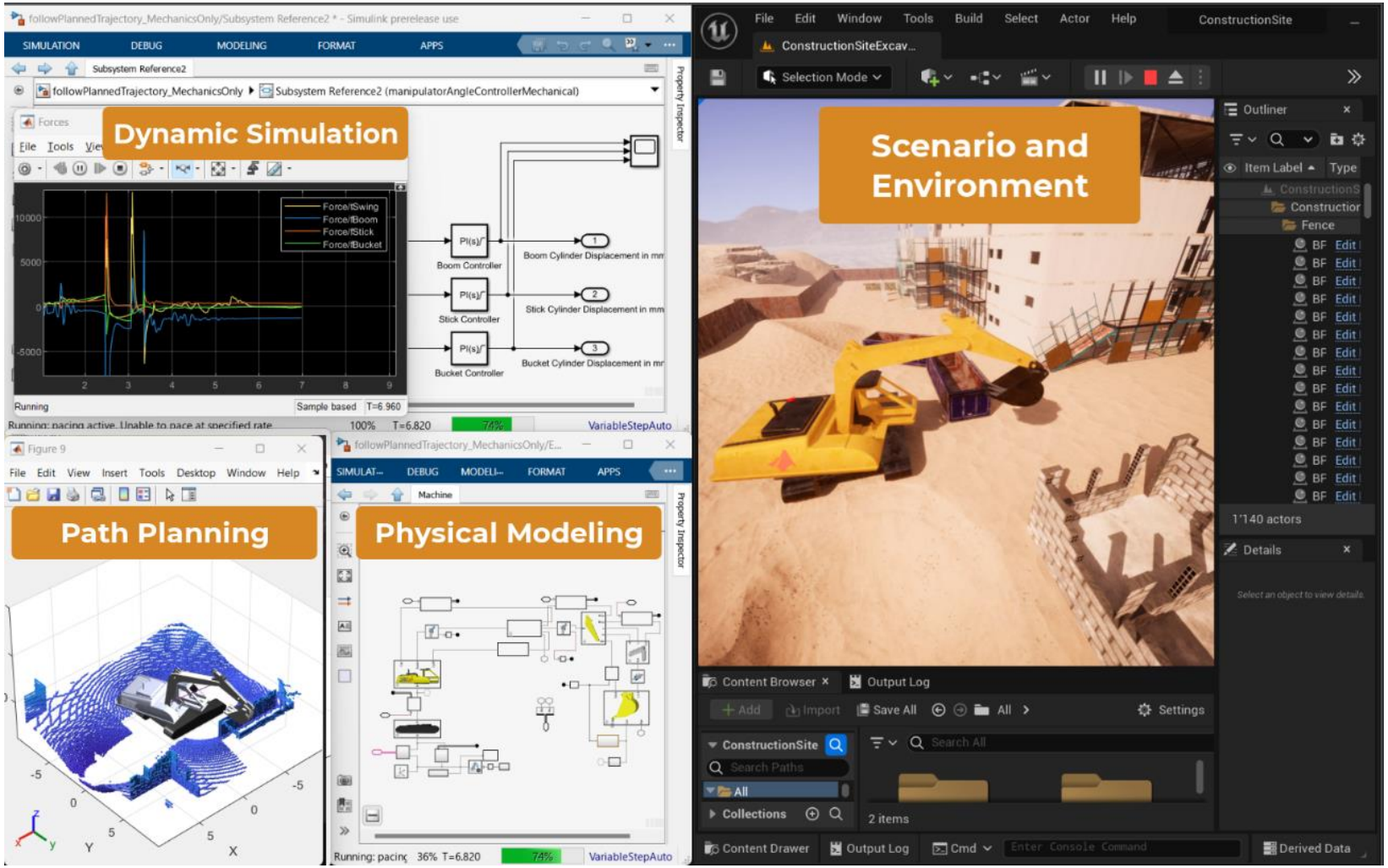


"Simulation is essential for all stages of development process and entire product lifecycle"


System Engineering
Autonomy Algorithms
Perceive
Plan
Control
Connect/Deploy
Platform
Scenario Simulation
Autonomous Algorithm Development
Physical Modeling

System-Level Closed-Loop Dynamic Simulation of Autonomous Offroad Machinery

System-Level Closed-Loop Dynamic Simulation of Autonomous Offroad Machinery



System-Level Closed-Loop Dynamic Simulation of Autonomous Offroad Machinery

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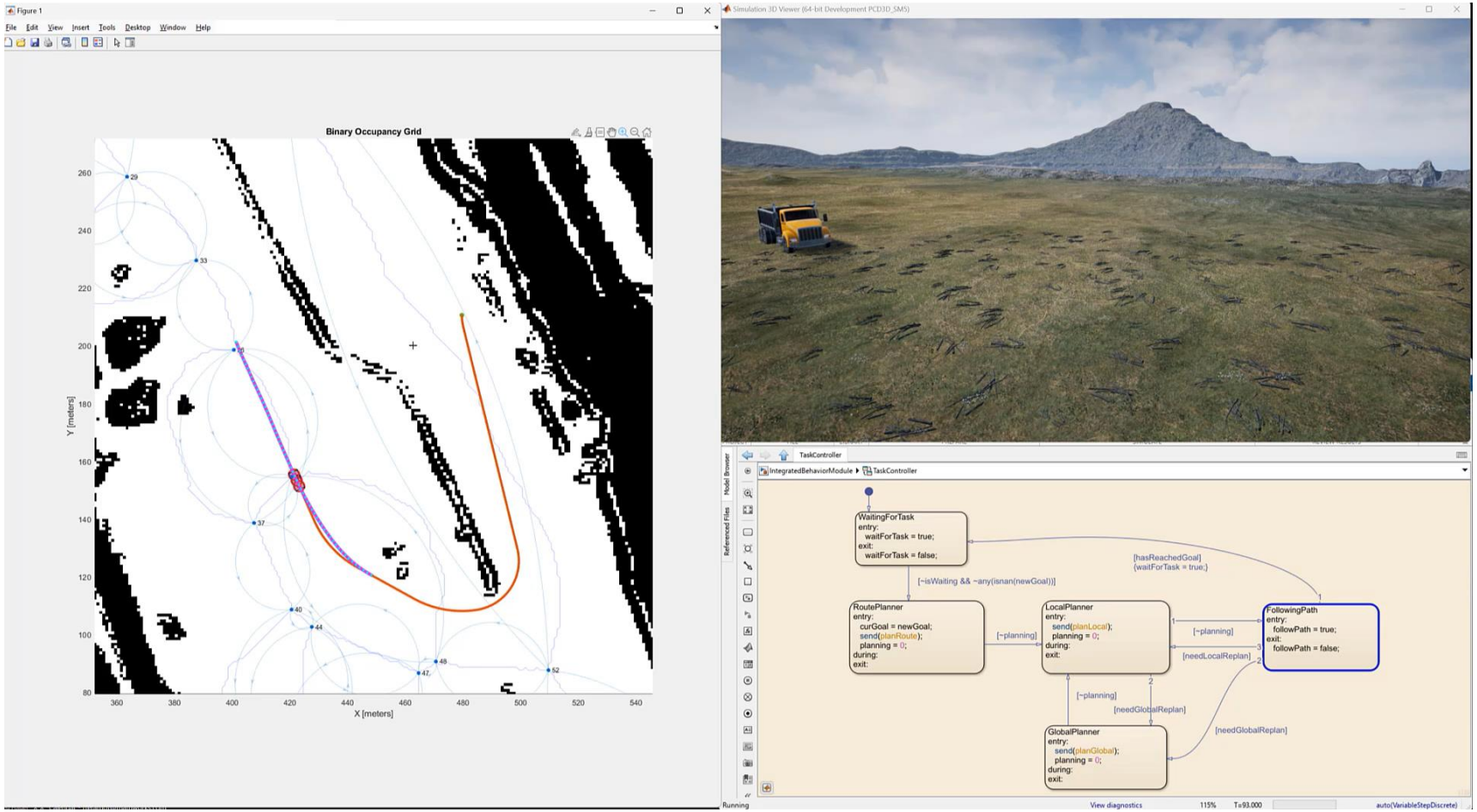
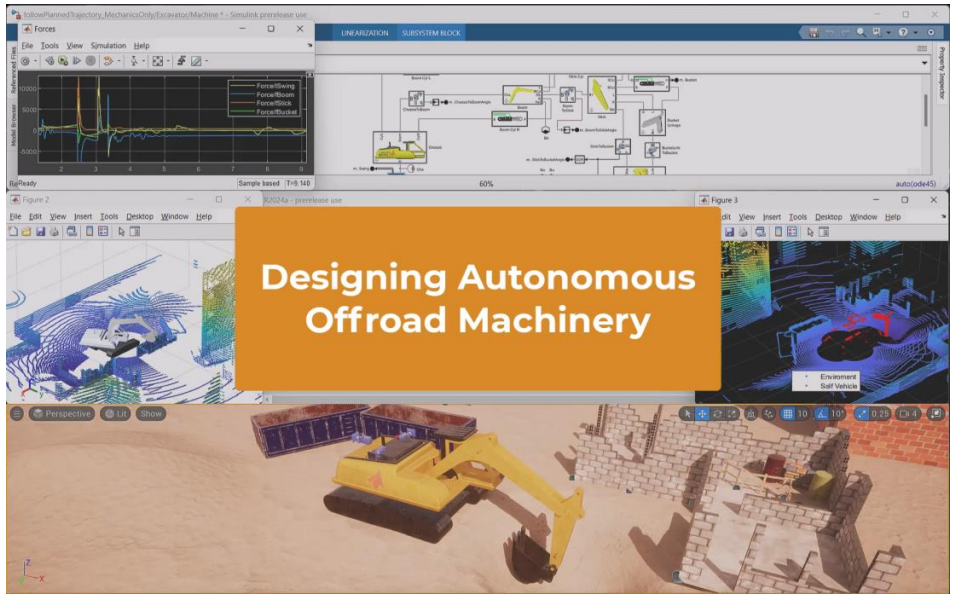
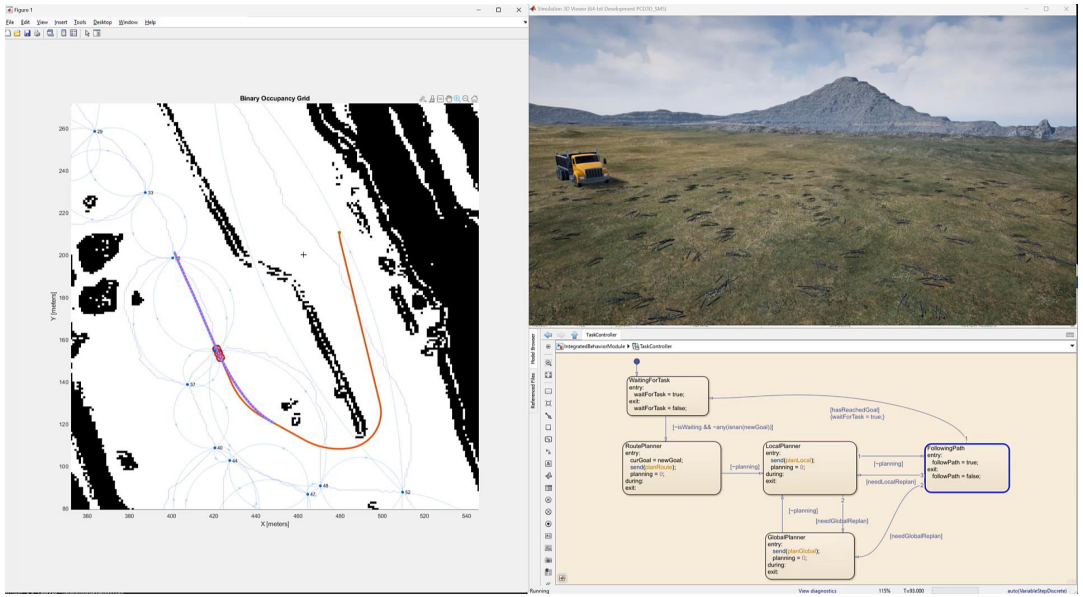


