

MathWorks
**AUTOMOTIVE
CONFERENCE 2023**
North America

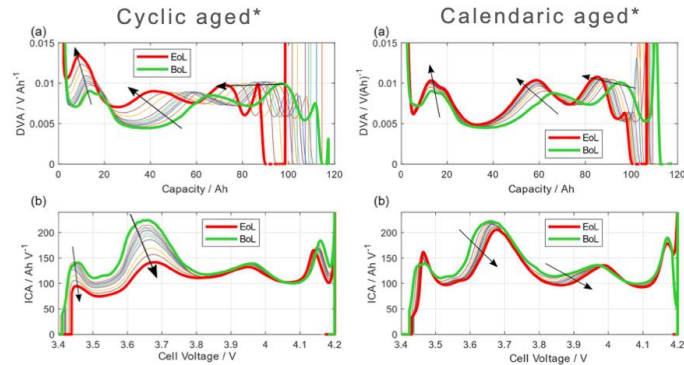
How AI Trends are Impacting Automotive Development

Mary Ann Freeman, MathWorks



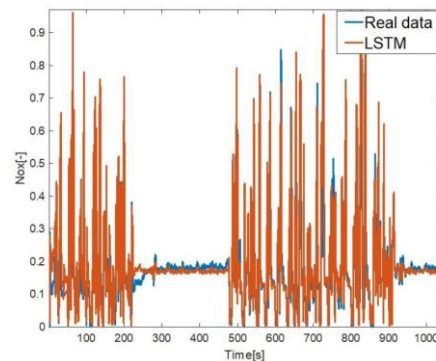
Significant increase in use of AI in Automotive Development

R&D



Gotion

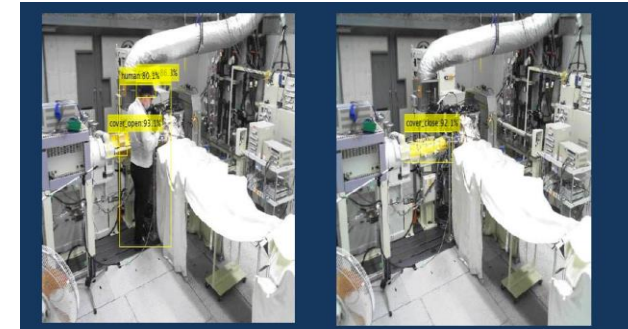
Battery SOH Estimation



Renault

Virtual sensor for NOx estimation

Manufacturing



Toyota

Predictive maintenance of engine bench



Daihatsu

Engine knock detection

Goals for this talk

Trends observed across MATLAB/Simulink users incorporating AI in automotive development

