

# MATLAB EXPO

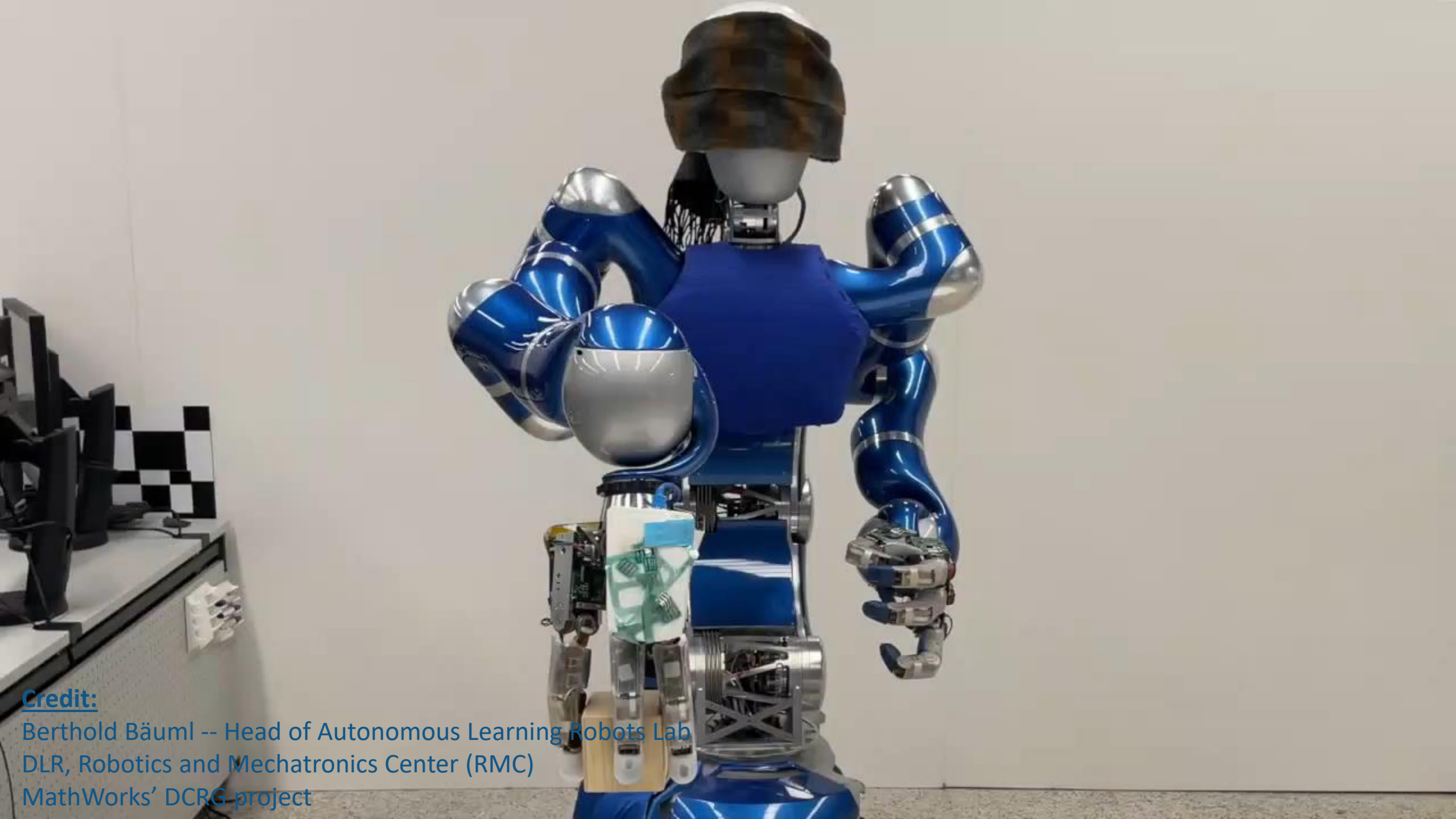
## Applying AI to Enable Autonomy in Robotics Using MATLAB

*YJ Lim, MathWorks*



*Tohru Kikawada, MathWorks Japan*

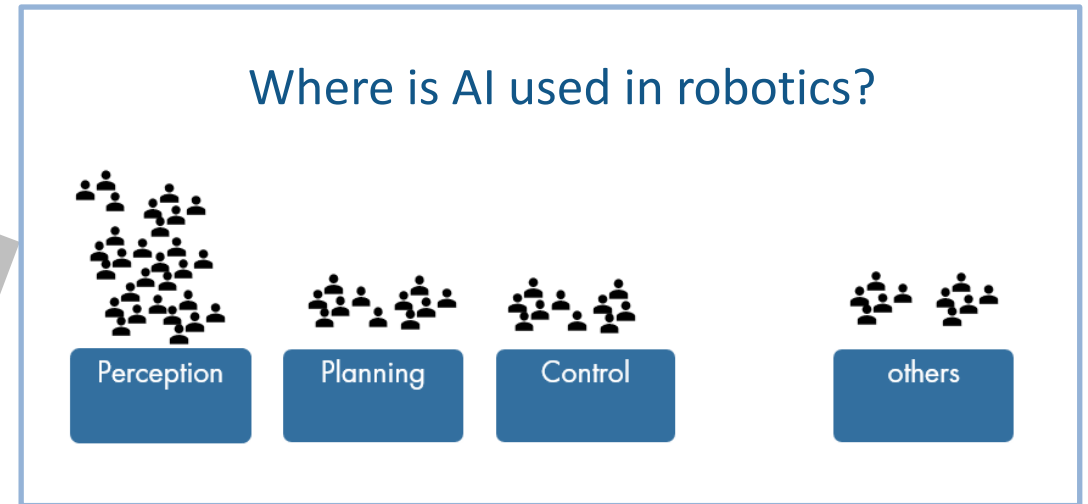
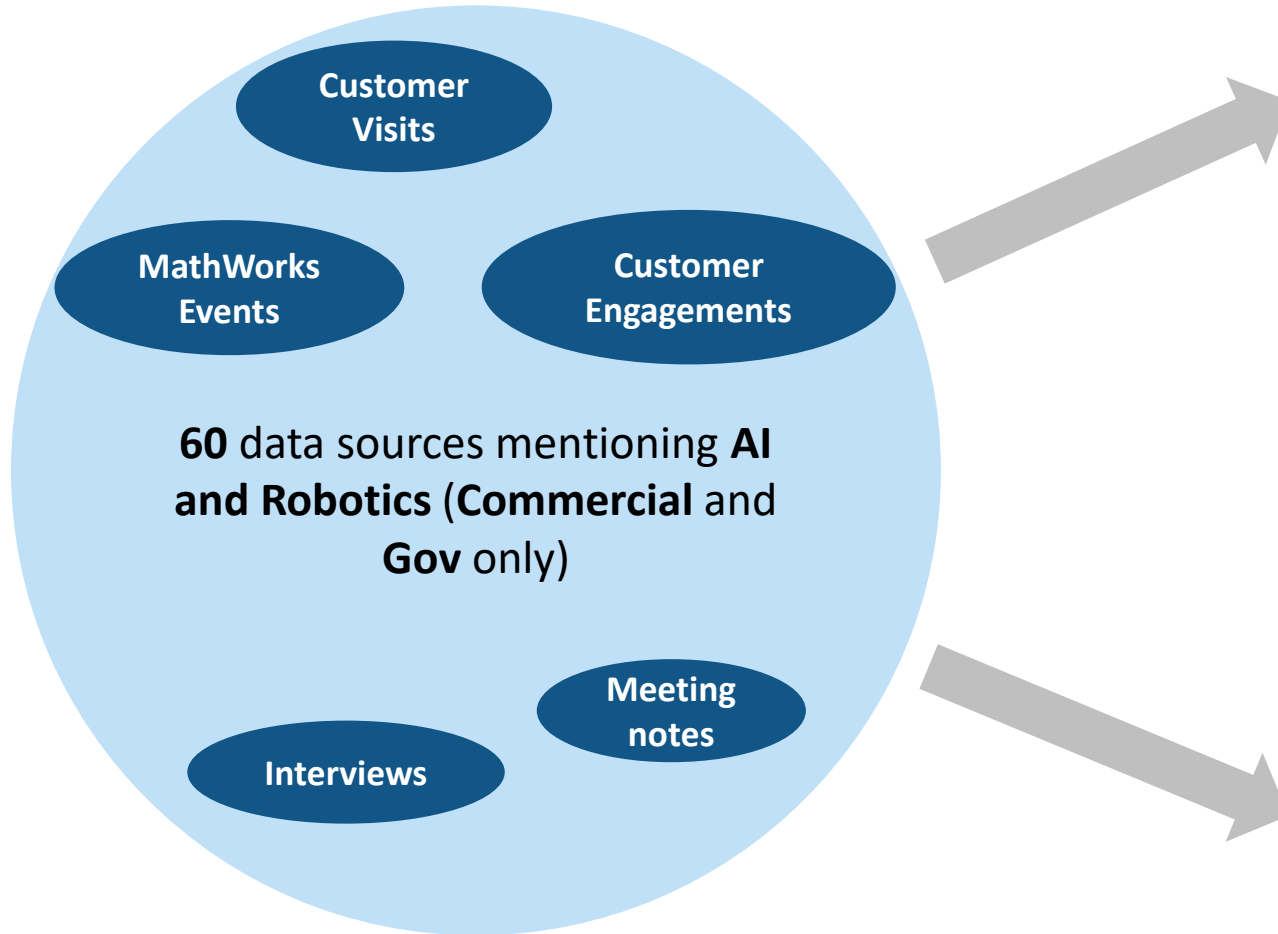




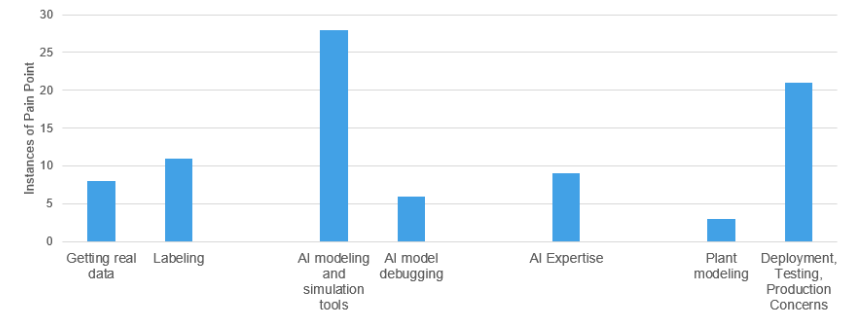
**Credit:**

Berthold Bäuml -- Head of Autonomous Learning Robots Lab  
DLR, Robotics and Mechatronics Center (RMC)  
MathWorks' DCRG project