System-Level Closed-Loop Dynamic Simulation of Autonomous Offroad Machinery





Robotics System Toolbox Offroad Autonomy Library

by MathWorks Robotics and Autonomous Systems Team STAFF

Design, Simulate, and Test Autonomous Offroad Vehicle Applications

Autonomous Offroad Heavy Machinery Development

1. Scenario Simulation using Unreal Engine
2. Sensor Modeling and Synthetic Data Generation

3. Motion planning for Excavator

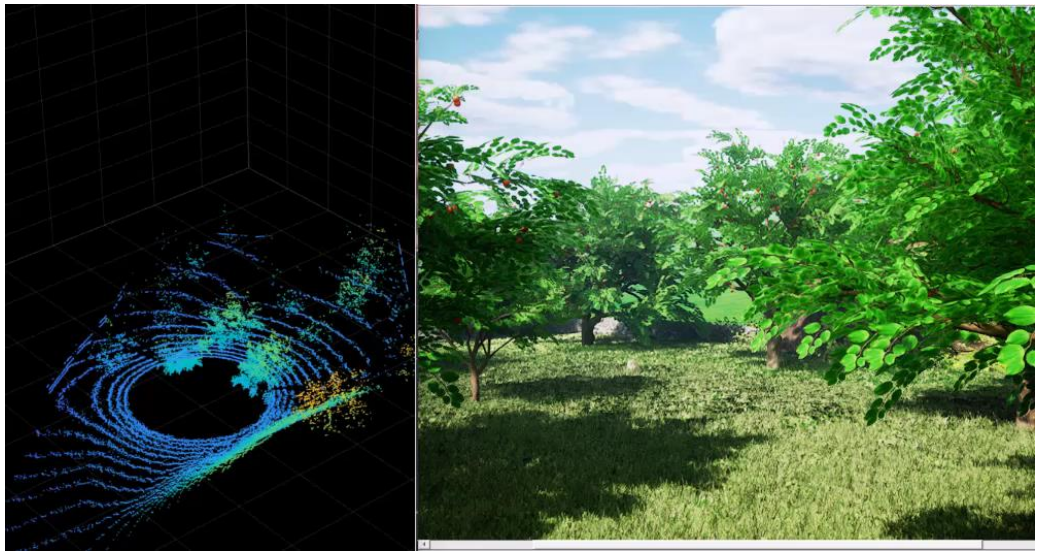
4. Autonomous navigation algorithm development

5. High-fidelity multi-domain physics models

Why 3D Scenario Simulation?

- Visuals are universal
  - Easily debug issues
  - Sell your concept or product

- 3D environments are data-rich
  - Simulate camera, radar, or lidar data
  - Ray tracing enables other sensor simulations



- Complex scenario simulation
  - Create complex scenes with multiple actors
  - Test and validate complete system in simulation

You can perform closed-loop, deterministic simulations with Unreal Engine

MATLAB & Simulink

- **Physics of main actor(s)**
- **Perception, Planning, Control Algorithms**

actor position

sensor location

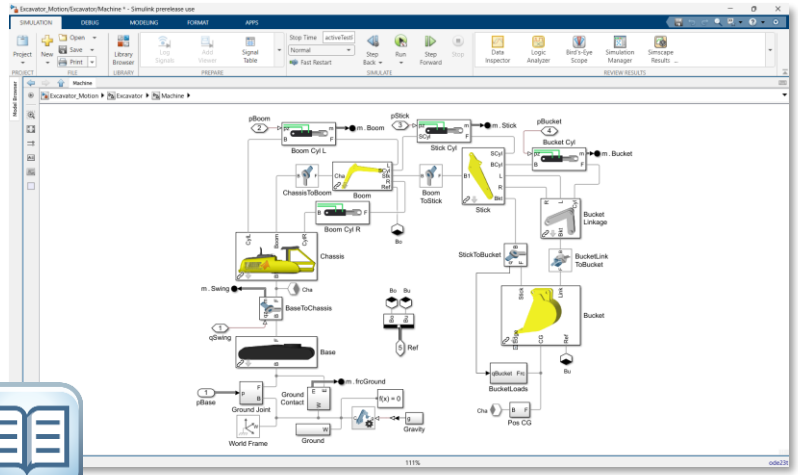
sensor information

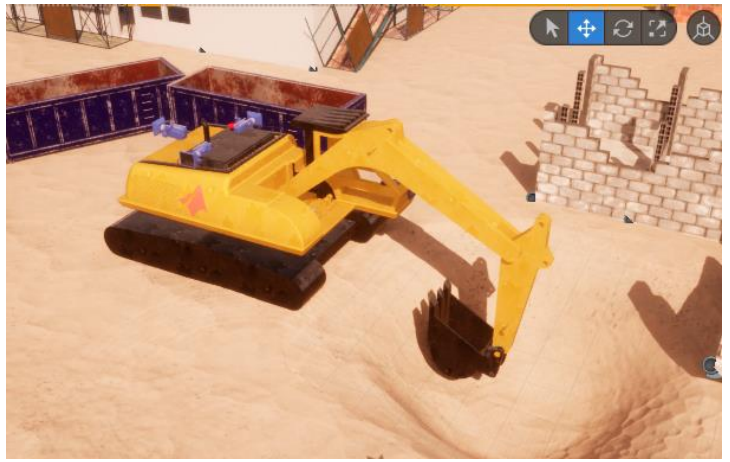
collision information

Unreal Engine

- **Rendering / lighting**
- **Physics of non-Simulink actors**
- **Collision detection**

Lock-step co-simulation (solvers take turns) provides **deterministic results**

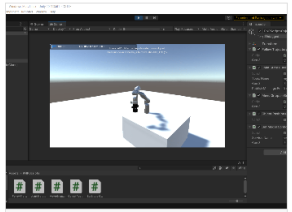




MathWorks supports other simulators as well

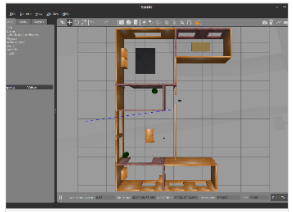
ROS, ROS2

TCP, UDP



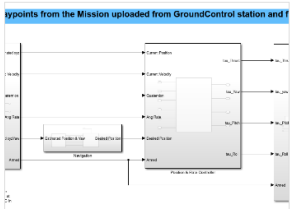
Pick-and-Place Workflow in Unity 3D Using ROS

Set up an end-to-end pick-and-place workflow for a robotic manipulator like the Kinova Gen3, and simulate the robot in the Unity game engine.