How MathWorks is supporting these trends

Market trends driving AI in Automotive Development

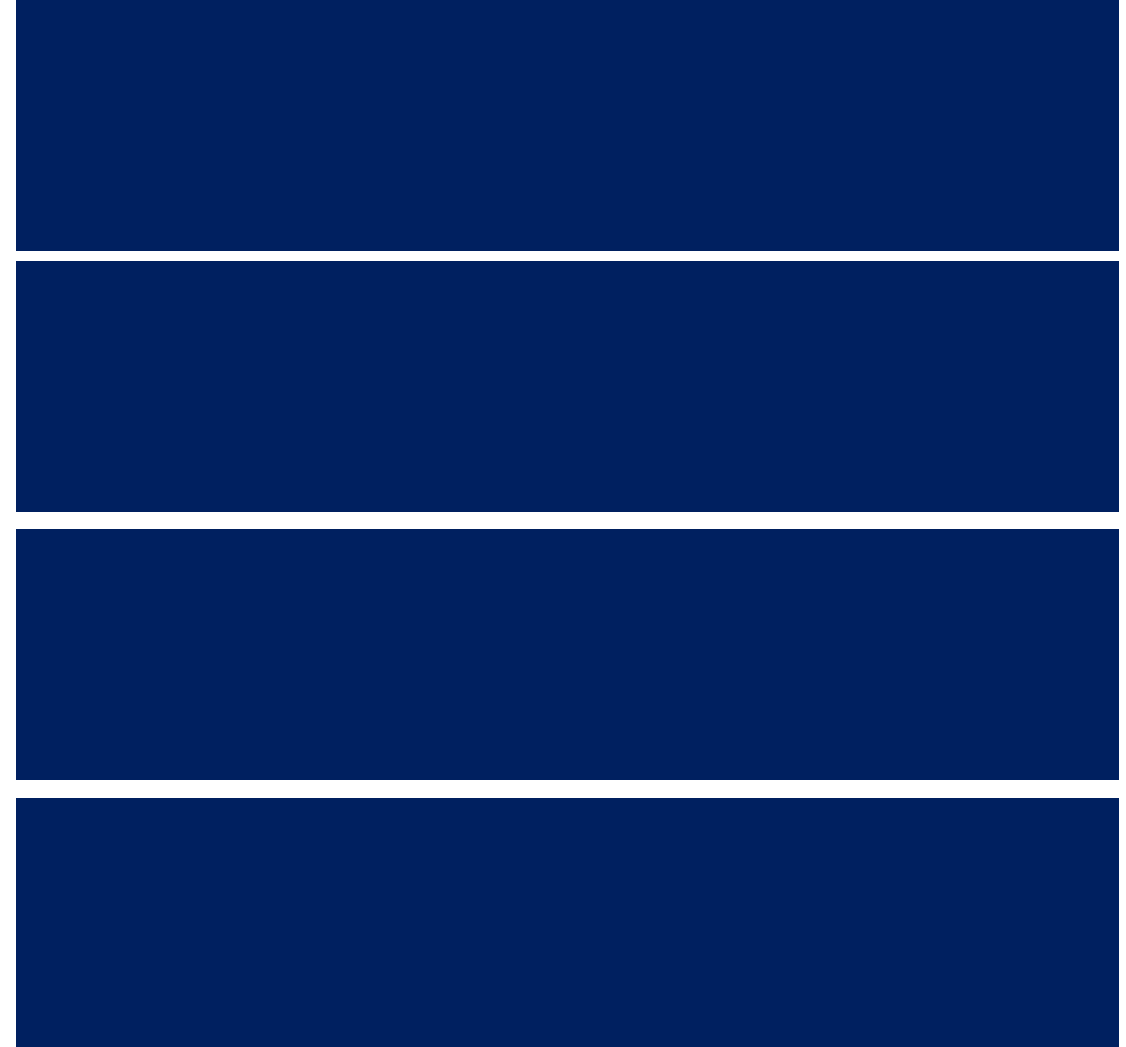
1. AI improves existing systems and processes