# User Study - roboticists interested in AI to learn how they are using it



## What challenges have engineers encountered?



## Commercial robotics customers: **Where is AI being used in Robotics?**

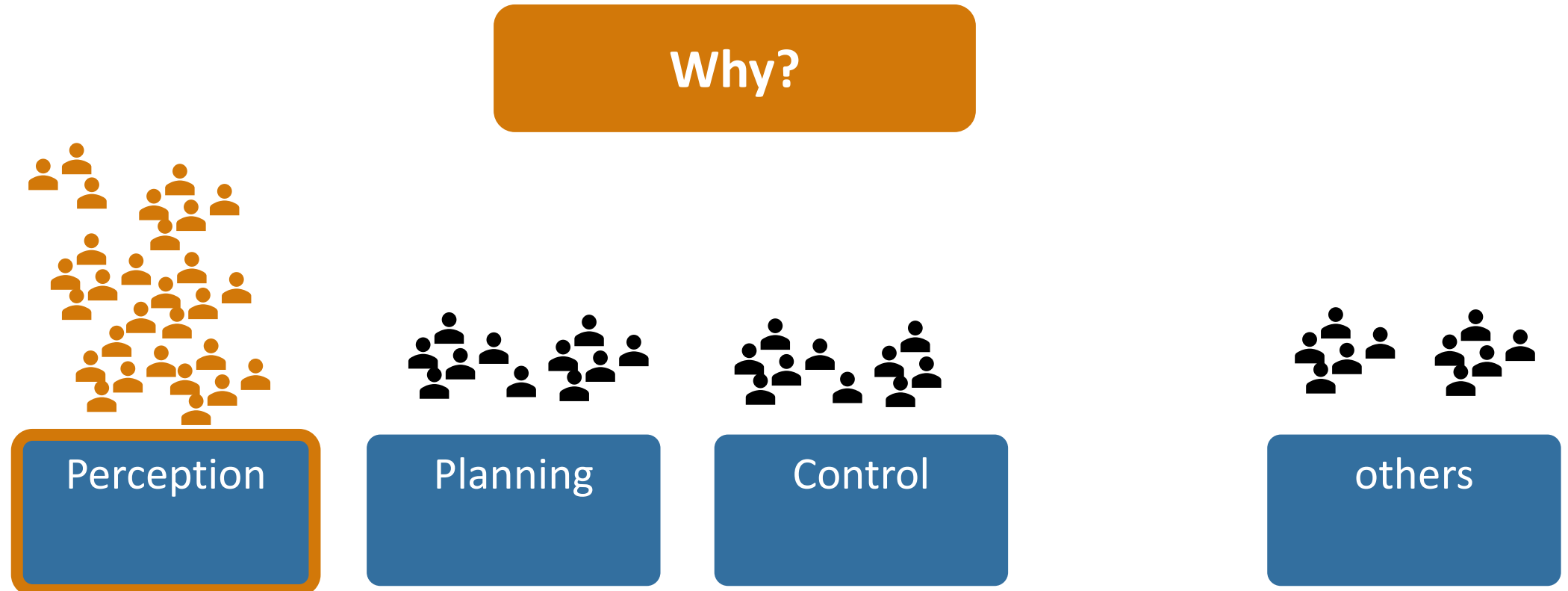
Perception

Planning

Control

others

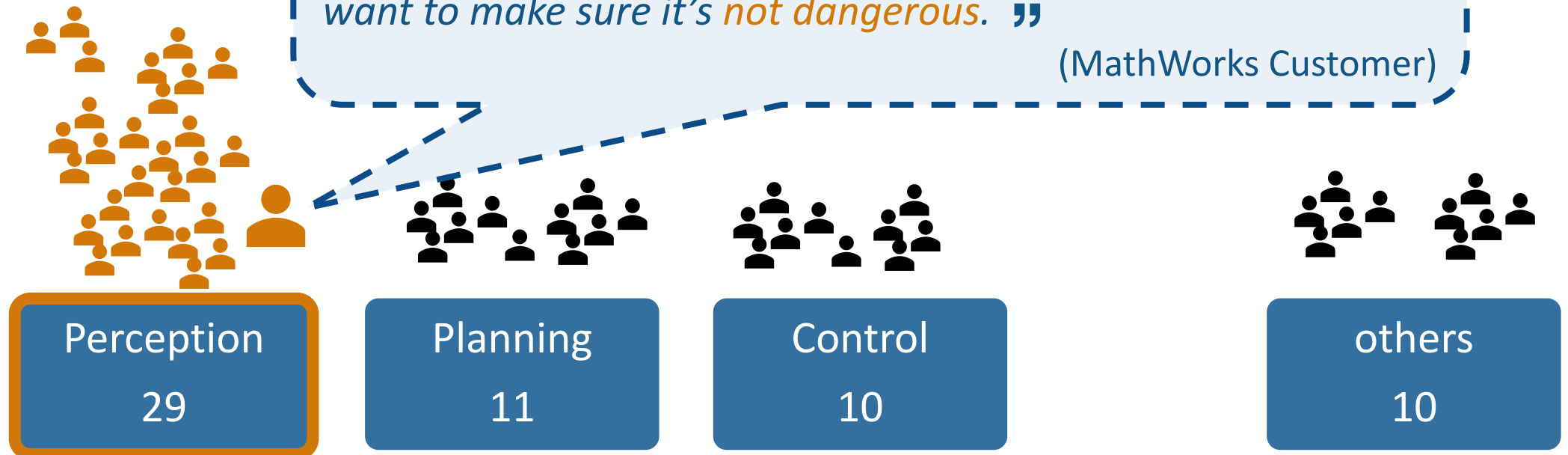
Commercial robotics customers are using AI more for *Perception* than elsewhere



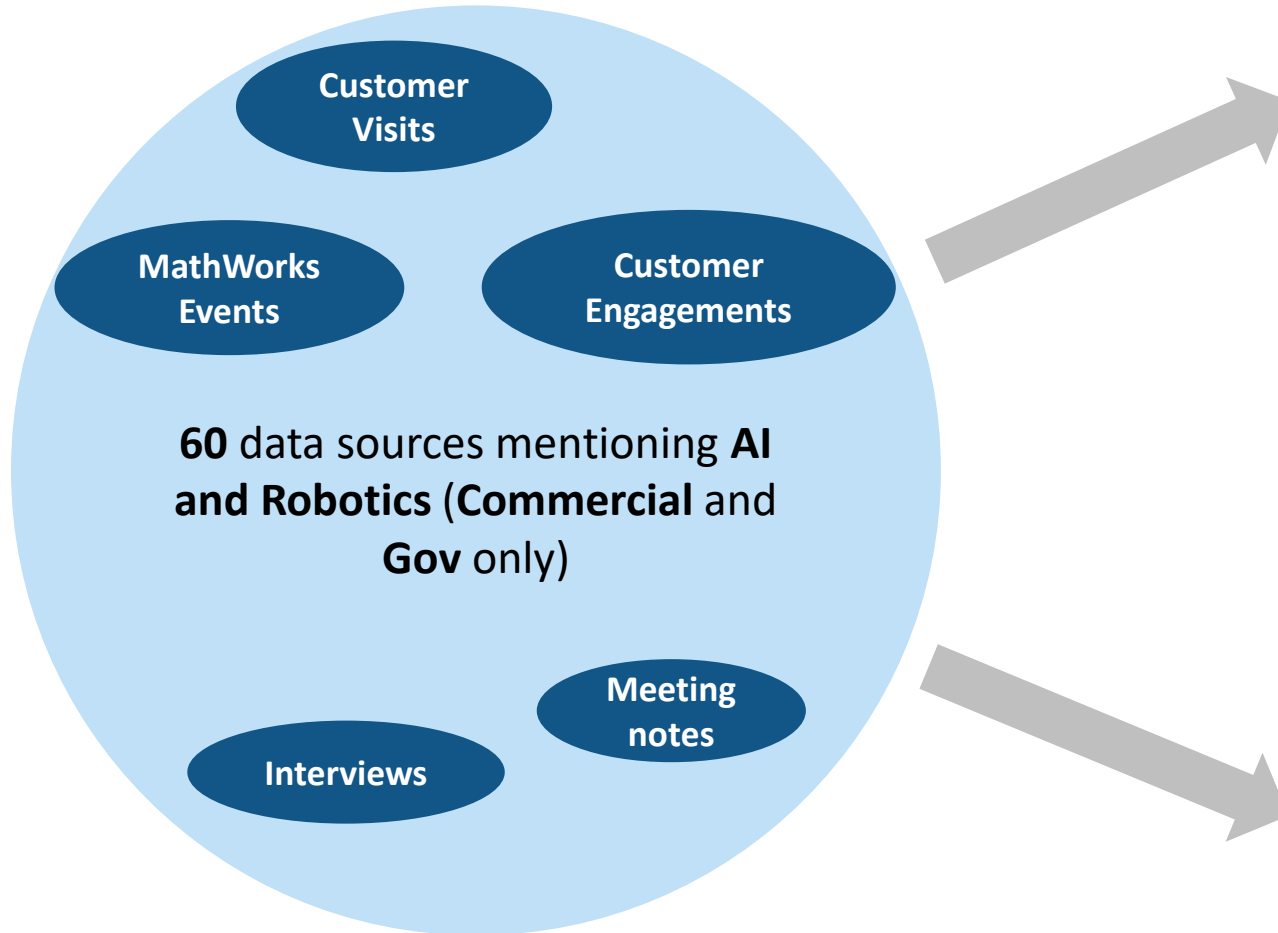
Safety, robustness, and certifications matter for production. Traditional algorithms have an advantage over AI in this regard.

*“ We want to limit whatever the neural net – or even (for) teleop.... whatever action is commanded there. We want to make sure that it[Robot]’s not stupid. Or even if it’s stupid, we want to make sure it’s not dangerous. ”*

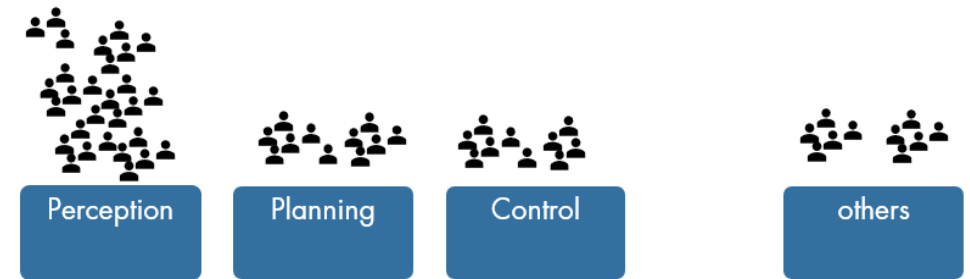
(MathWorks Customer)



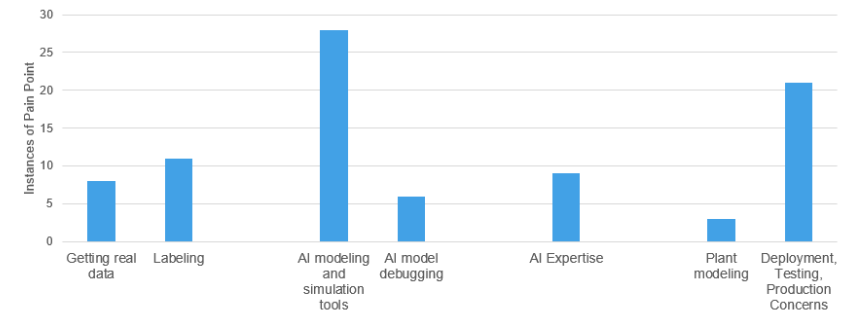
# UX researched roboticists interested in AI to learn how they are using it



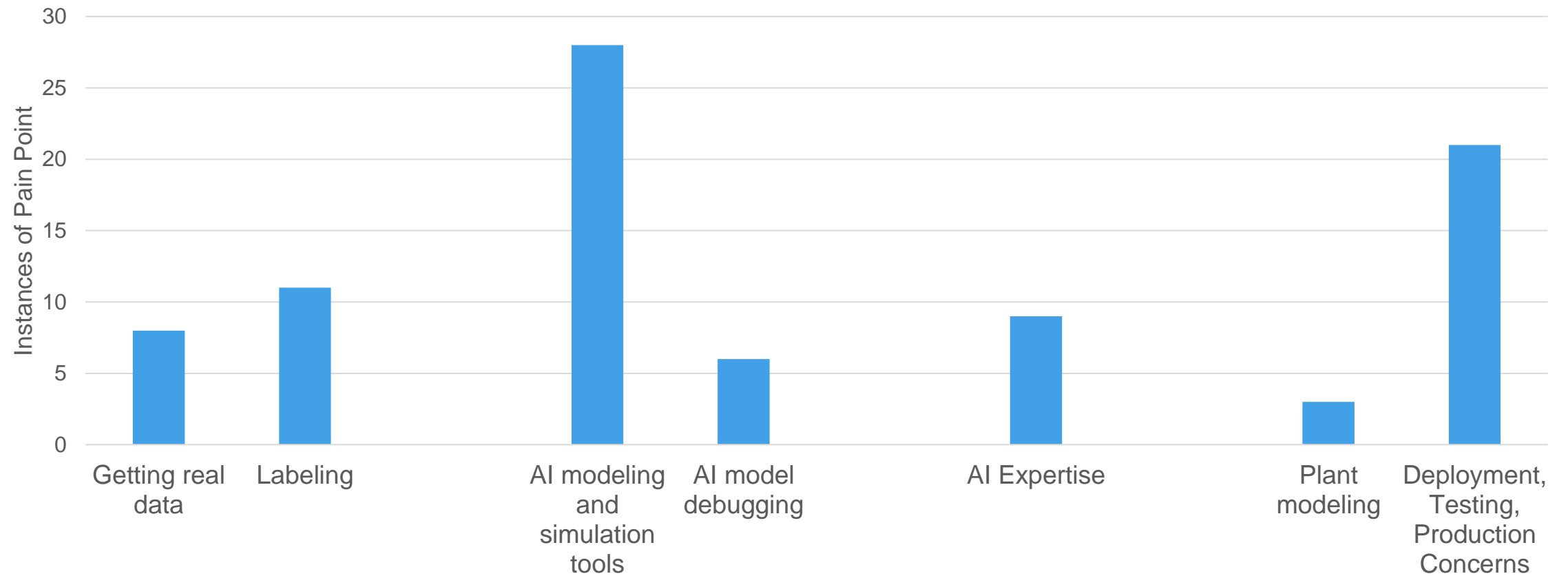
## Where is AI used in robotics?