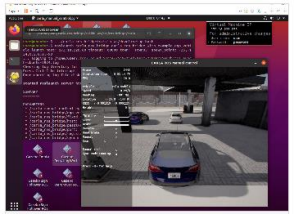
Get Started with Gazebo and Simulated TurtleBot

Set up the Gazebo® simulator engine and further explore Gazebo with a simulated TurtleBot.



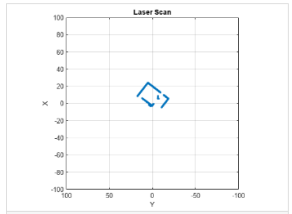
PX4 in Hardware-in-the-Loop (HITL) Simulation with jMAVSim Simulator

Use the UAV Toolbox Support Package for PX4 Autopilots to verify the controller design by deploying on the Pixhawk hardware board, in HITL



Emergency Braking of Ego Vehicle in CARLA Simulator Using Simulink and CARLA...

Emergency braking of ego vehicle in CARLA using Simulink.



Control NVIDIA Carter Robot in Isaac Sim Using ROS 2

Publish ROS 2 messages from MATLAB to NVIDIA Carter robot and subscribe to the published topics

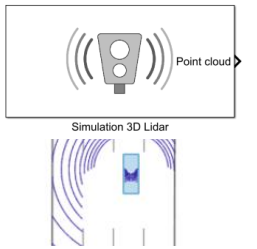
HL-20 Project with Optional FlightGear Interface

Model NASA HL-20 lifting body and controller modeled in Simulink and Aerospace Blockset, using FlightGear for visualization.