2. Integration of AI with automotive software development process

3. Government regulation and certification efforts

4. Shift from general-purpose AI to solving domain-specific problems using AI

MathWorks Response



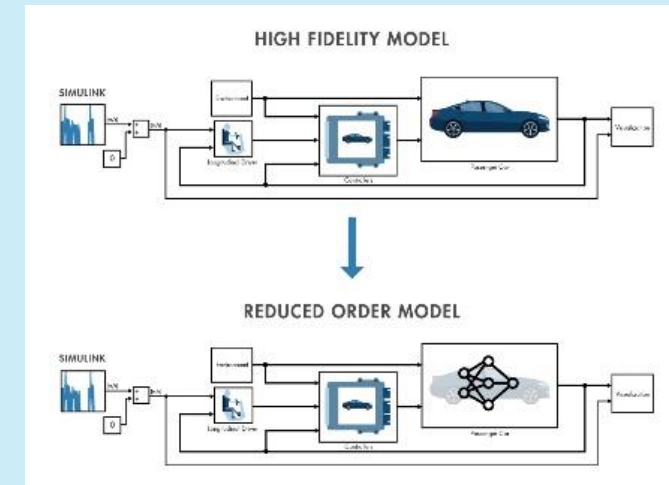
Trend #1

AI being used to improve existing systems and processes

Solving previously unsolvable problems now possible with AI



Improving existing systems and processes with AI



2015

2016

2017

2018

2019

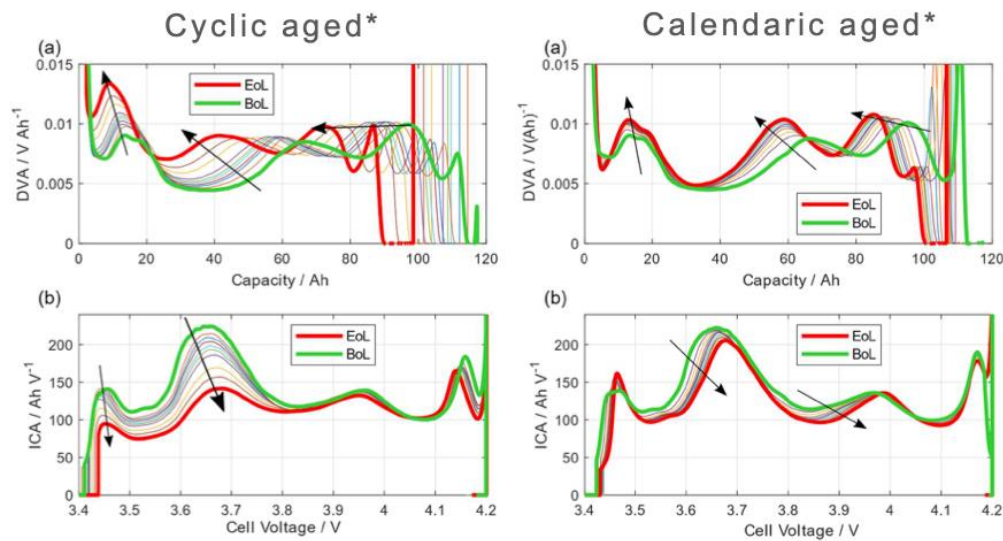
2020

2021

2022

Today

AI-Based Virtual Sensor for Battery State-of-Health



- Combined AI with traditional battery analysis techniques
- Implemented in Simulink for testing, requirements validation, and certification