## What challenges have engineers encountered?

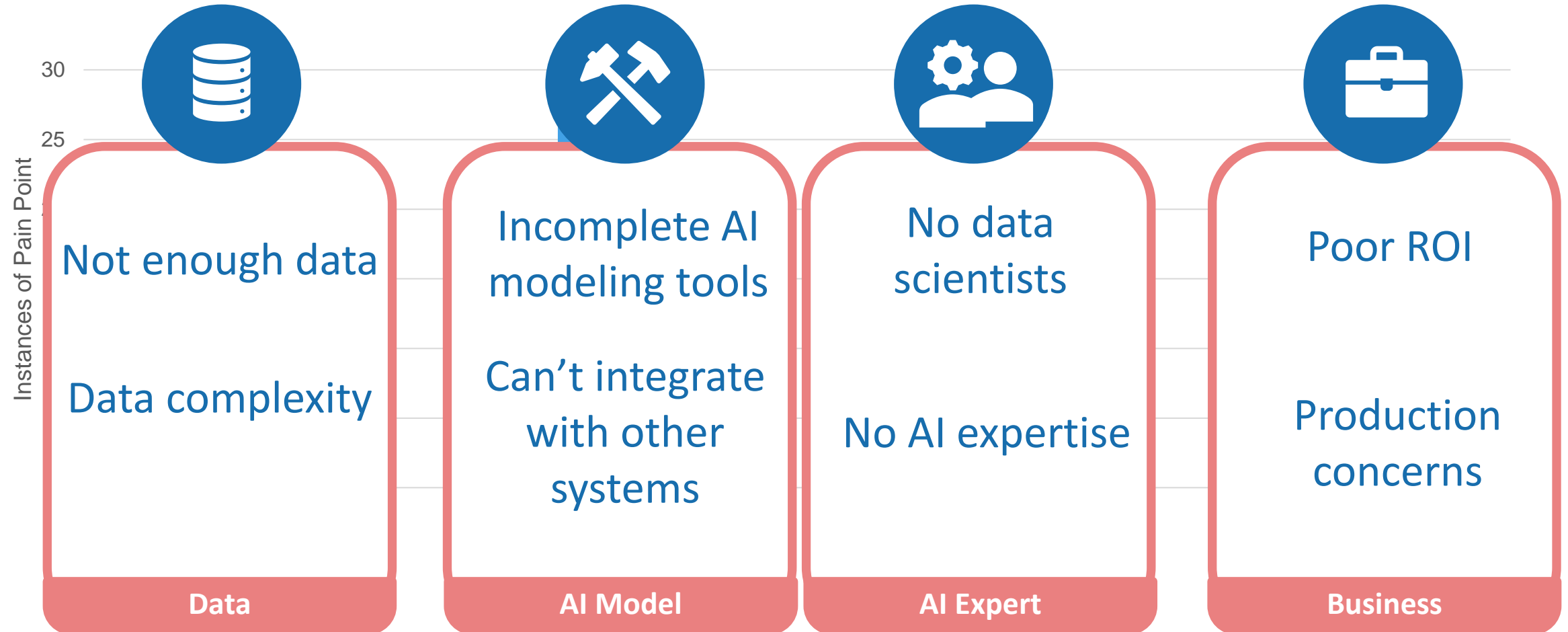


# What pains and challenges have engineers encountered?

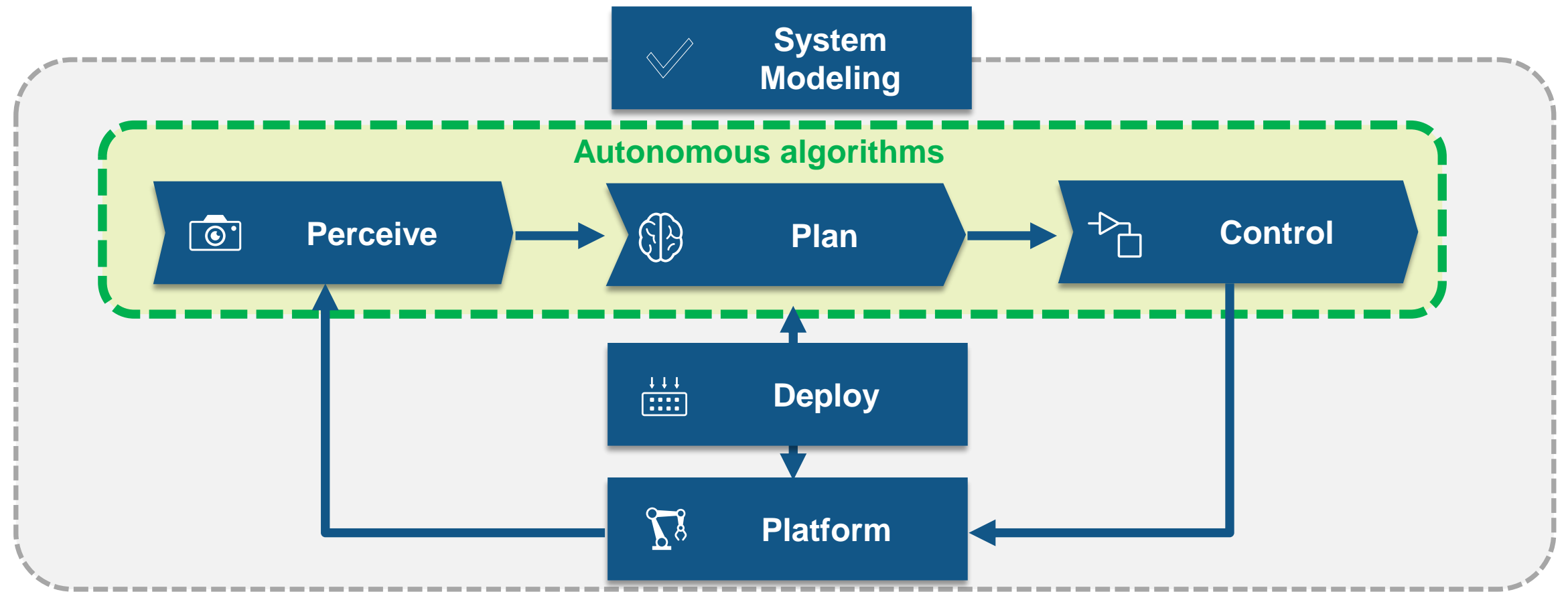




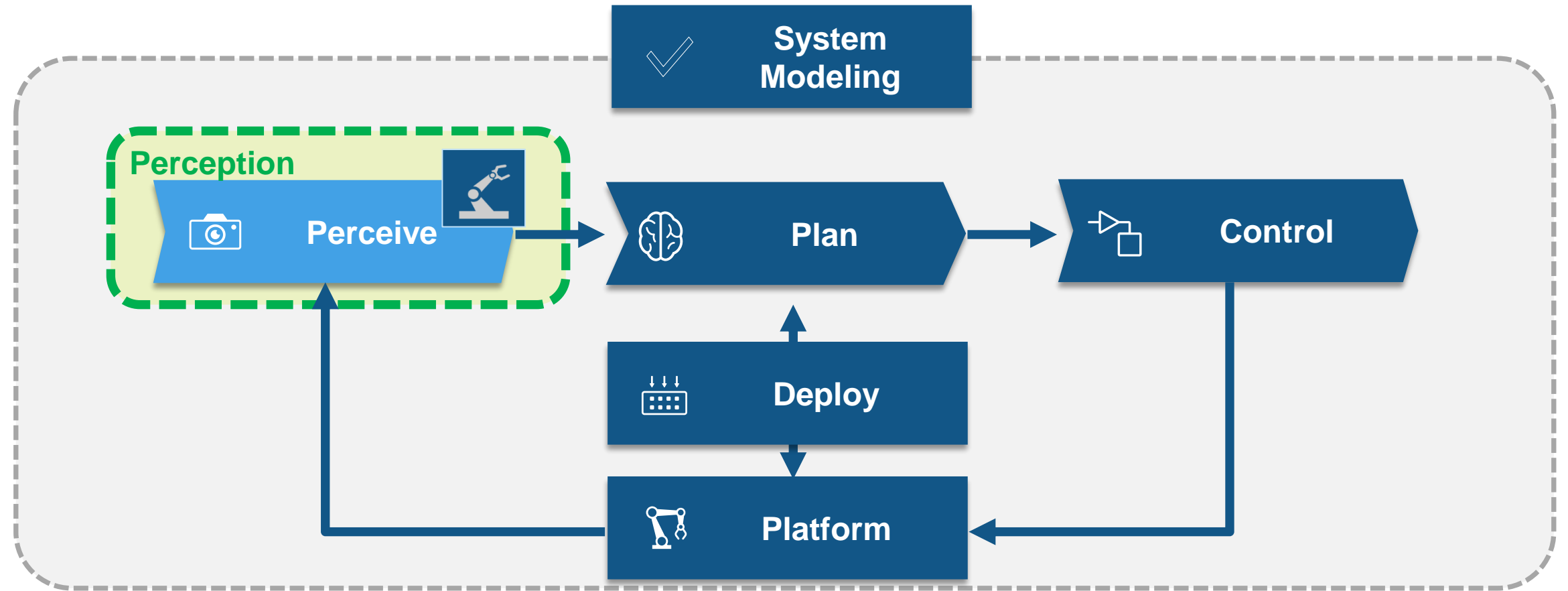
# What pains and challenges have engineers encountered?