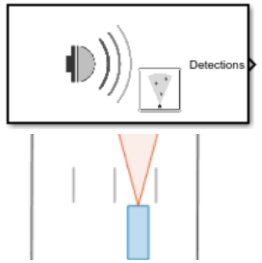
Perceive

Simulate virtual sensors models and generate synthetic sensor data

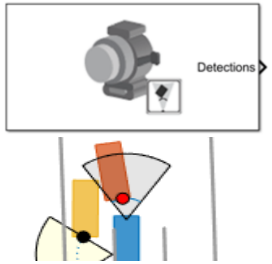
Lidar



Radar

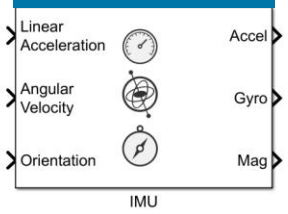


Ultrasonic

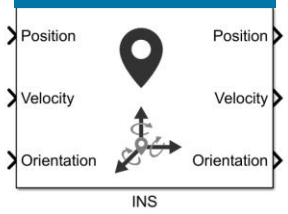


GPS

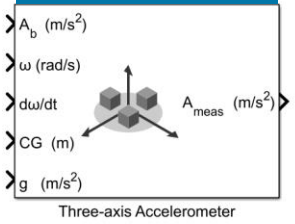
IMU



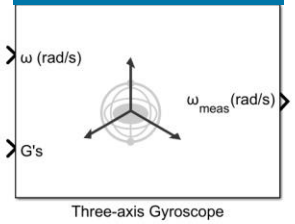
INS



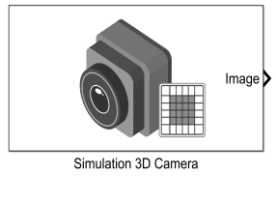
Accel

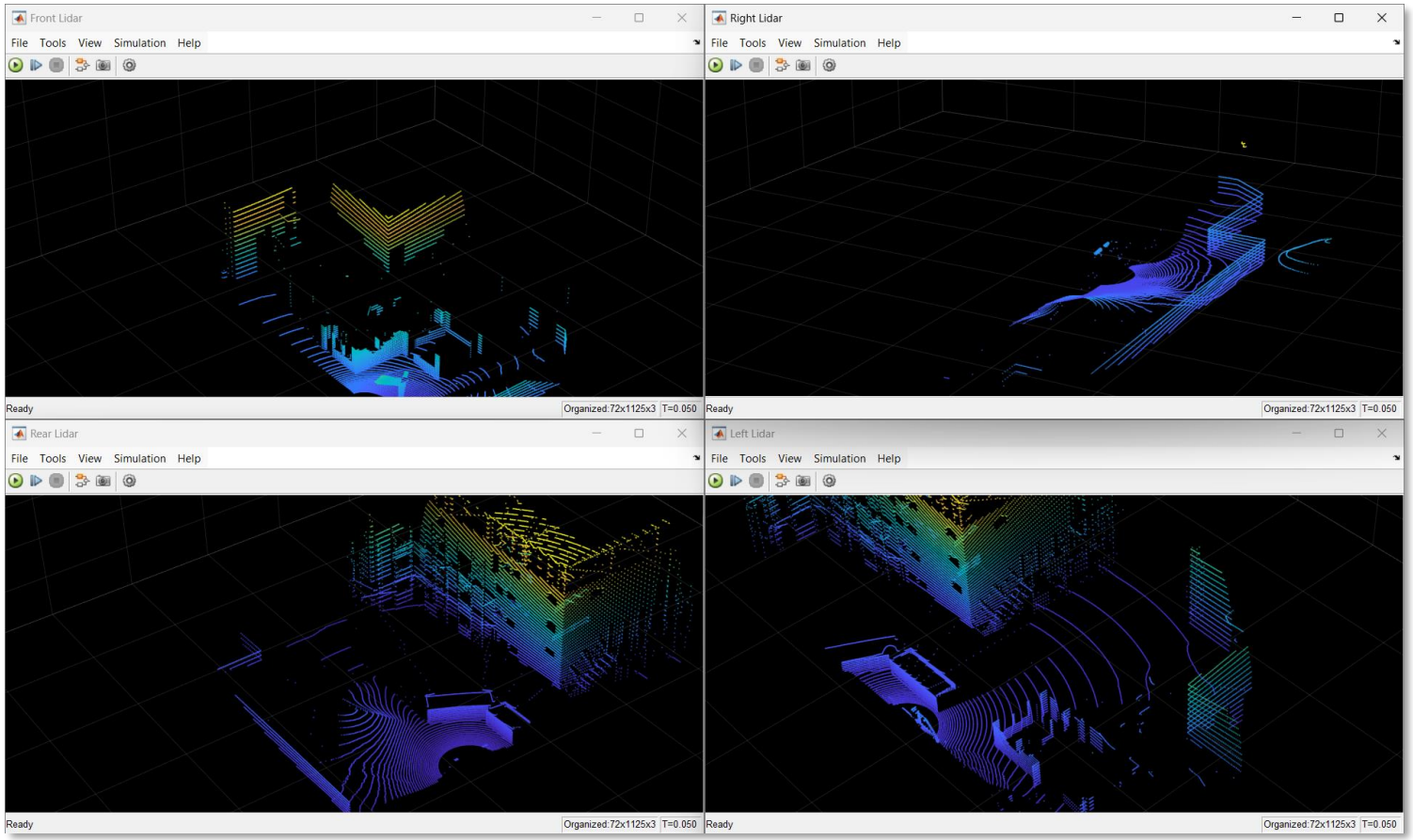


Gyro



Camera





MATLAB EXPO

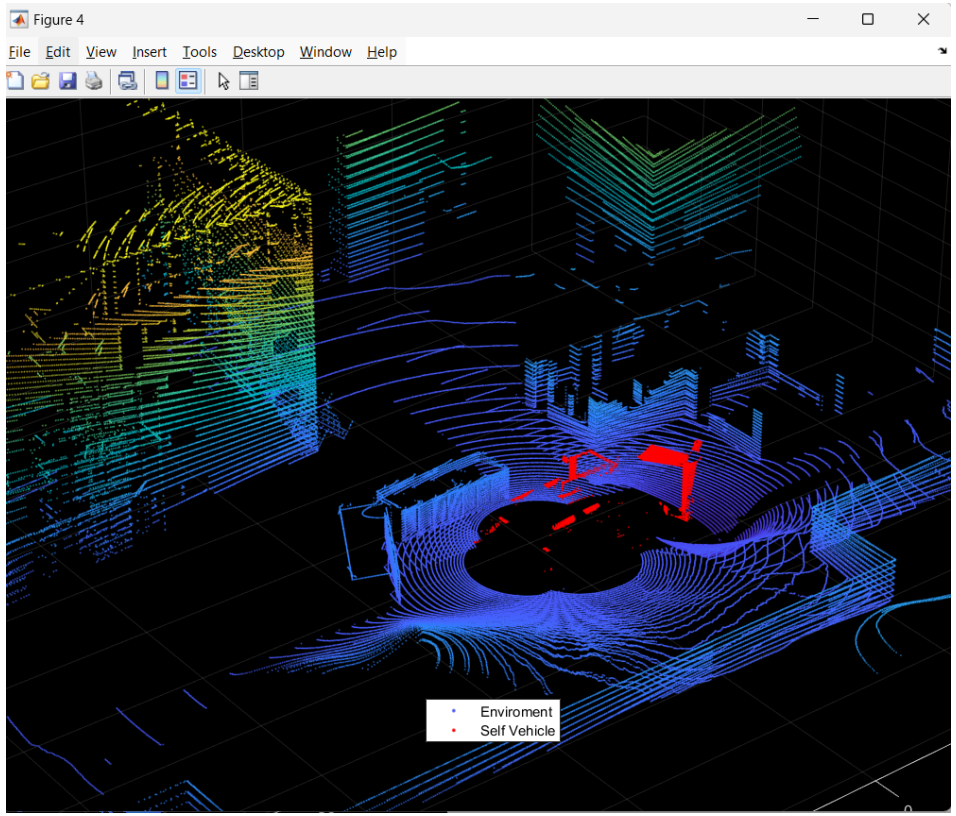
Perceive

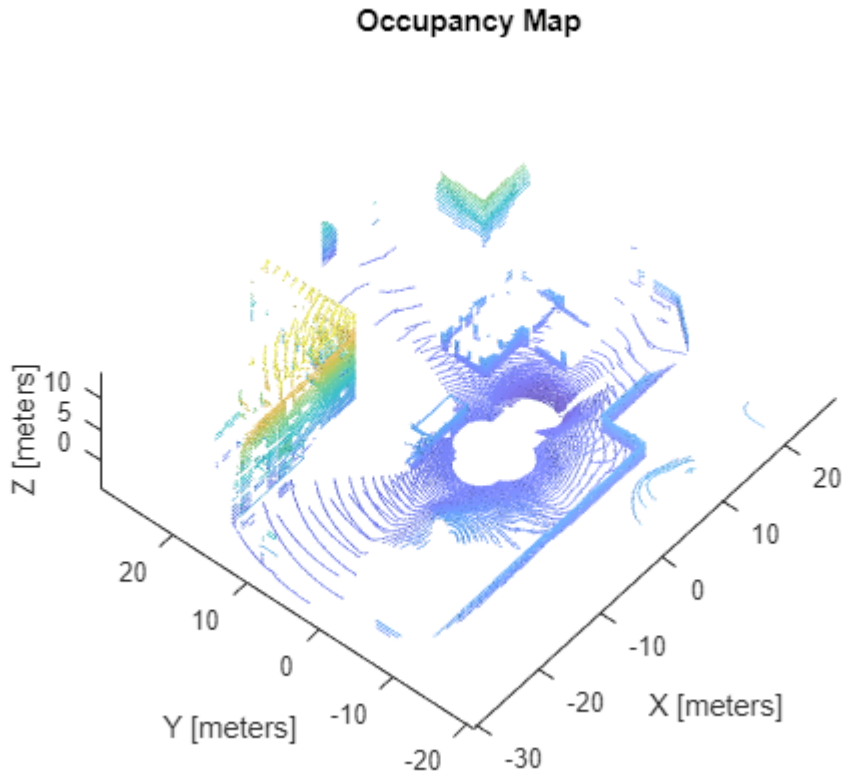
Simulate with adverse weather and environment conditions