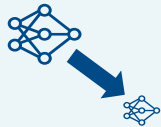
Trend #1

AI being used to improve existing systems and processes

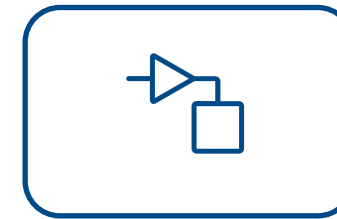
Impact on MATLAB and Simulink Users



Increase interest and use of AI in Simulink



Increase use of smaller/simpler models



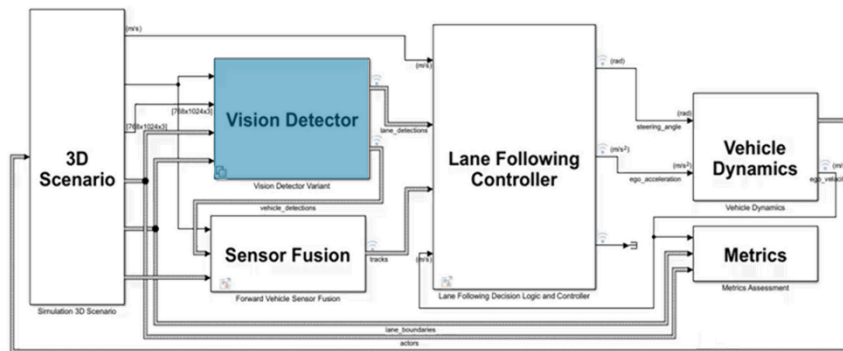
AI in Simulink

AI is often part of a larger system

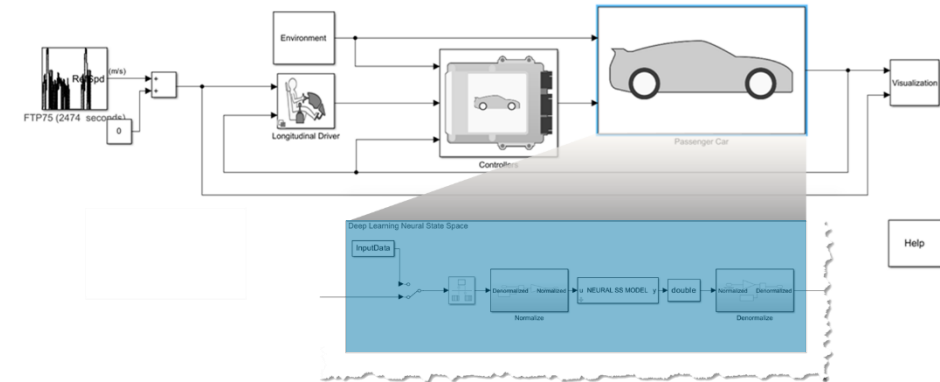
Virtual sensor for battery SOC estimation



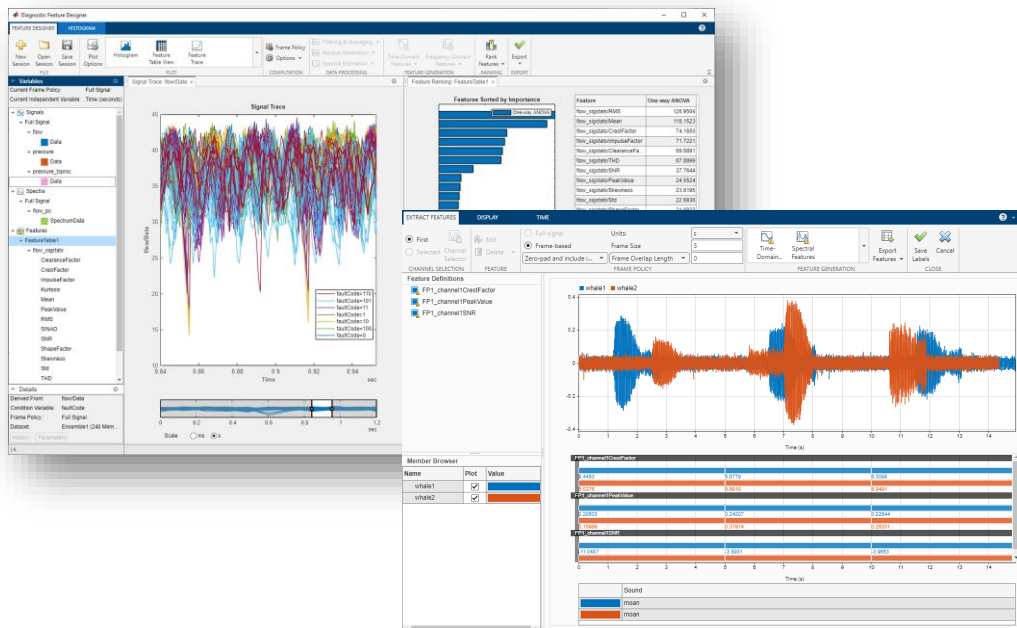
Vision Detector for a Highway Lane Following System