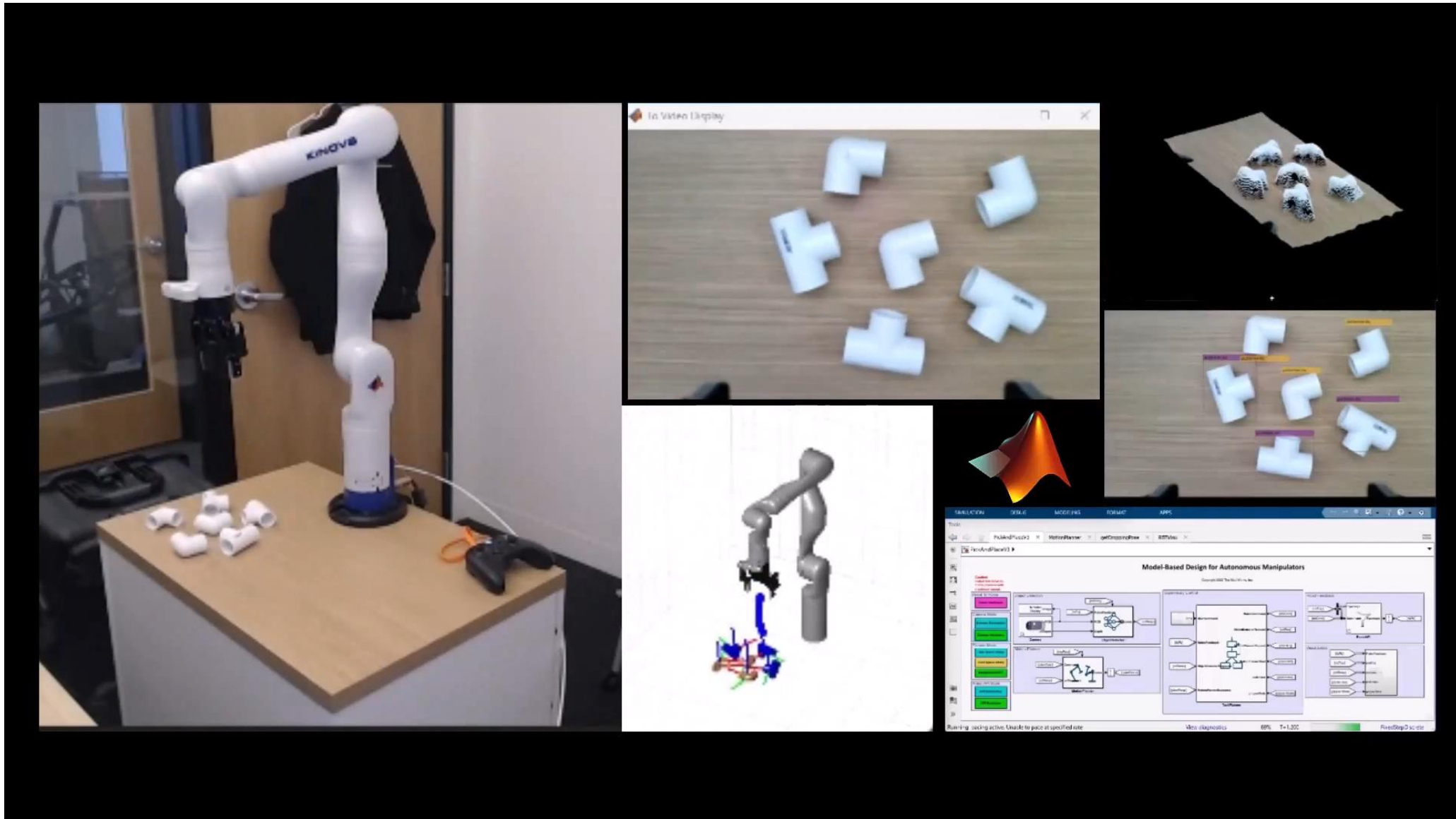
# Autonomous system design workflow



# Autonomous system design workflow



# Developing pick & place application using cobot



# How to get data for training?

Simulink 3D Animation  
Robotics System Toolbox  
Computer Vision Toolbox

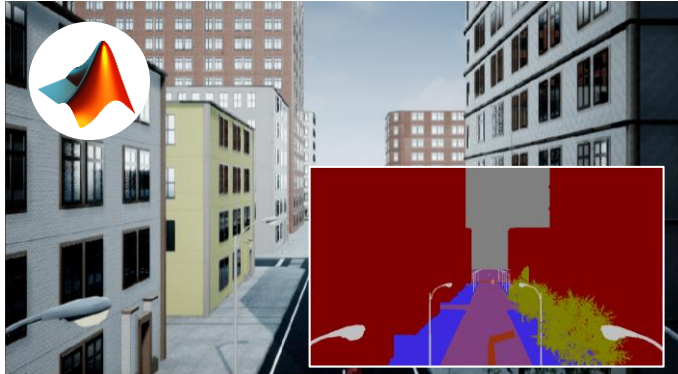


Synthetic data generation with simulator



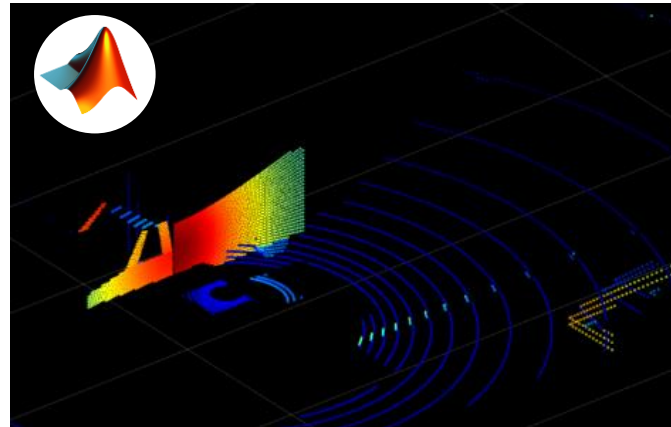
Data acquisition with hardware

# Generate synthetic data to improve your datasets



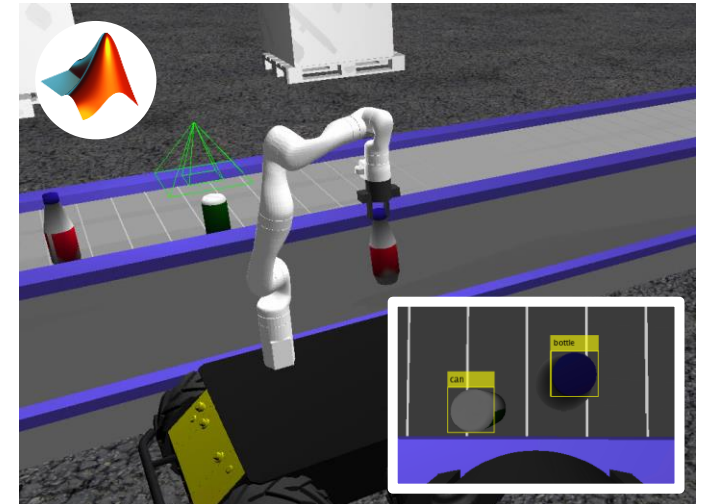
## Semantic Segmentation from Unreal for UAV

UAV Toolbox  
Simulink



## Lidar Sensor Model: Simulate lidar sensor and generate point cloud data

Lidar Toolbox

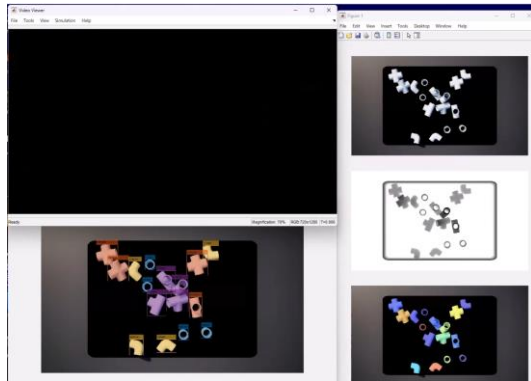


## Gazebo Co-simulation with a Pretrained Deep Learning Model to Detect Recyclable Parts

Robotics System Toolbox  
ROS Toolbox

# Automated labeling apps save you weeks to months

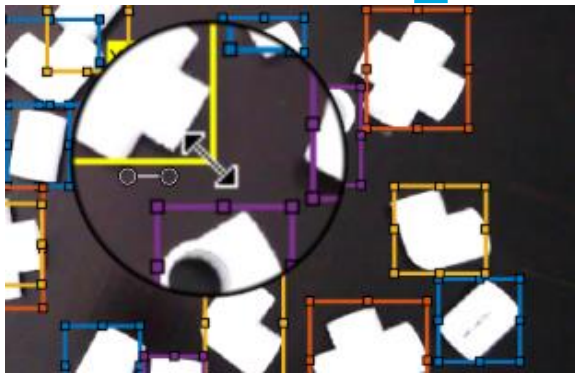
Computer Vision Toolbox  
 Deep Learning Toolbox  
 Simulink 3D Animation



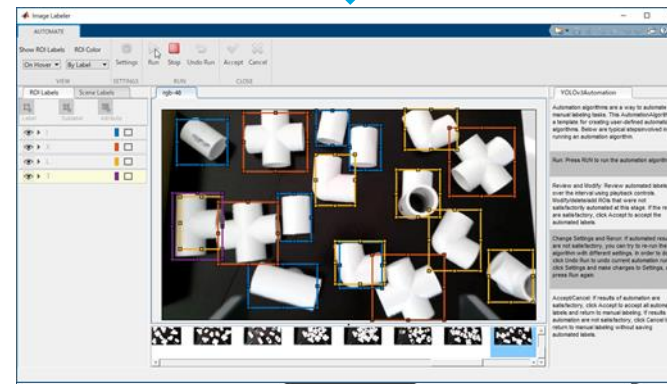
Synthetic data generation with CAD models



Train object detector



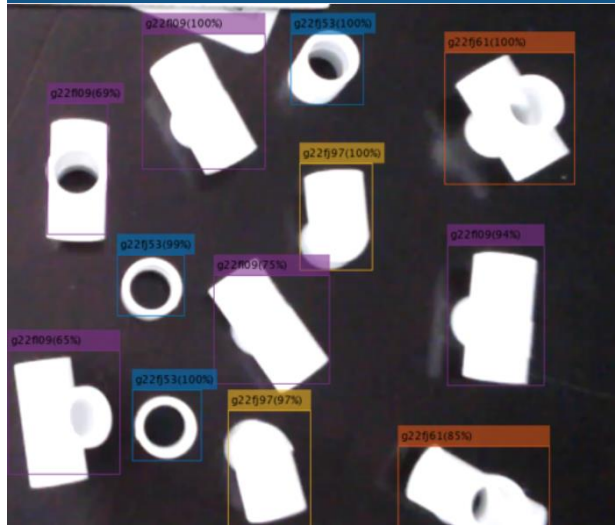
Correct wrong labels



Automated labeling with actual images

# Start with a complete set of algorithms and pre-built models

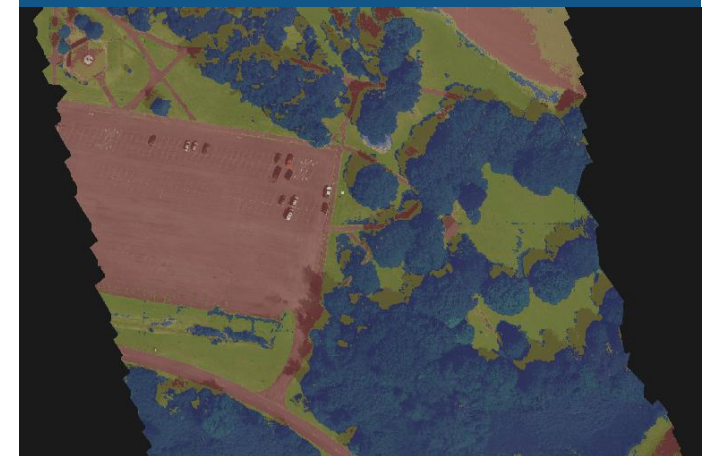
## Object Detection with YOLOv4



## Instance Segmentation with Mask R-CNN



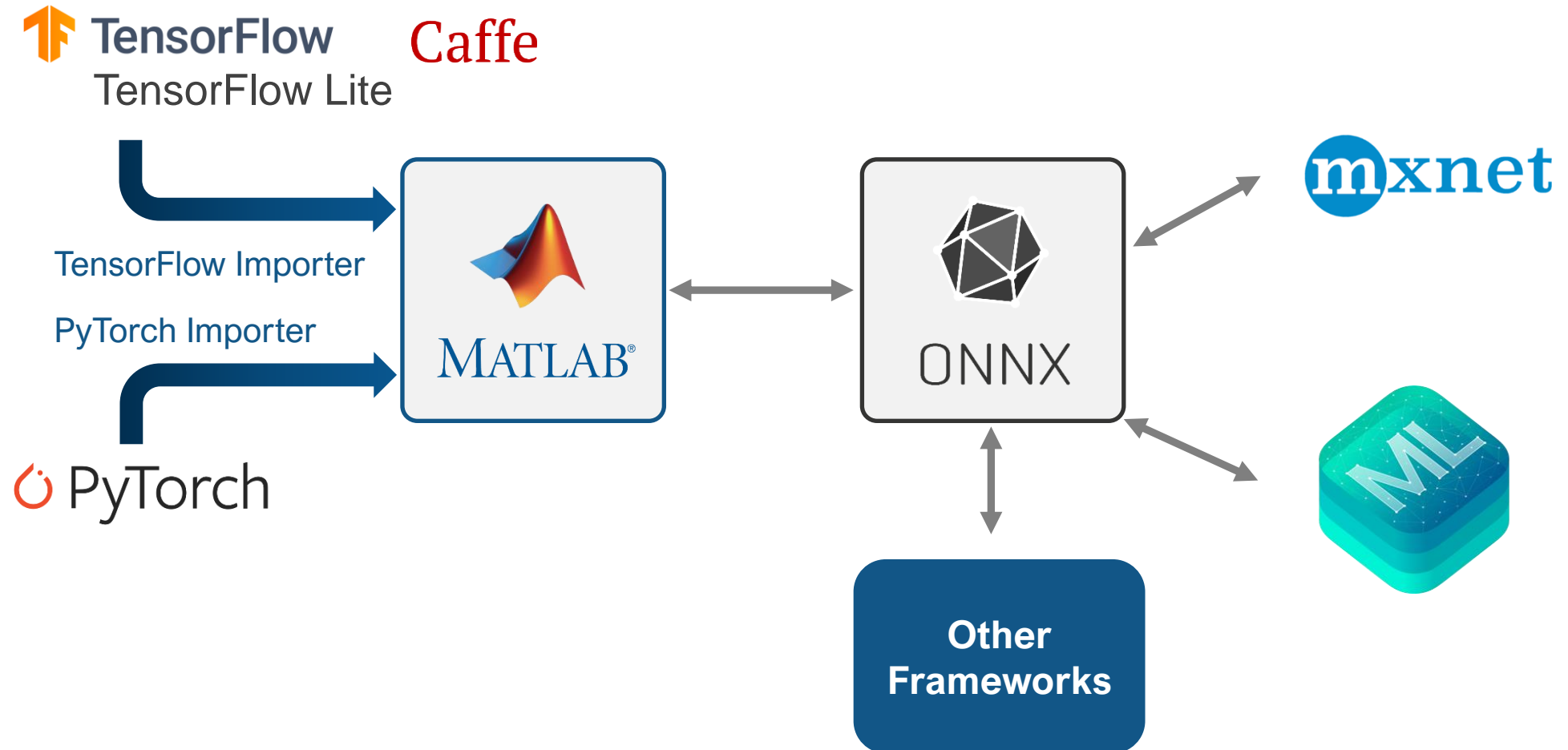
## Semantic Segmentation with U-Net



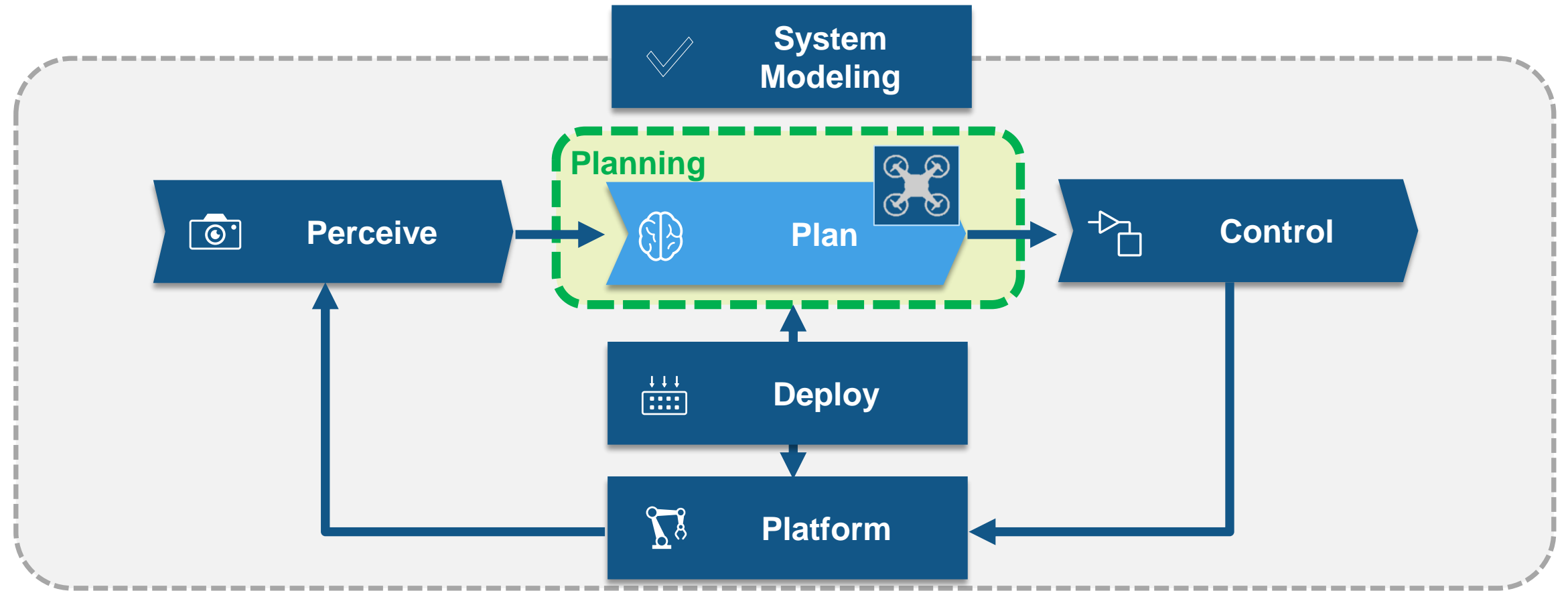
Deep Learning Toolbox  
Image Processing Toolbox  
Computer Vision Toolbox