Plan

Control

Plan collision-free motion for an excavator



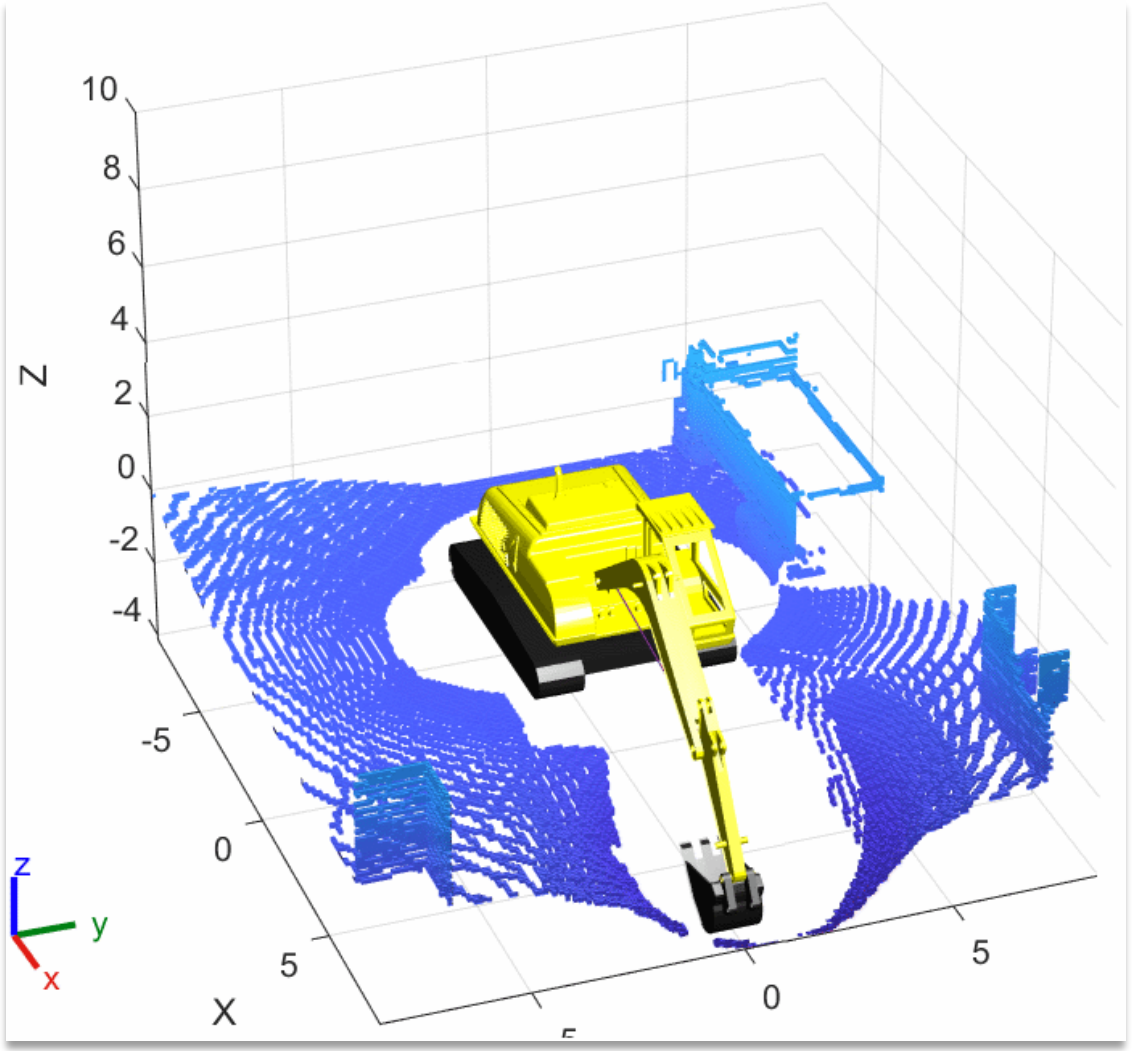


MATLAB EXPO

Plan

Control

Plan collision-free motion for an excavator



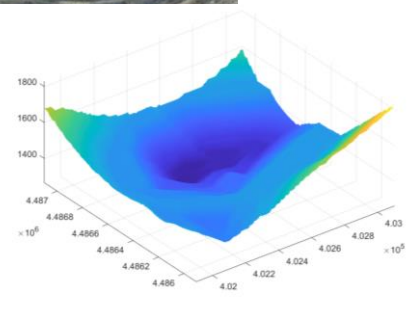
MATLAB EXPO

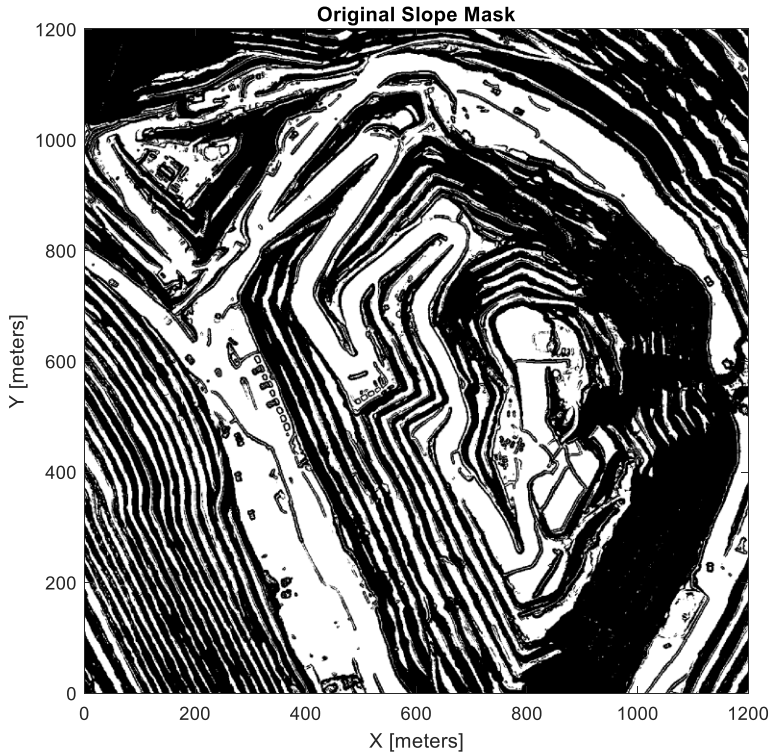
Plan

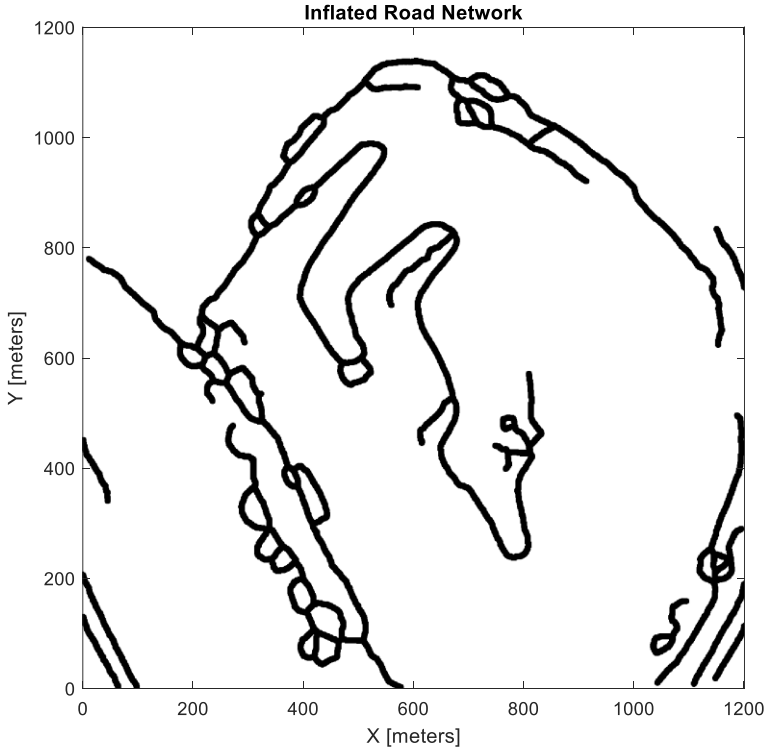
Control

Convert existing data to maps for planning and navigation on uneven terrain

Satellite Imagery → Slope Mask → Road Map



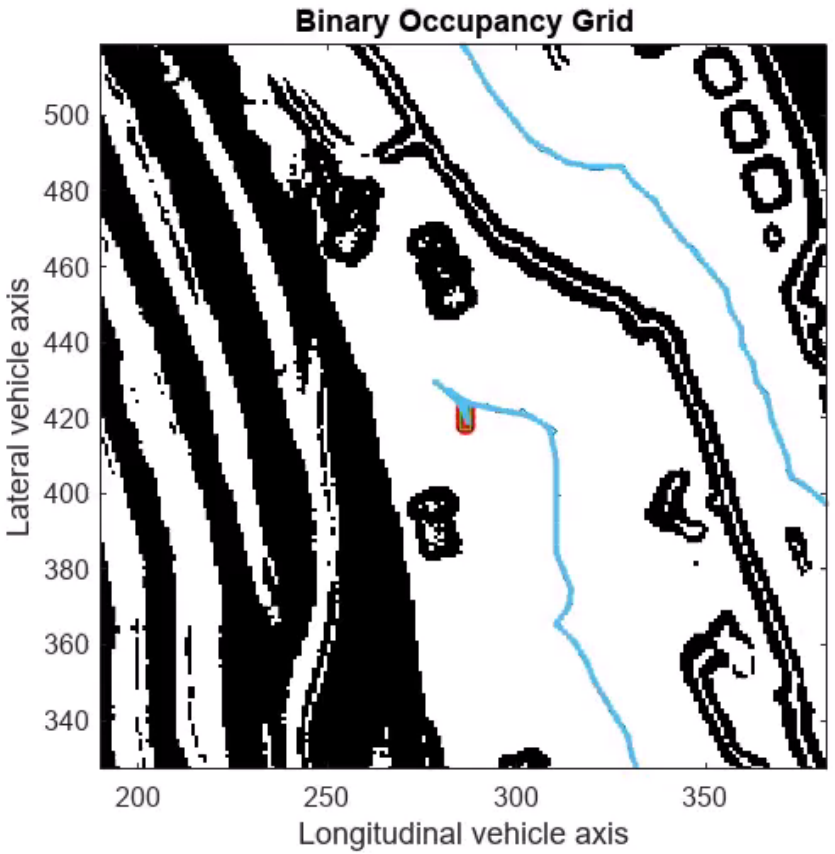


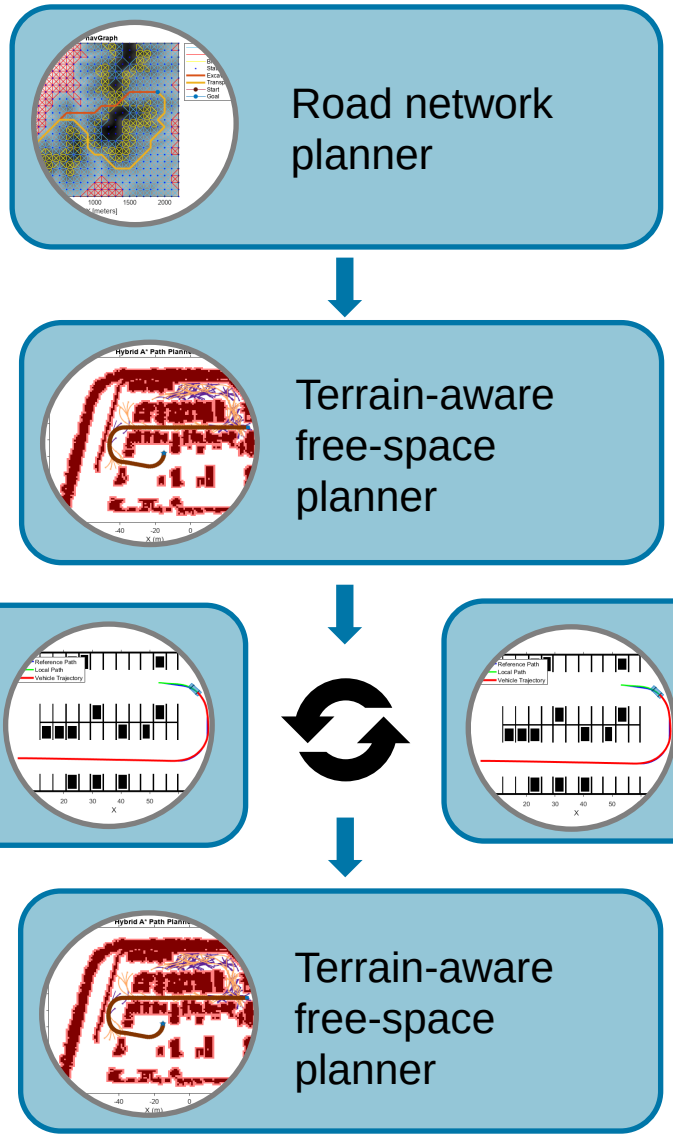


Plan

Control

Develop an offroad navigation stack



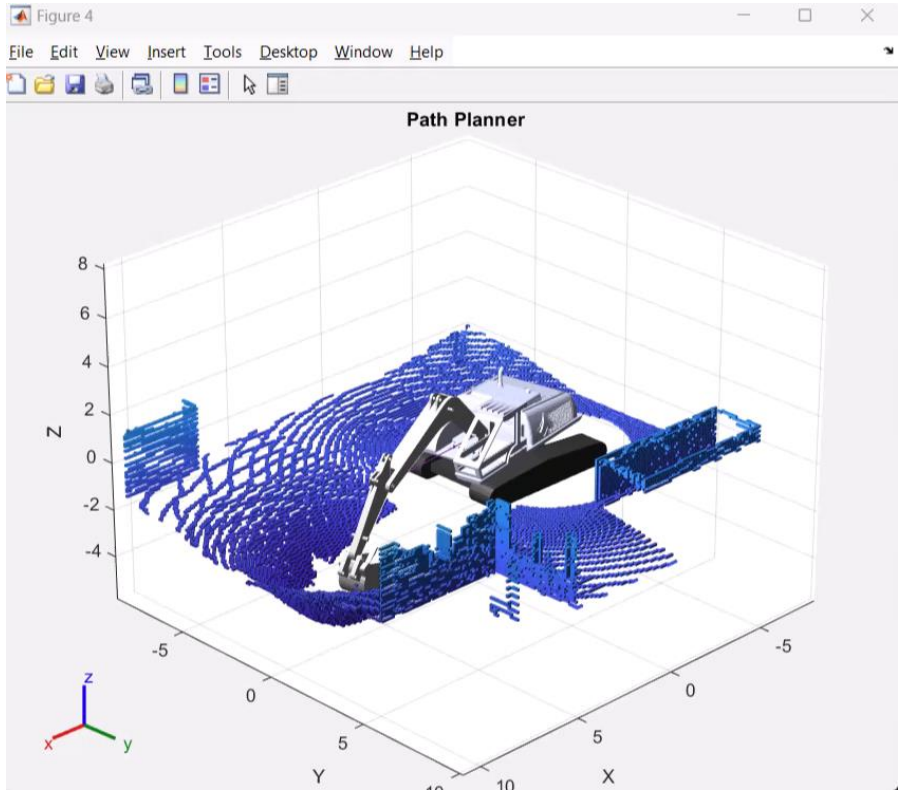


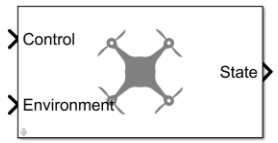
Platform

Use different types of motion models for different tasks

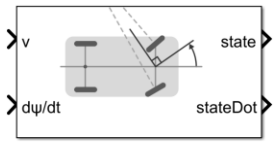
Kinematic Models

[Toolboxes for Robotics]