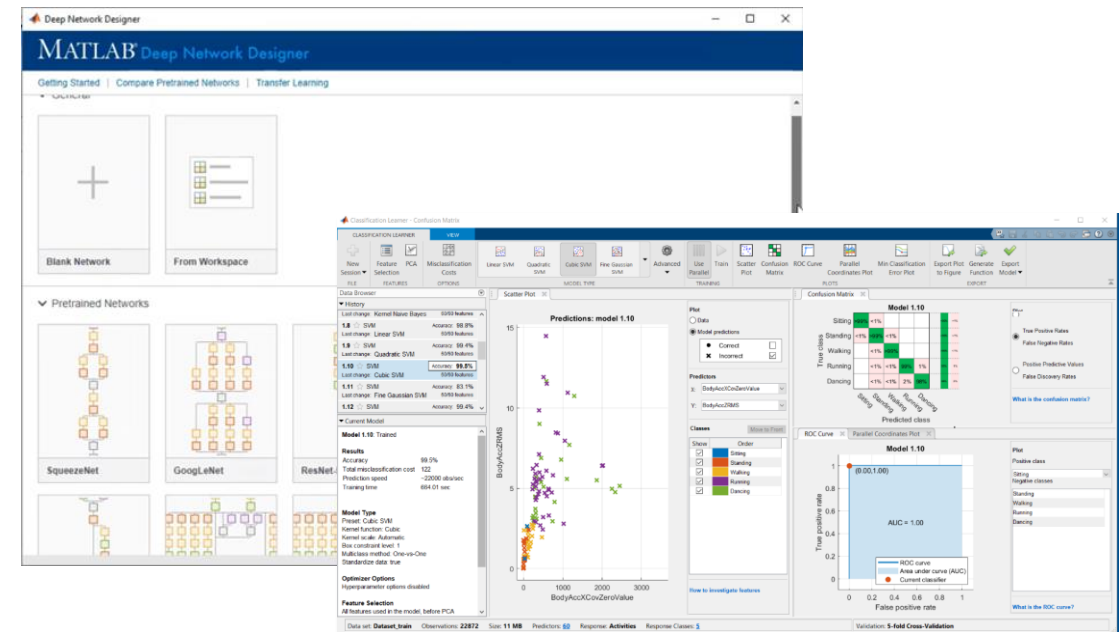
AI-based Reduced-Order Modeling



Get started faster with low-code app-based workflows

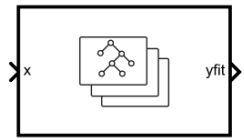


Feature Extraction



Deep Learning and Machine Learning Training

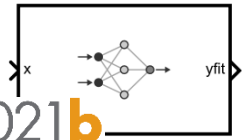
AI libraries in Simulink are expanding to include more AI blocks for more applications



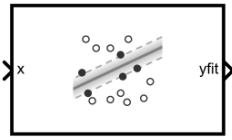
RegressionEnsemble Predict



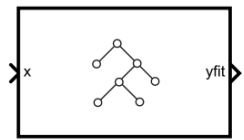
RegressionGP Predict



RegressionNeuralNetwork Predict



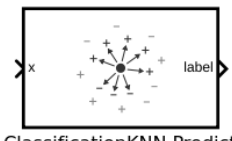
RegressionSVM Predict



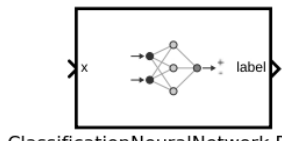
RegressionTree Predict



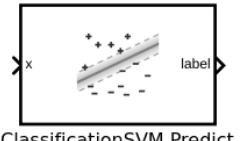
ClassificationEnsemble Predict



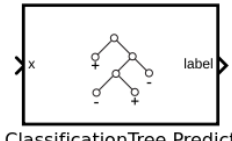
ClassificationKNN Predict



ClassificationNeuralNetwork Predict



ClassificationSVM Predict



ClassificationTree Predict

Statistics and Machine Learning Toolbox

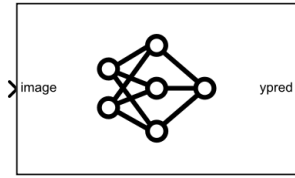
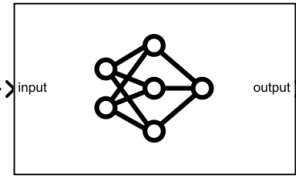
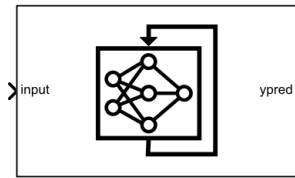