# Access AI models from the broader AI community

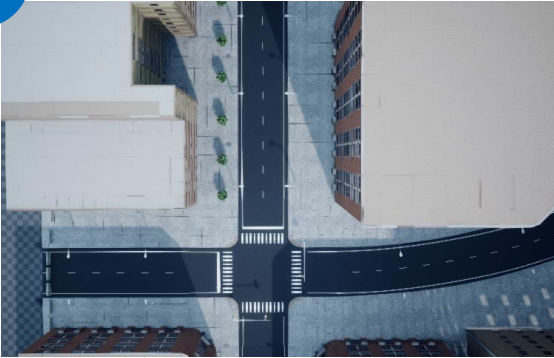


# Autonomous system design workflow



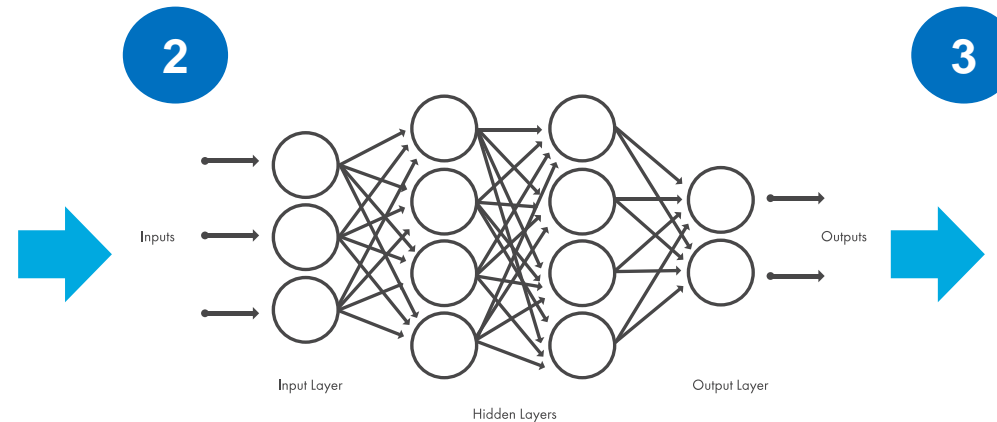
# Pre-built AI model is ready to use for perception in UAV application

1



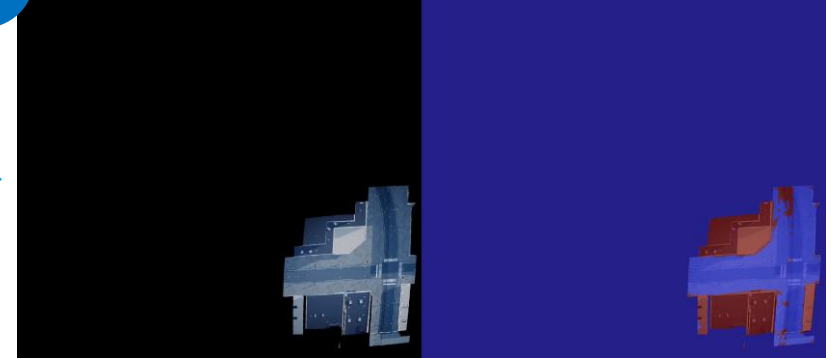
Obtain drone captures images and convert into orthophotos

2



Pass through semantic segmentation network

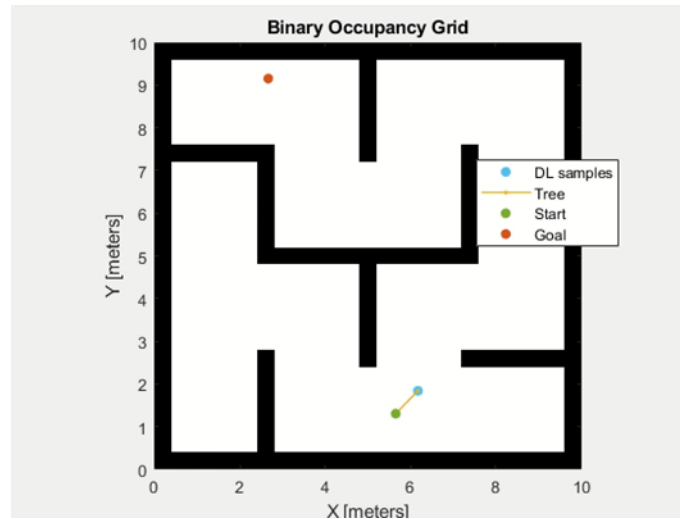
3



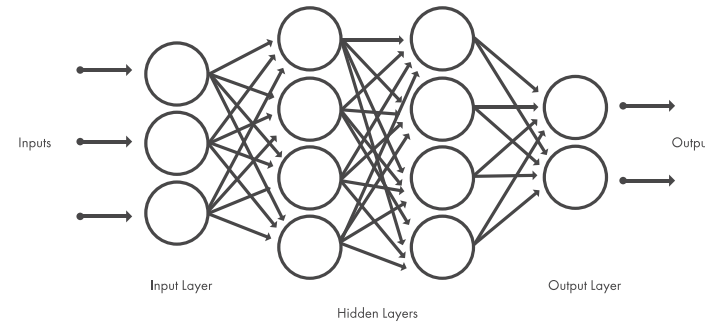
Combine output labels to get final 2D map

Deep Learning Toolbox  
UAV Toolbox  
Computer Vision Toolbox  
Navigation Toolbox

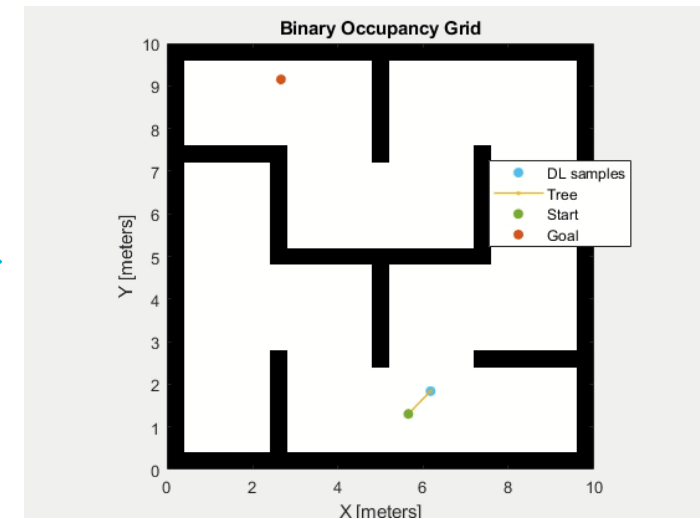
# AI model for motion planning in UAV application



Define takeoff and landing locations

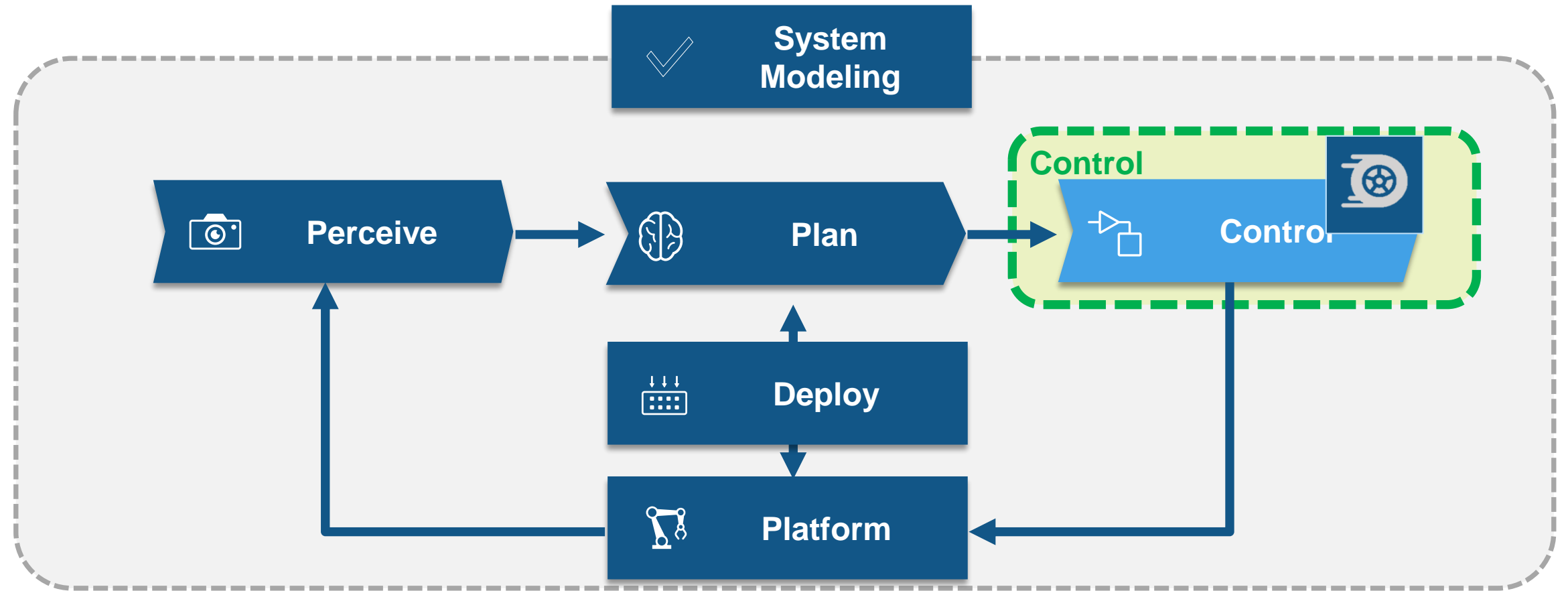


Exploit AI sampler to inform sample-based path planning



Path planned in a feasible time

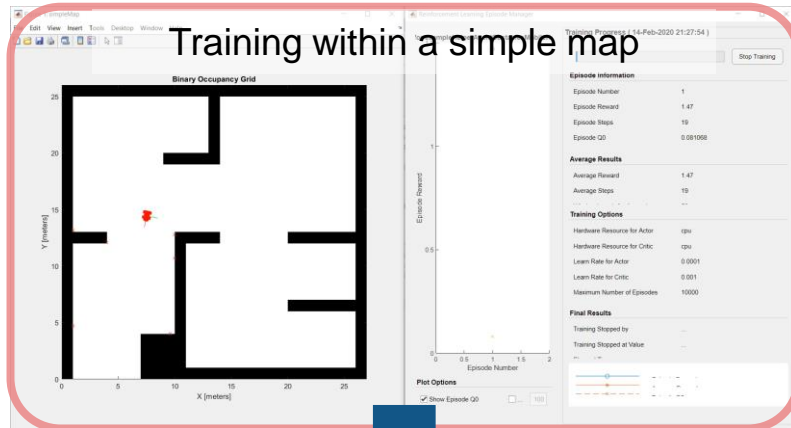
# Autonomous system design workflow



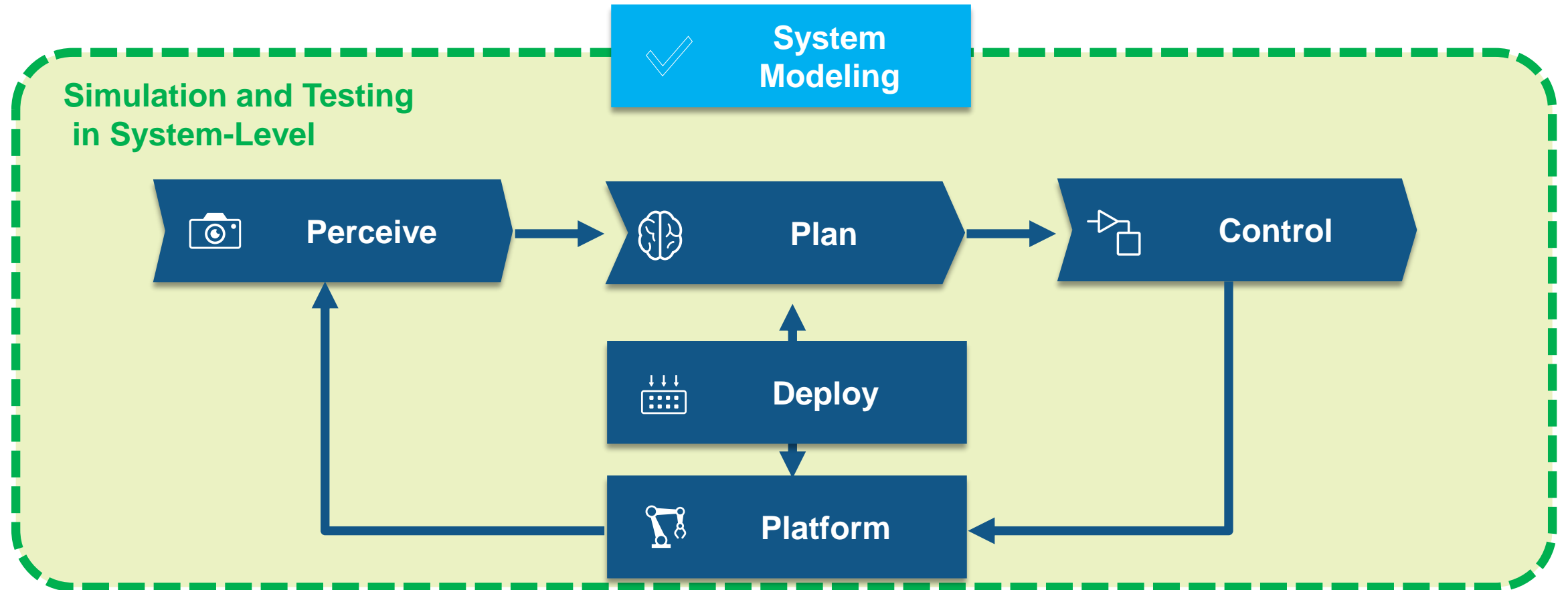
# Obstacle avoidance with reinforcement learning