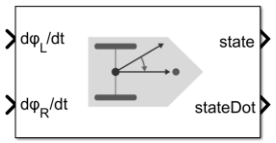




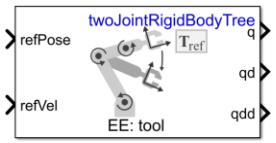
Guidance Model



Ackermann Kinematic Model



Differential Drive Kinematic Model

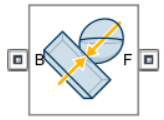


Task Space Motion Model

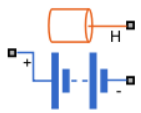
Dynamic Models

[Simscape]

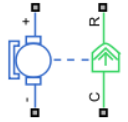
CAD



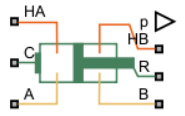
Contact Force



Battery

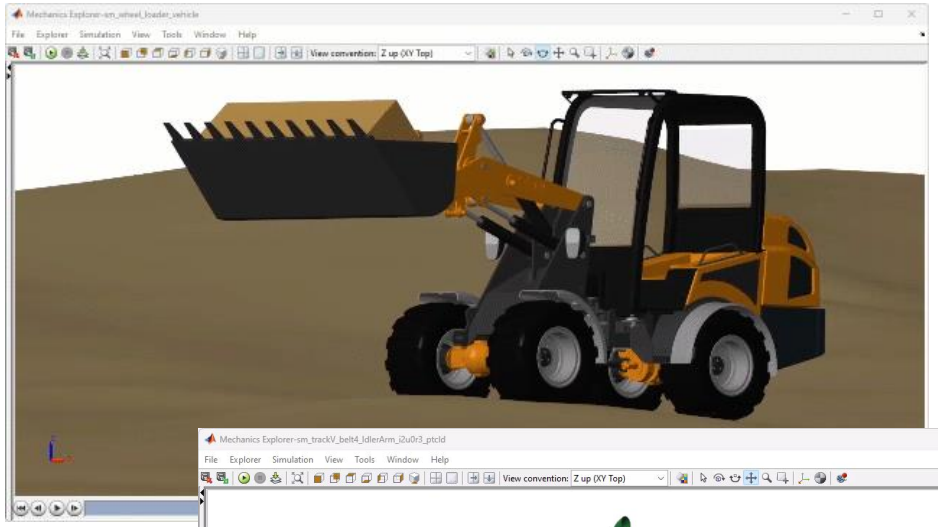


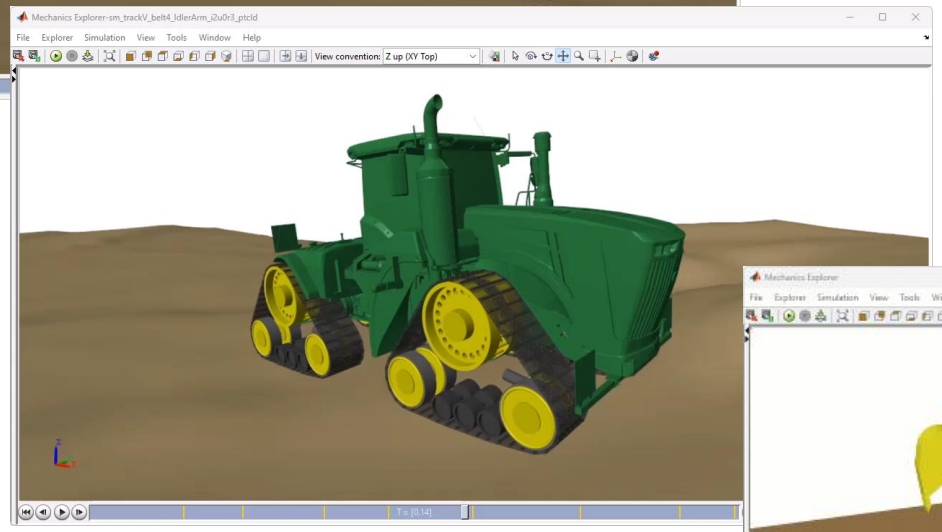
DC Motor

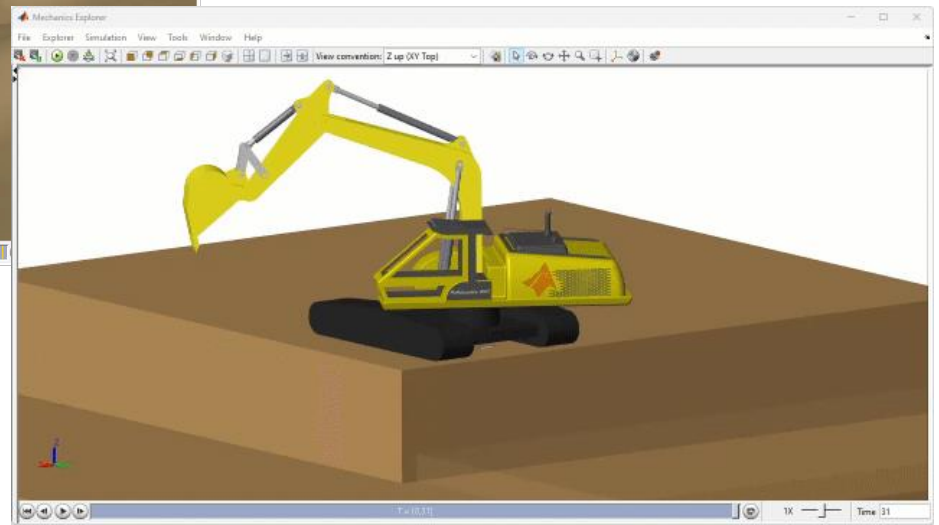


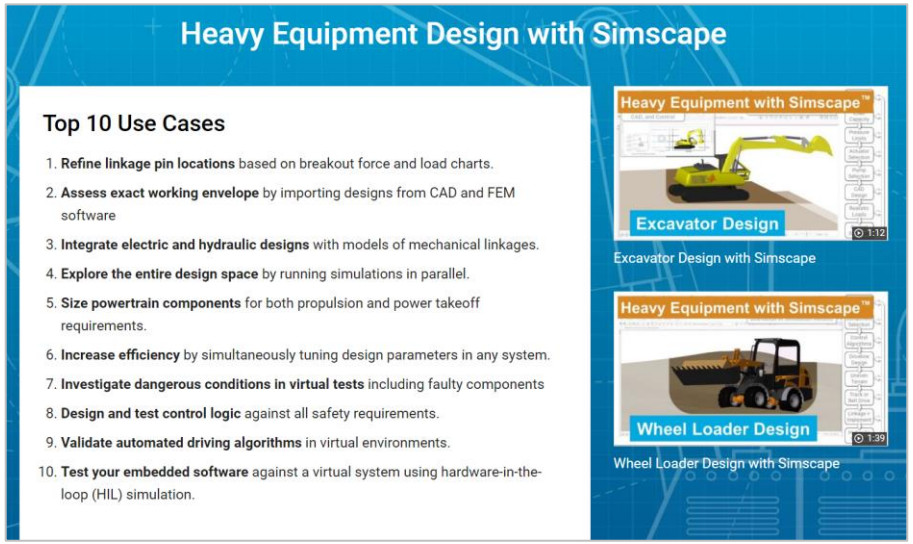
Hydraulic Cylinder

Dynamic Modeling (Simscape) Reference Examples

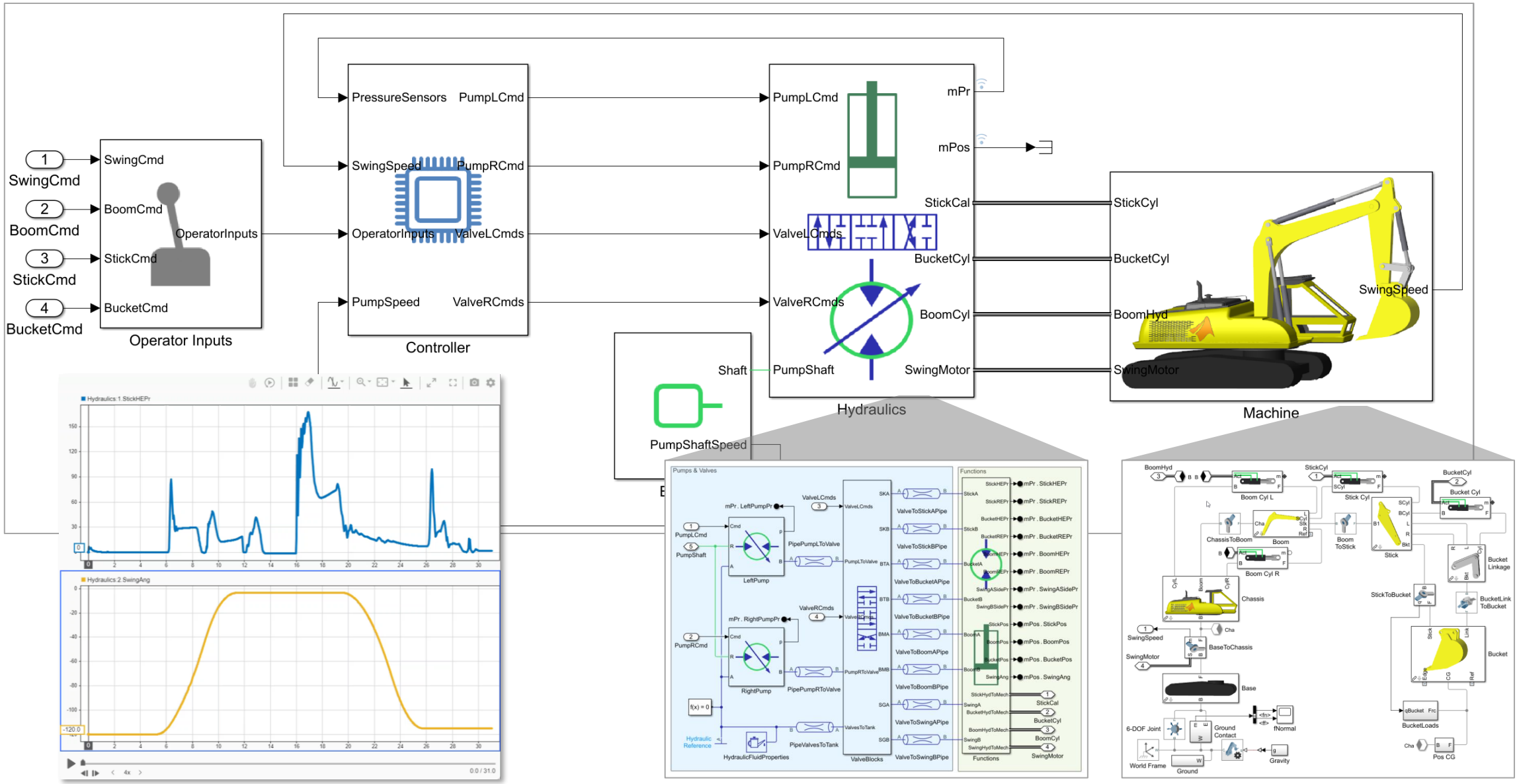








Test integrated hydraulic, mechanical, and electrical designs

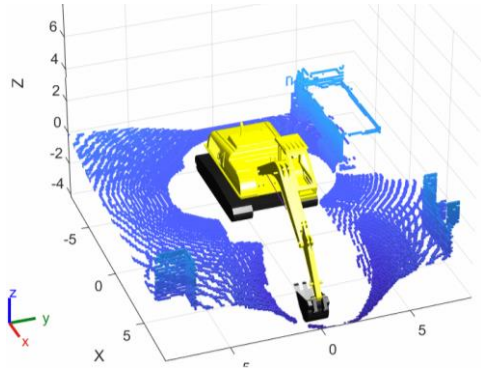


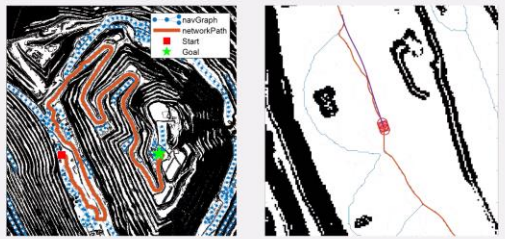
Virtual Testing and Simulation play a key role in development and testing of autonomous offroad vehicle systems on all terrains