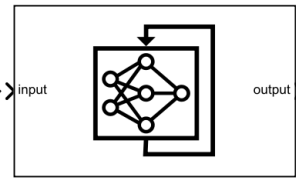
Image Classifier



Predict

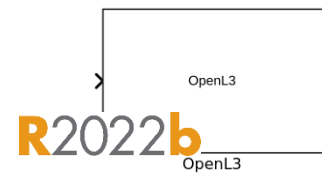


Stateful Classify



Stateful Predict

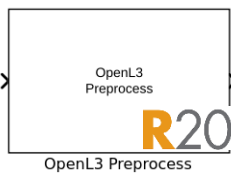
Deep Learning Toolbox



OpenL3



OpenL3 Embeddings



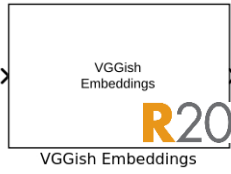
OpenL3 Preprocess



Sound Classifier



VGGish



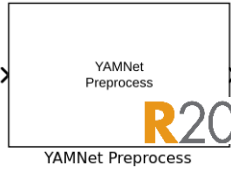
VGGish Embeddings



VGGish Preprocess



YAMNet

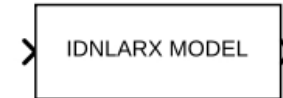


YAMNet Preprocess

Audio Toolbox

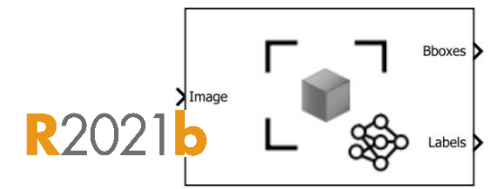


Neural State Space Model



Nonlinear ARX Model

System Identification Toolbox



Deep Learning Object Detector

Computer Vision Toolbox

Evolution of AI in MATLAB

2016 - 2019

Toolboxes

- Deep Learning Toolbox
- Text Analytics Toolbox
- Reinforcement Learning
- Predictive Maintenance Toolbox

Code Generation

- GPU Coder
- MATLAB Coder

Apps

- Image Labeler
- Deep Network Designer
- Video Labeler
- Signal Labeler

Interoperability

- TensorFlow-Keras Importer
- ONNX Support

2020 - 2021

Apps

- Experiment Manager
- Lidar Labeler
- Reinforcement Learning Designer

Compression

- Quantization

Code Generation

- Deep Learning HDL Coder

Model-Based Design

- Image Classification & Model Prediction
- Recurrent Neural Networks
- Object Detectors