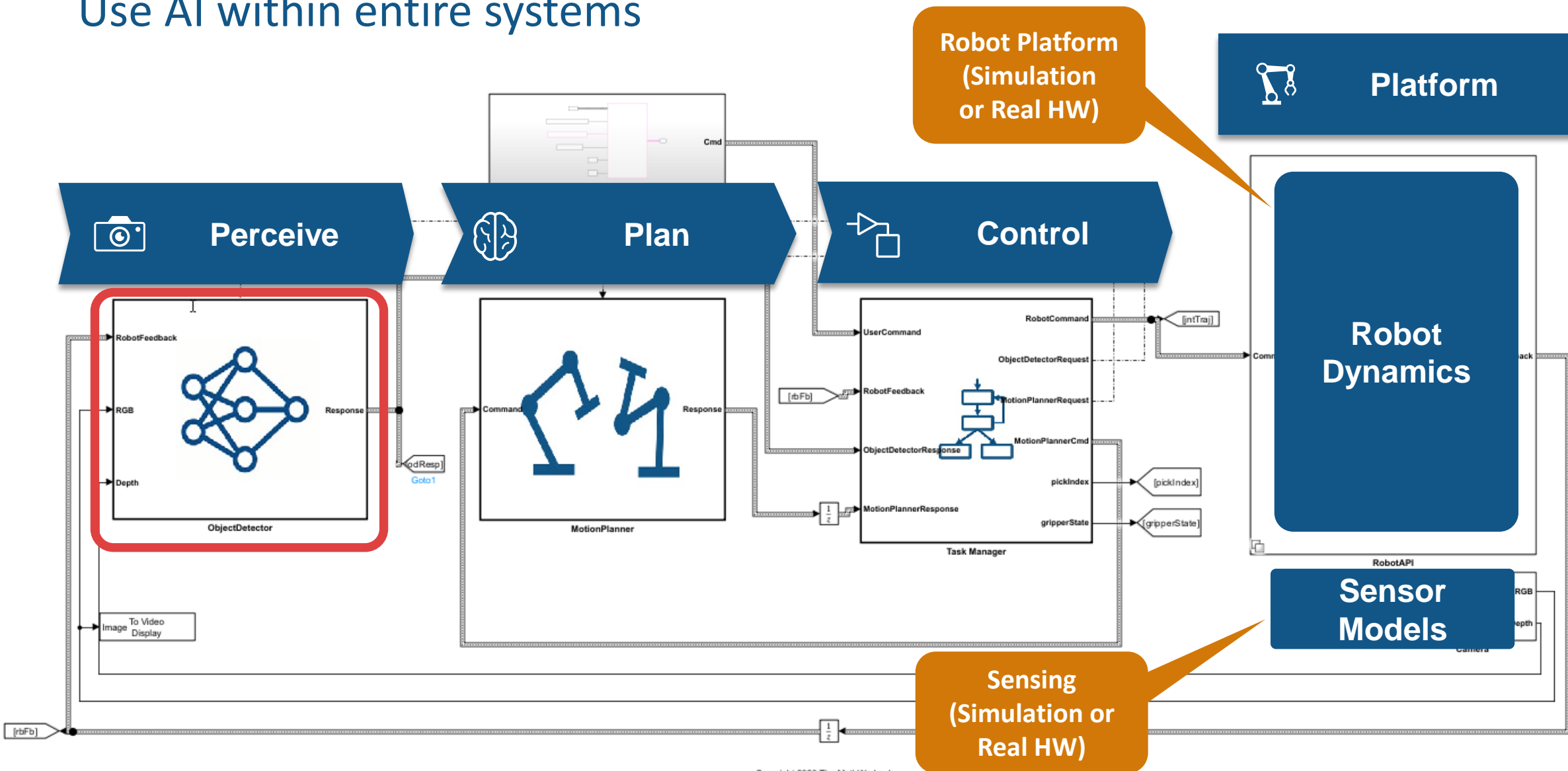
Visualized in a realistic environment



# Autonomous system design workflow



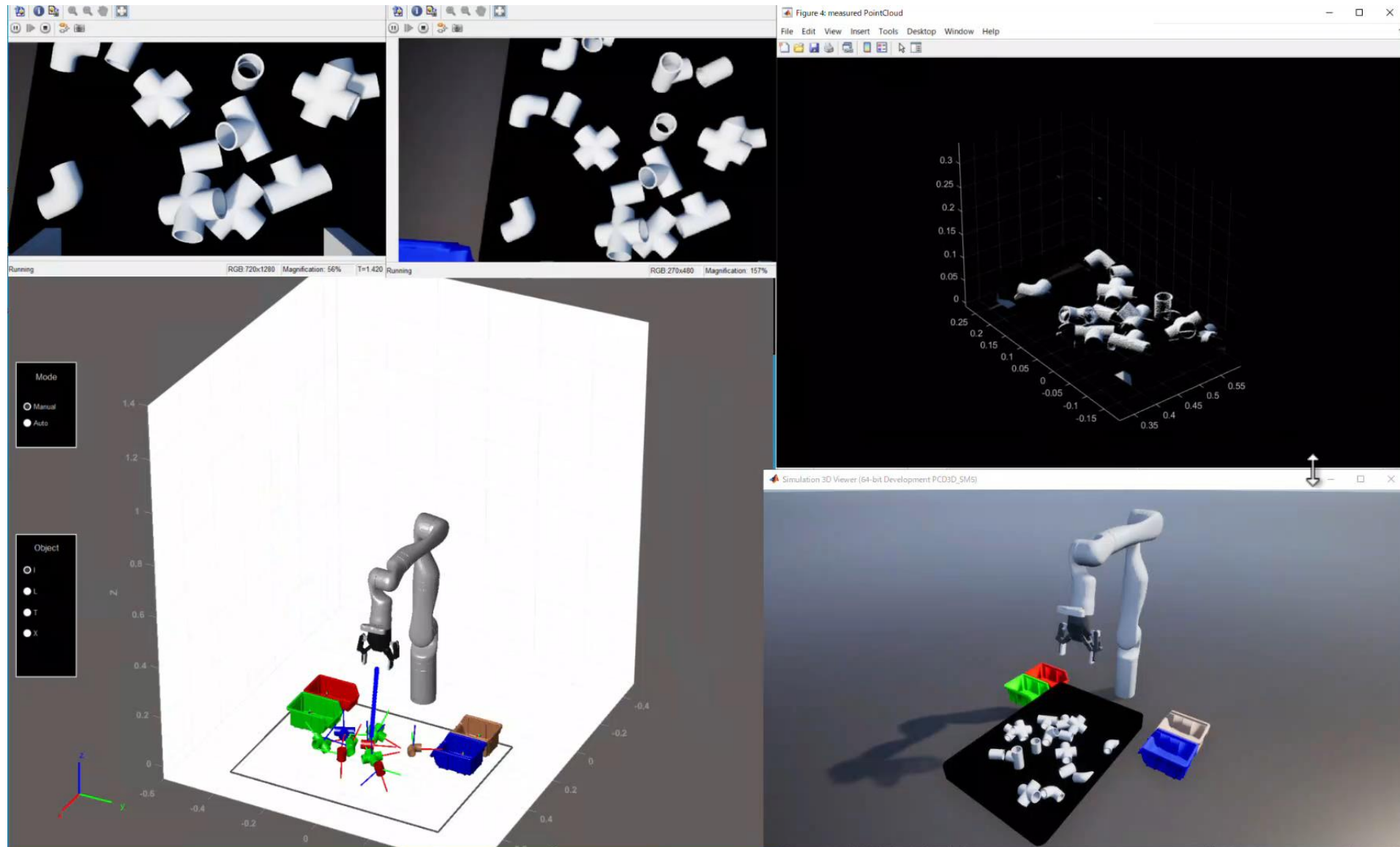
# Use AI within entire systems



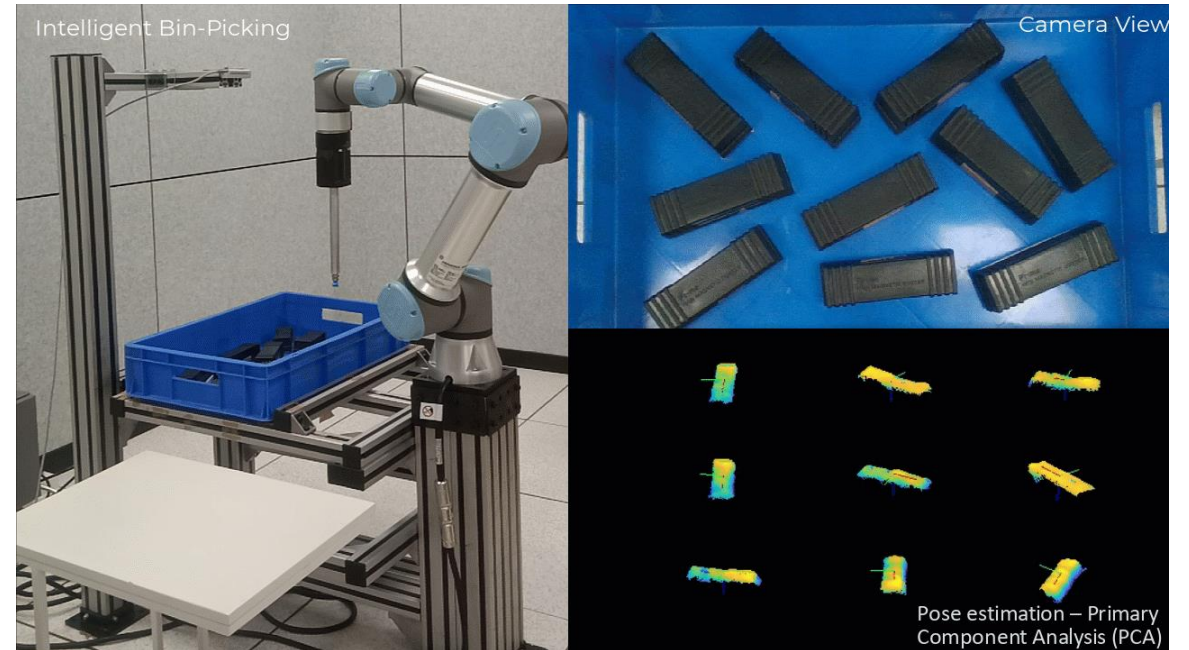
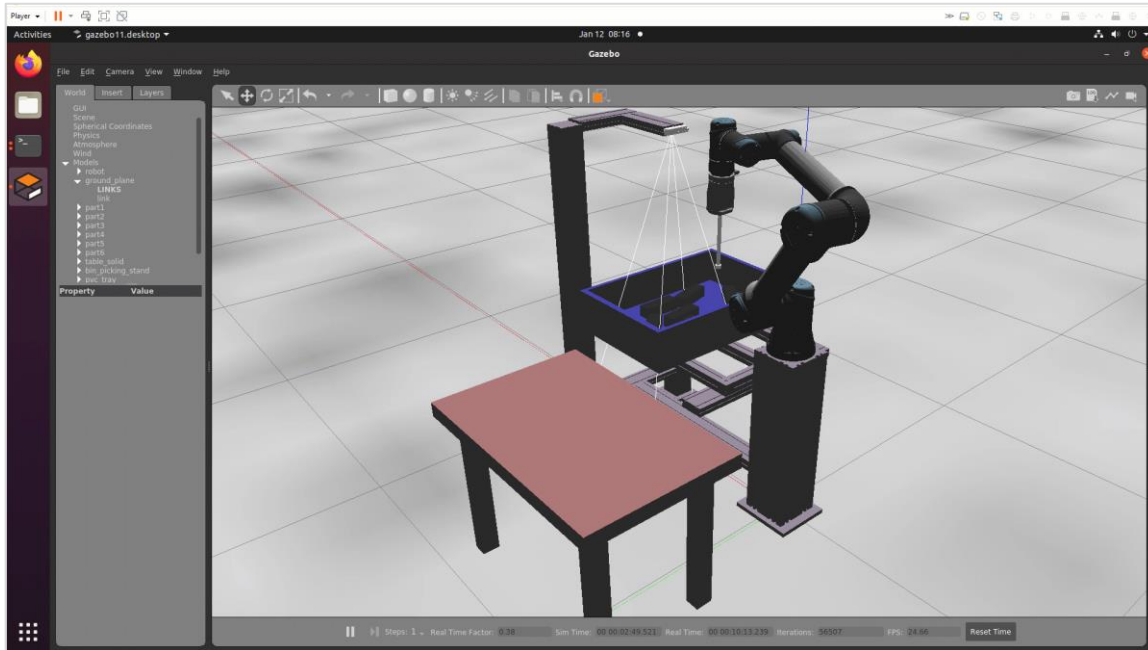