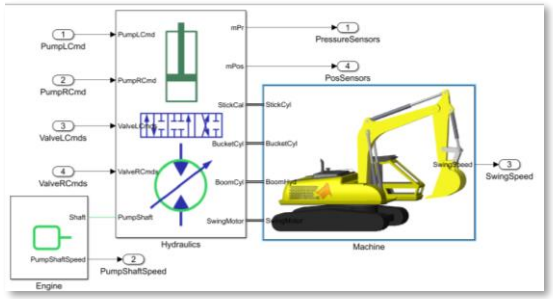
Test in Scenario Simulation

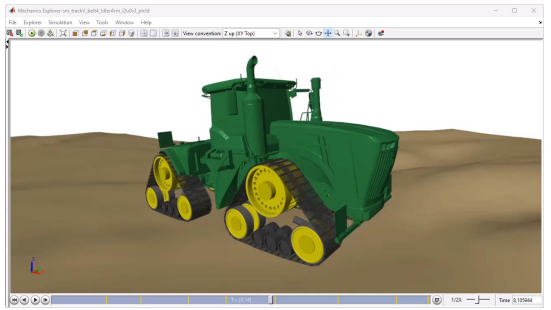
Develop and Simulate Autonomy

Design Physical Model









MATLAB EXPO

We offer comprehensive tools for the development and testing of autonomous offroad vehicle systems

Toolbox

Test in Scenario Simulation

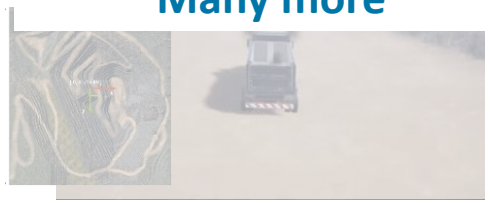
Simulink 3D Animation
Simulate and visualize dynamic systems in a 3D environment

Robotics System Toolbox
Design, simulate, test, and deploy robotics applications

ROS Toolbox
Design, simulate, and deploy ROS-based applications

\+

Many more



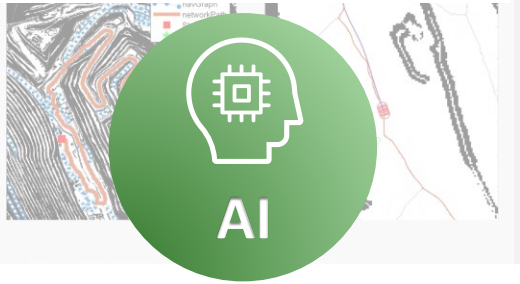
Develop and Simulate Autonomy

Robotics System Toolbox
Design, simulate, test, and deploy robotics applications

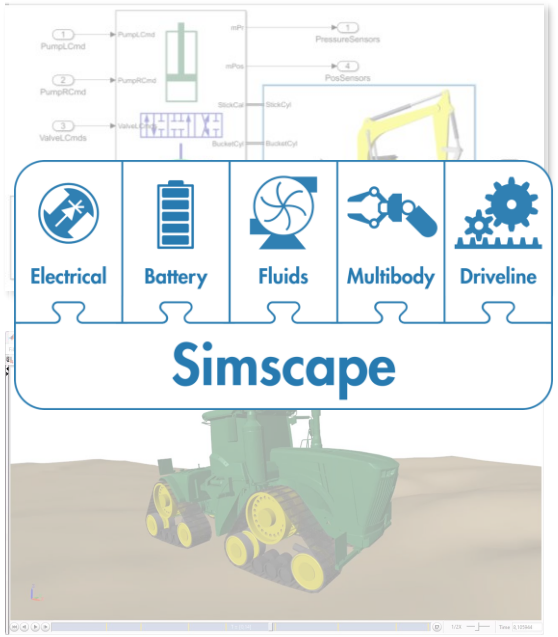
Navigation Toolbox
Design, simulate, and deploy algorithms for autonomous navigation

\+

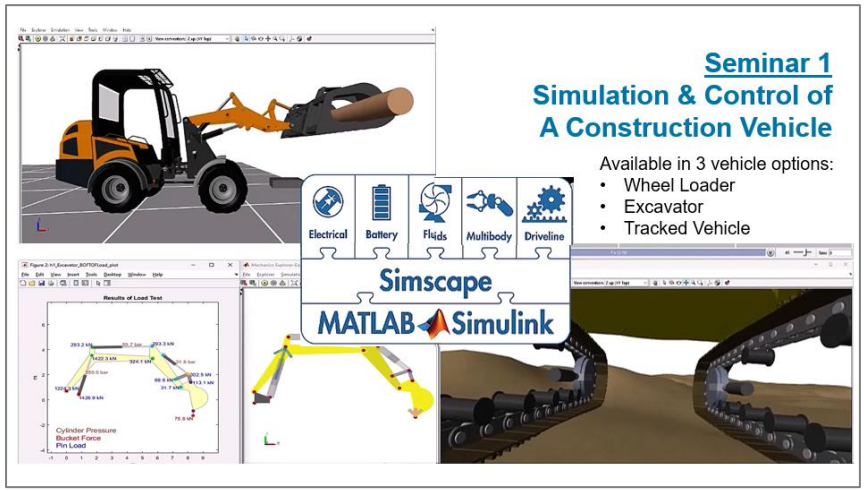
Many more

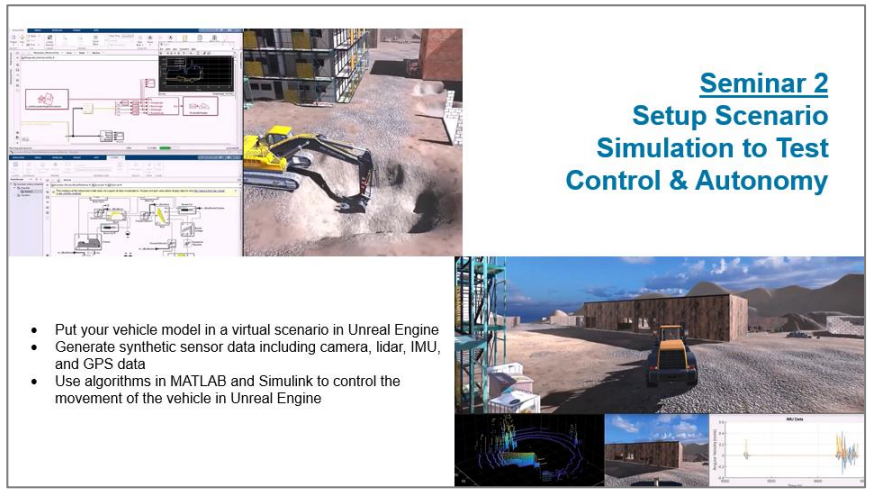


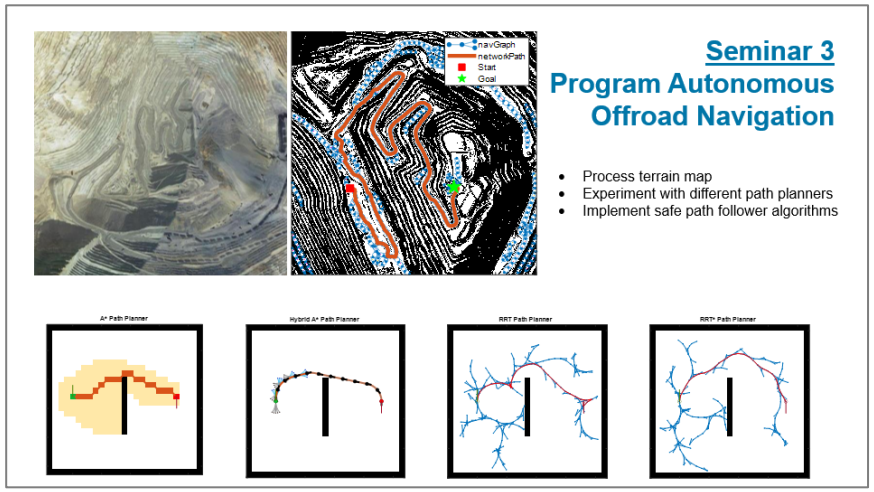
Design Physical Model



Call to Action:
Tell us about your applications & ask for a trial







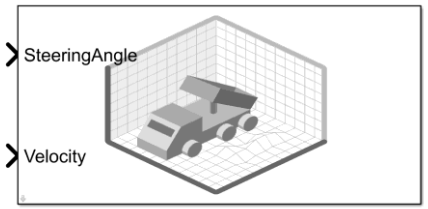
Call to Action:

Try New Offroad Autonomy Library Support Package!

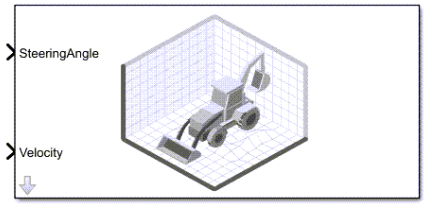
Robotics System Toolbox Offroad Autonomy Library

by MathWorks Robotics and Autonomous Systems Team STAFF

Design, Simulate, and Test Autonomous Offroad Vehicle Applications

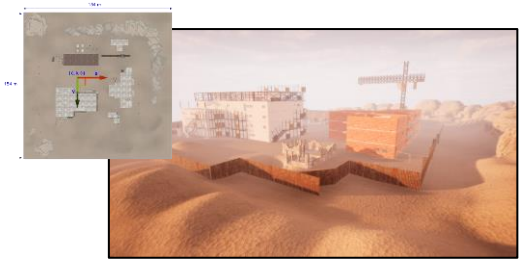


Simulation 3D Physics Dump Truck

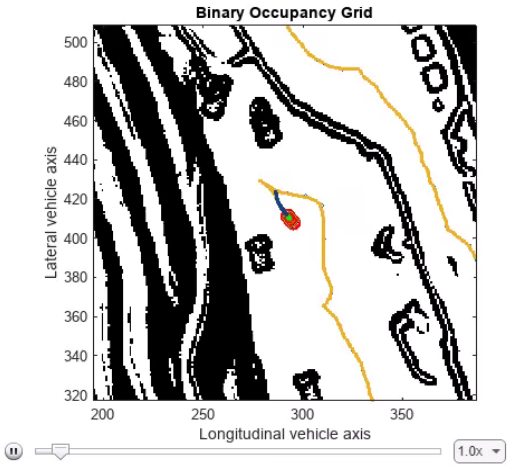


Simulation 3D Physics Backhoe

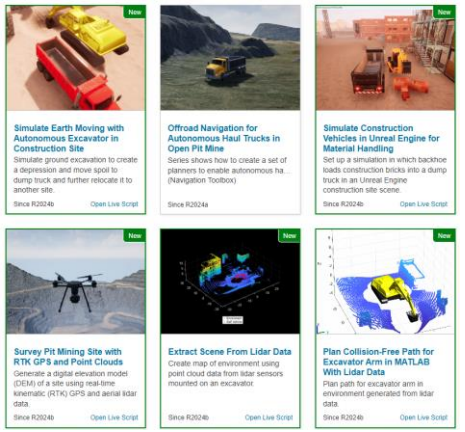
Physics Models



Scenes



Algorithms

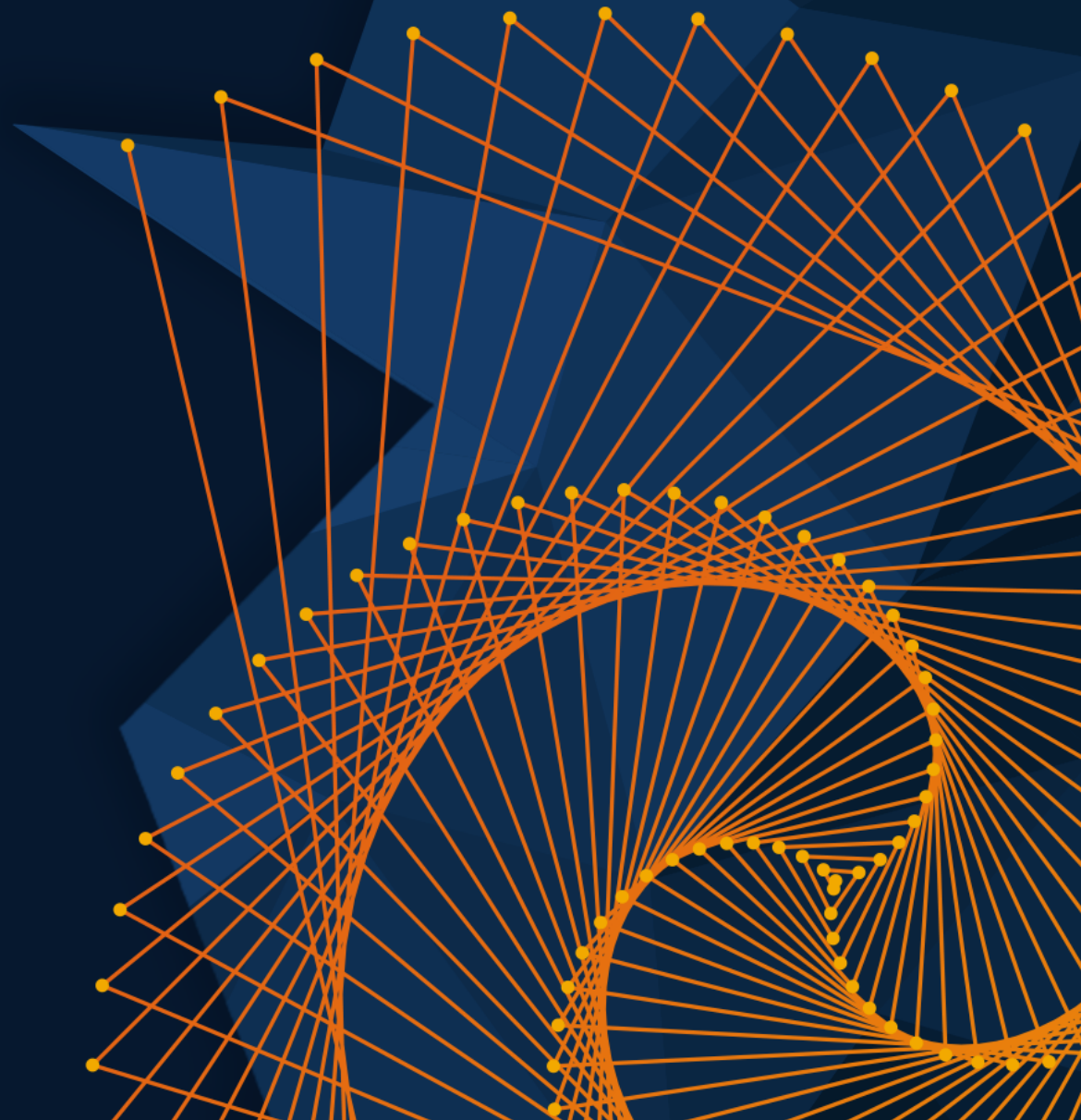


Examples

MATLAB EXPO

MATLAB EXPO

Thank You!



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