# Validation of AI models in end-to-end simulation

Simulink 3D Animation  
Robotics System Toolbox  
Automated Driving Toolbox

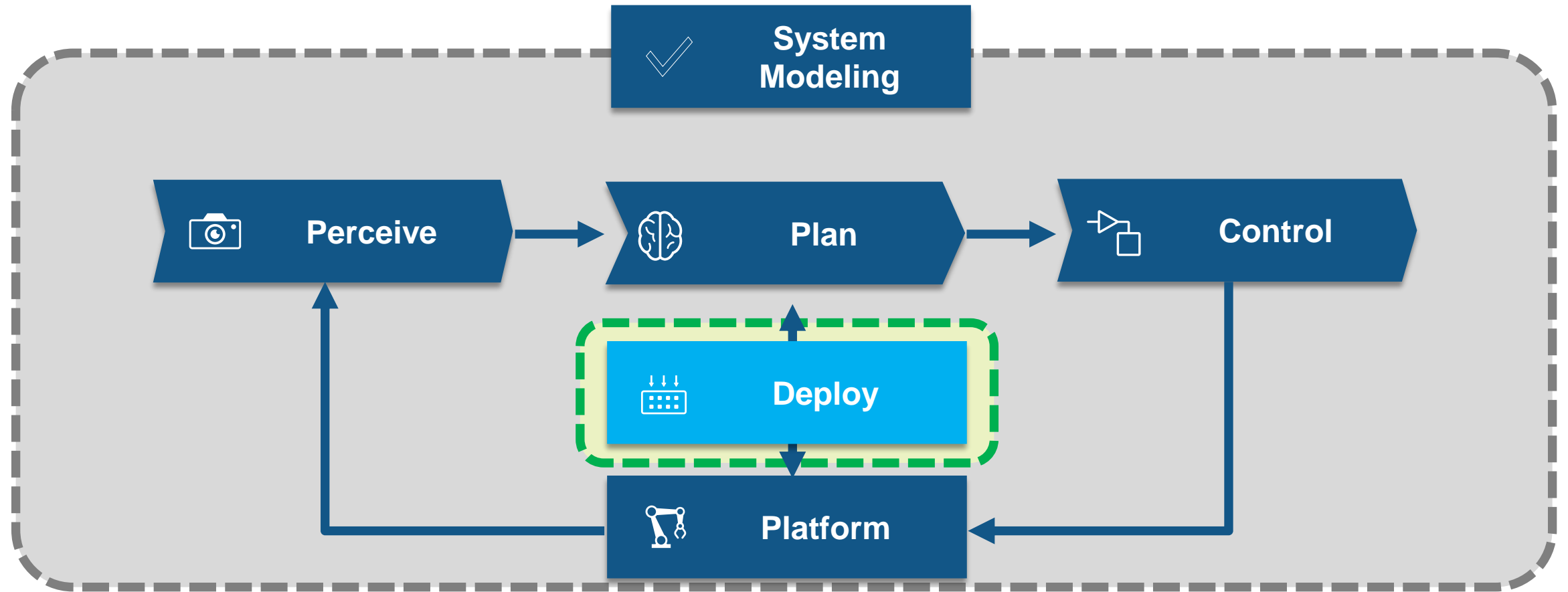


## Easy to change the robot hardware

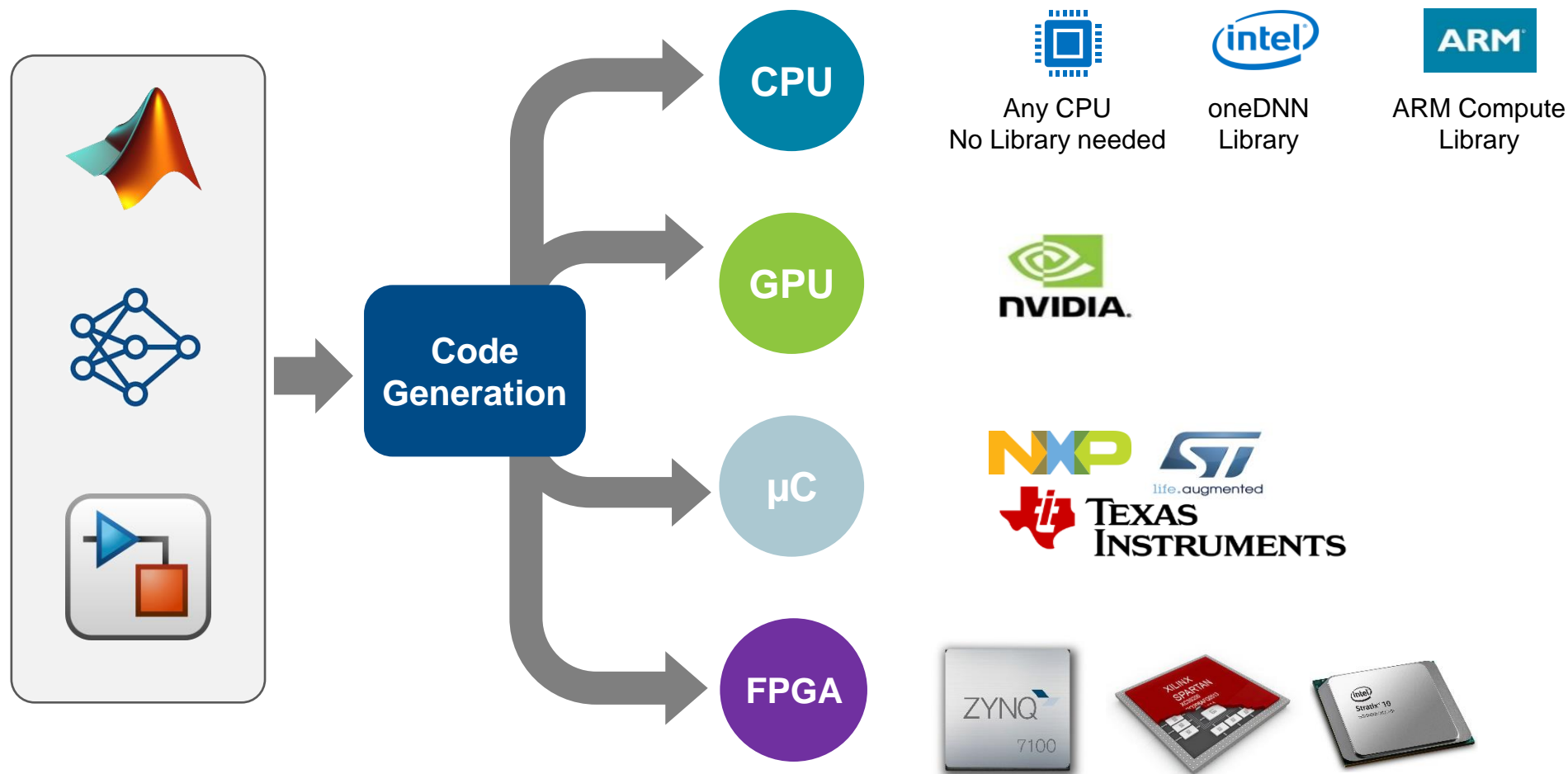


[Robotics System Toolbox Support Package for Universal Robots UR Series Manipulators](#) allows user to connect to and control Universal Robots Cobots over ROS.

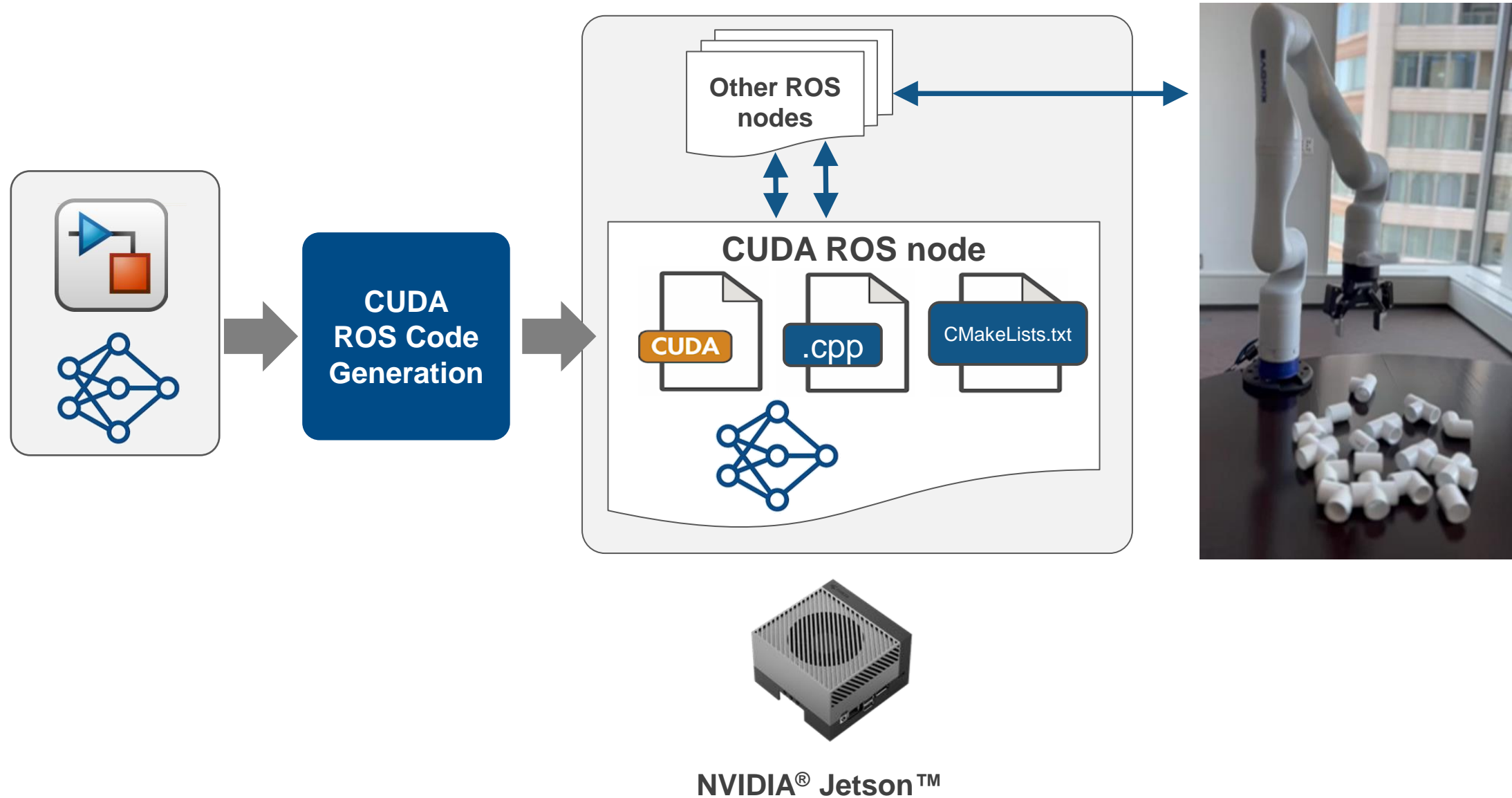
# Autonomous system design workflow



# Deploy to target with zero coding errors



# Deploy to Jetson device as CUDA ROS node

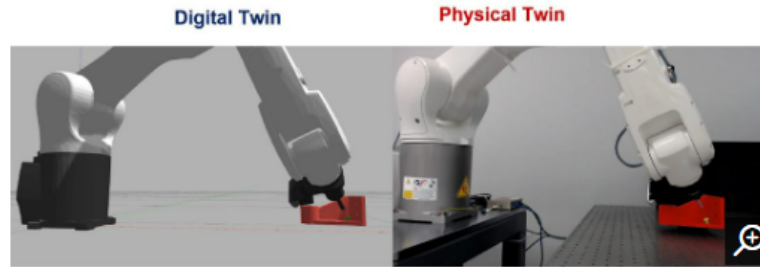


## ASTRI Accelerates Development of Robotic Manipulation System Using MBSE Digital Twin

[Related Link](#)

“The integration of MATLAB, Simulink, and Deep Learning Toolbox gave us the confidence to move forward with the MBSE digital twin project.”

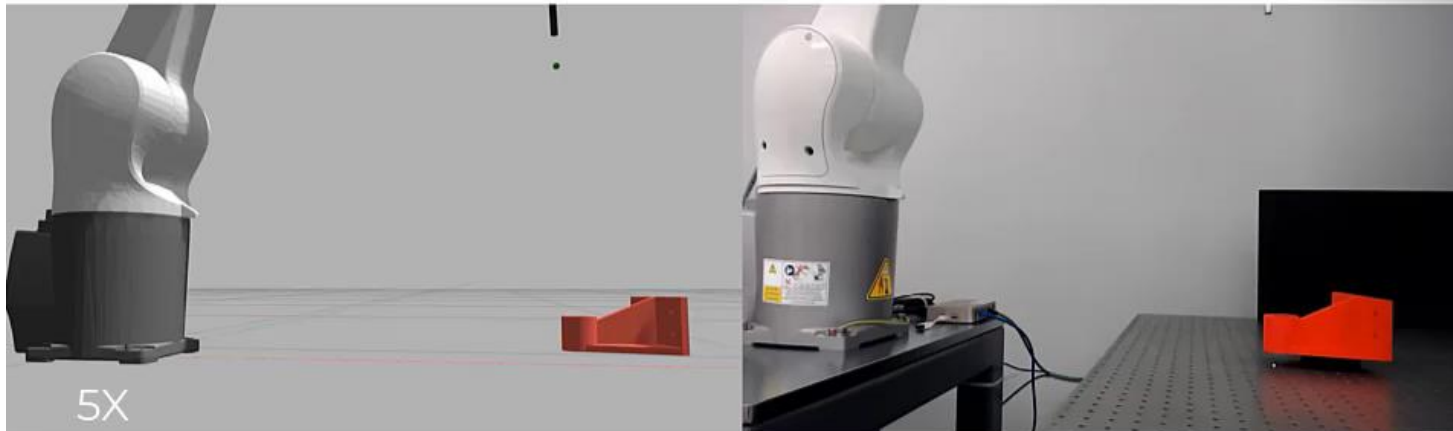
— Dr. T. John Koo, ASTRI



ASTRI created a digital twin to design, build, and validate its robotic welding system.

Digital Twin

Physical Twin



### Challenge

Reduce development time, manual processes, and costs

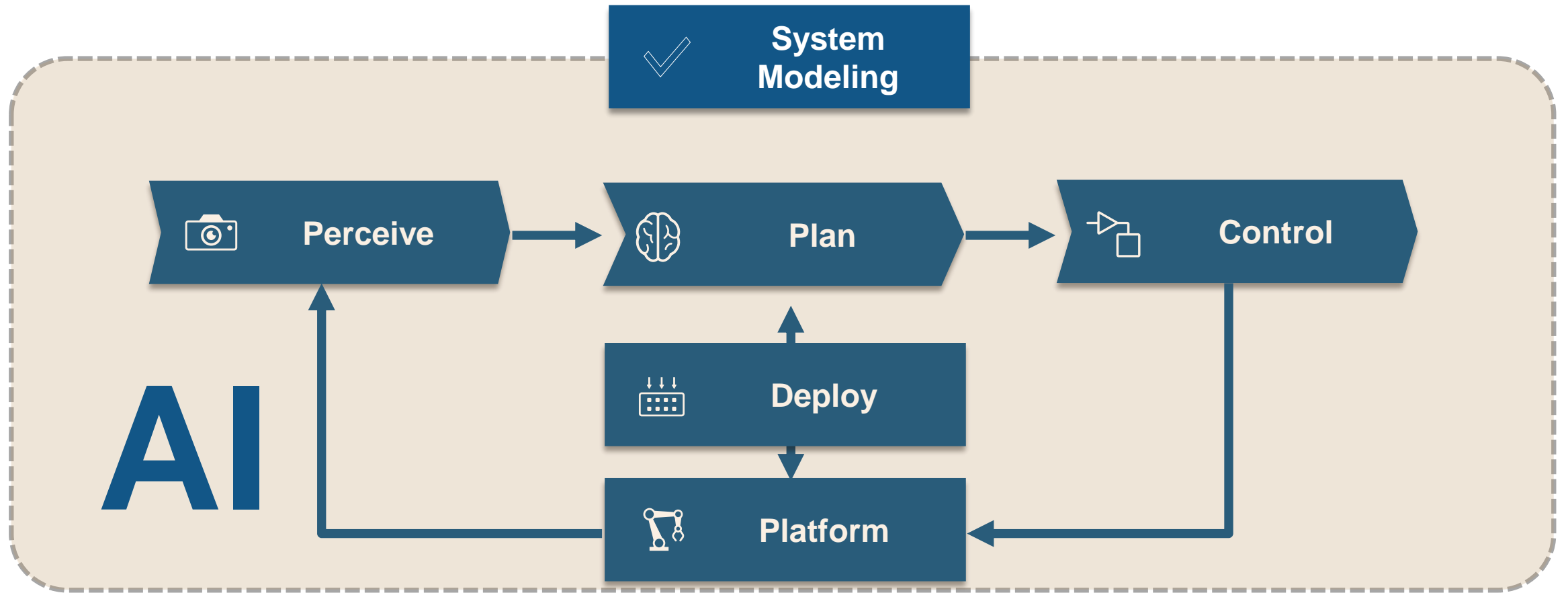
### Solution

Adopt model-based systems engineering and develop a digital twin with MATLAB, Simulink, and Deep Learning Toolbox

### Results

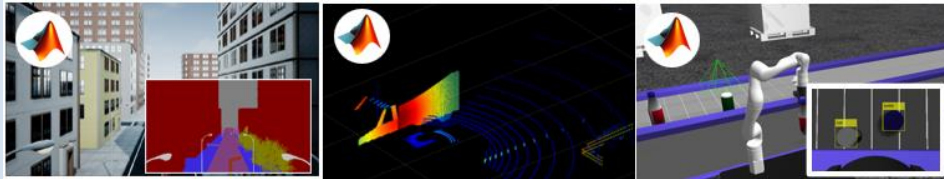
- Integration time reduced by 40%
- Issues resolved in the design stage
- Teams worked collaboratively

# Autonomous system design workflow



# Why MATLAB for AI in Robotics?

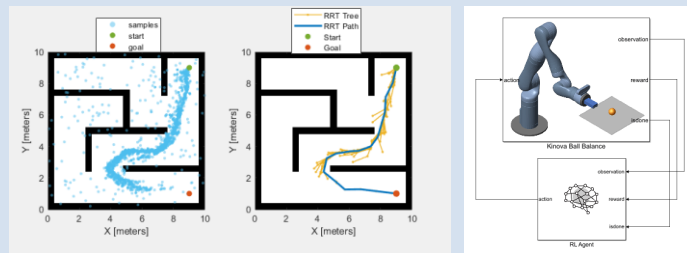
## ❑ Synthetic Training Data Generation



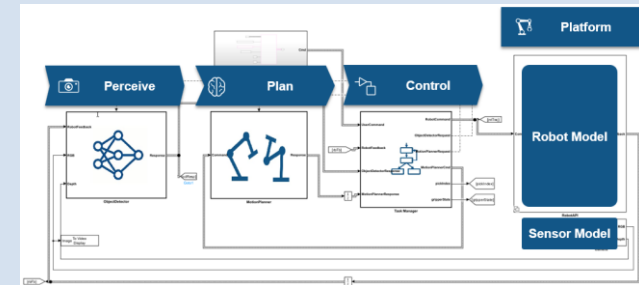
## ❑ Object Identification & Mapping



## ❑ Motion Planning & Controls



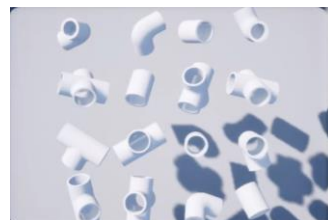
## ❑ System Level Testing & Deployment





# Challenges using AI for Solutions with MATLAB

 Data Complexity



Simulation

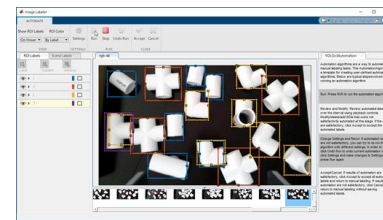
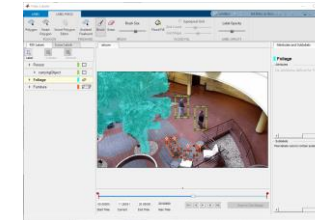



Image Labeler



Video Labeler

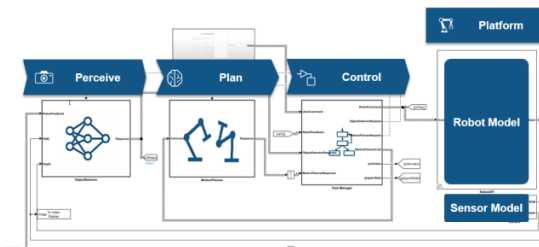
Signal Labeler

Lidar Labeler

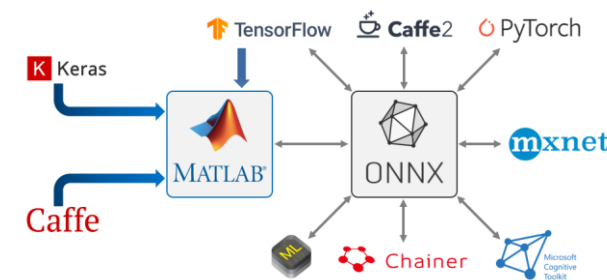
 Model Complexity



Pre-trained models



System-level Simulation, testing, & Deployment



Interoperability with other OS AI models

 AI Expertise

Robotics Expertise

vs. AI

# Challenges using AI for your robots:

 Data Complexity



Simulation

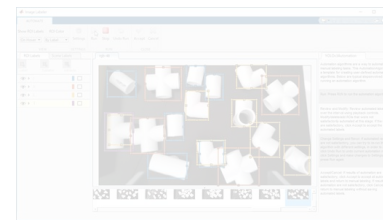
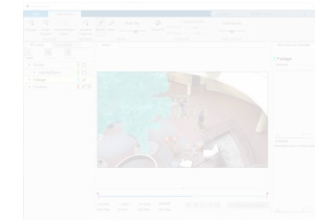


Image Labeler



Video Labeler

Signal Labeler

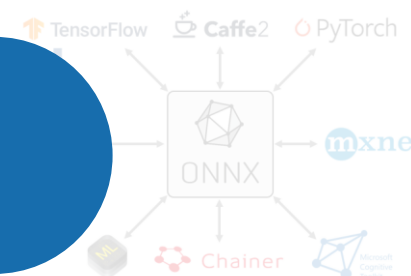
Lidar Labeler

 Model Complexity



Pre-trained models

 Business



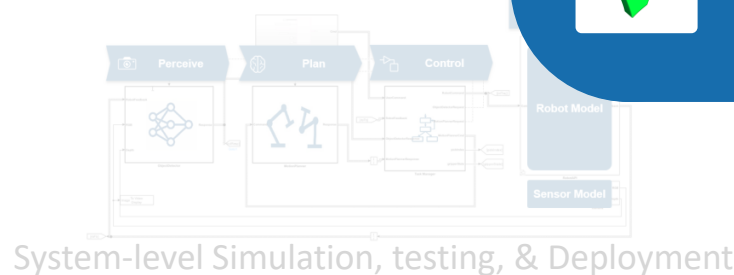
Interoperability with other OS AI models

 AI Expertise

Robotics Expertise



AI



# Get Started with AI in MATLAB

## Onramp



### Deep Learning Onramp

Get started quickly using deep learning methods to perform image recognition.

Details and launch



### Machine Learning Onramp

An interactive introduction to practical machine learning methods for classification problems.

Details and launch



### Reinforcement Learning Onramp

An interactive introduction to reinforcement learning methods for control problems.

Details and launch

## Videos

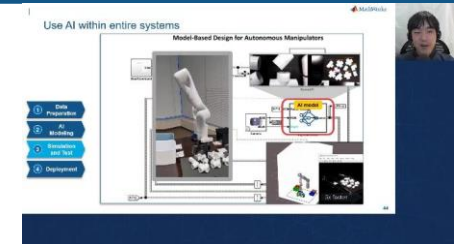


### Deep Learning Tech Talk



### Reinforcement Learning Tech Talk

## Webinars



### AI for robotics

AI for Simulink Users



### AI for Simulink Users

Deploy Deep Neural Networks to NVIDIA GPUs and CPUs from Simulink using GPU Coder

October 2020



### Deploy Deep Neural Networks

# MATLAB EXPO

Thank you



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