Interoperability

- TensorFlow Model Importer

2022 - 2023

Accessibility

- Deep Learning Model Hub

Compression

- Taylor, Projection Pruning

Code Generation

- TensorFlow Lite

Interoperability

- TensorFlow Export
- PyTorch Import
- Co-execution examples

Verification

- Out of distribution detection
- Robustness

Domain Specific AI

- Medical Imaging
- Automated Visual Inspection

Over 500+ examples

Market trends driving AI in Automotive Development

1. AI improves existing systems and processes

2. Integration of AI with automotive software development process

3. Government regulation and certification efforts

4. Shift from general-purpose AI to solving domain-specific problems using AI

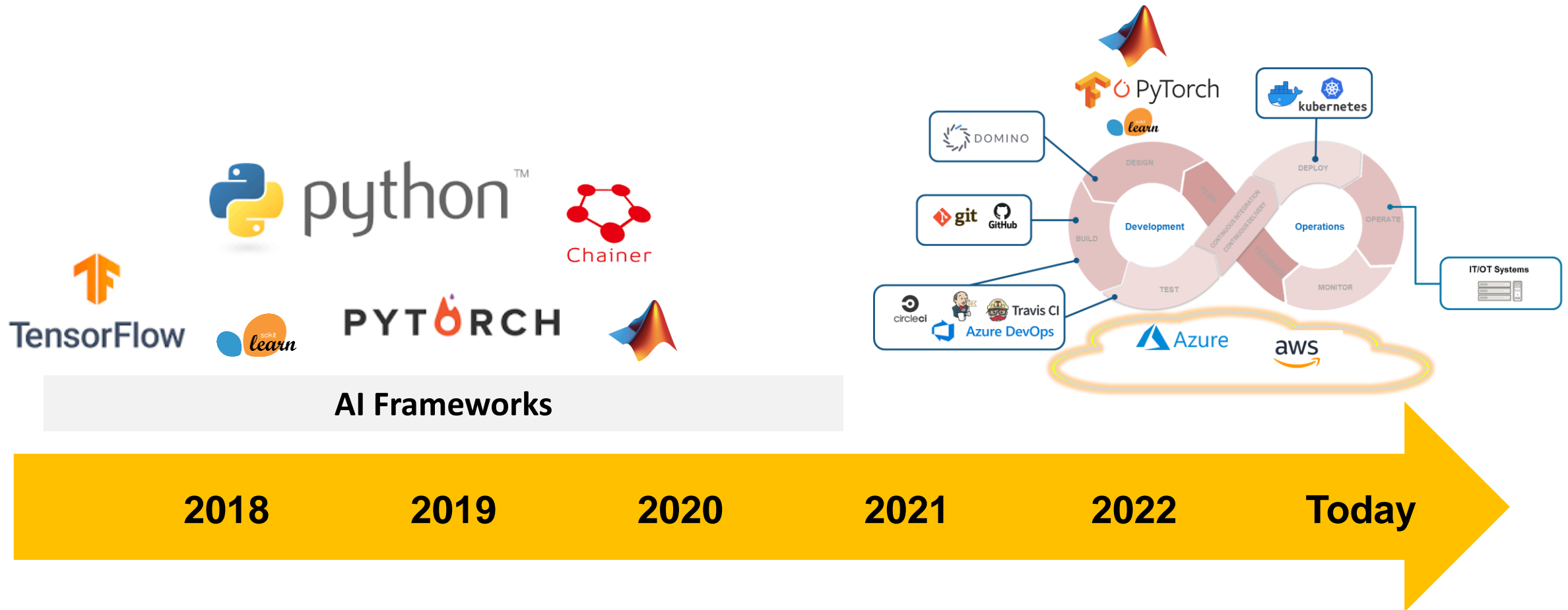
MathWorks Response



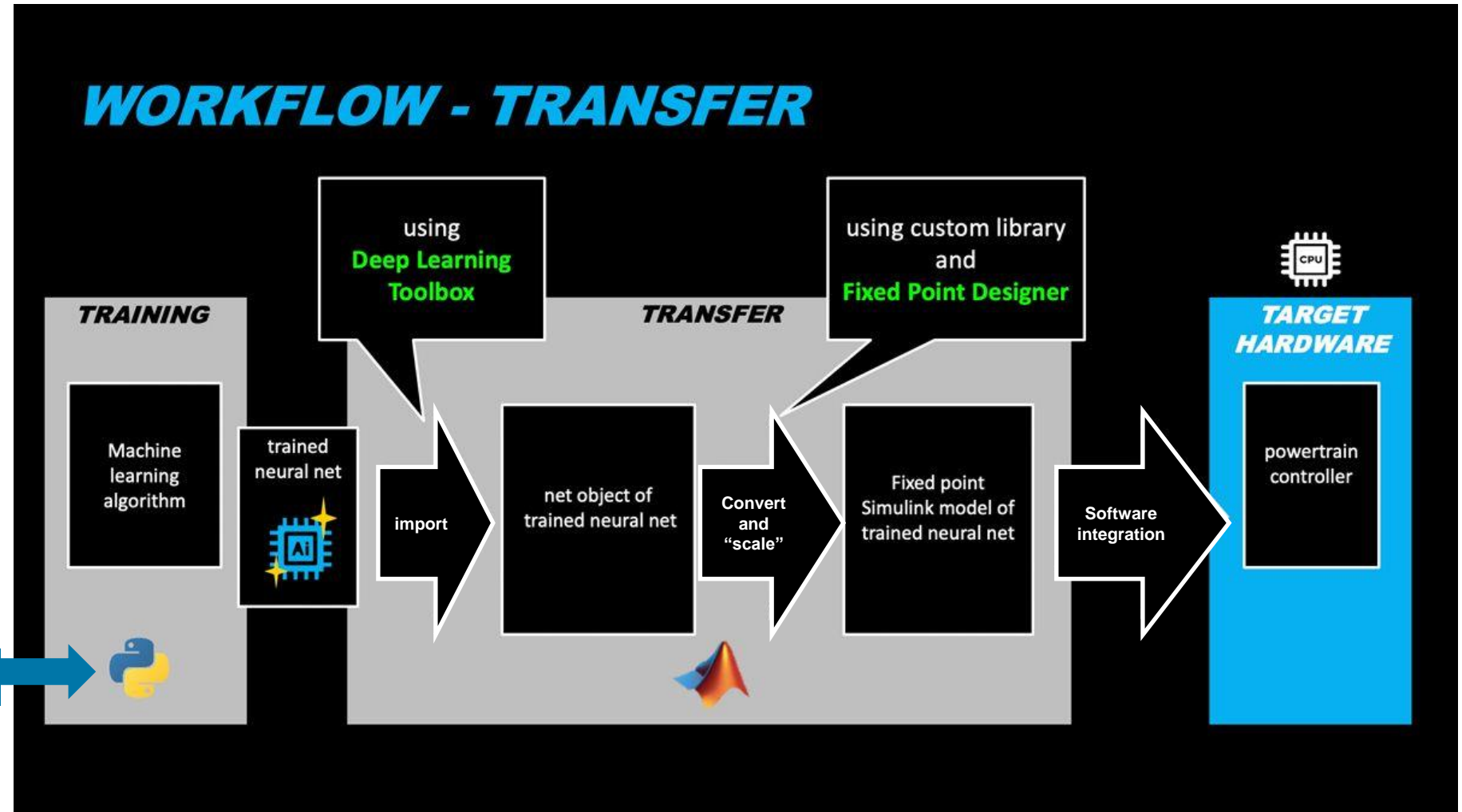
AI in Simulink

Trend #2

Integration of AI with software development process

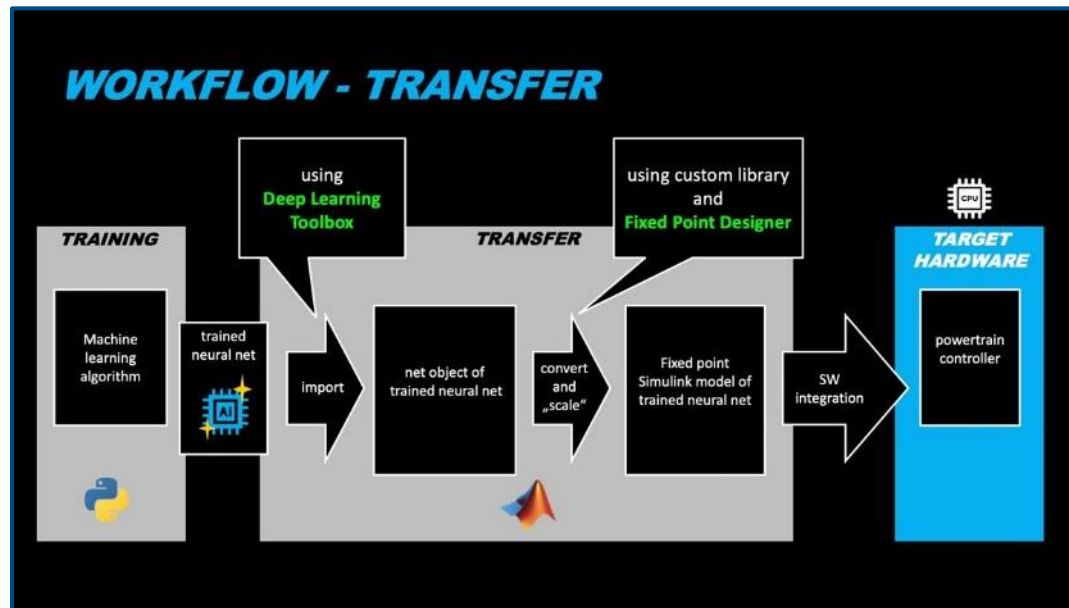


Mercedes-Benz Simulates Hardware Sensors with Deep Neural Networks based Virtual Sensor



AI model from Python

Mercedes-Benz Simulates Hardware Sensors with Deep Neural Networks based Virtual Sensor



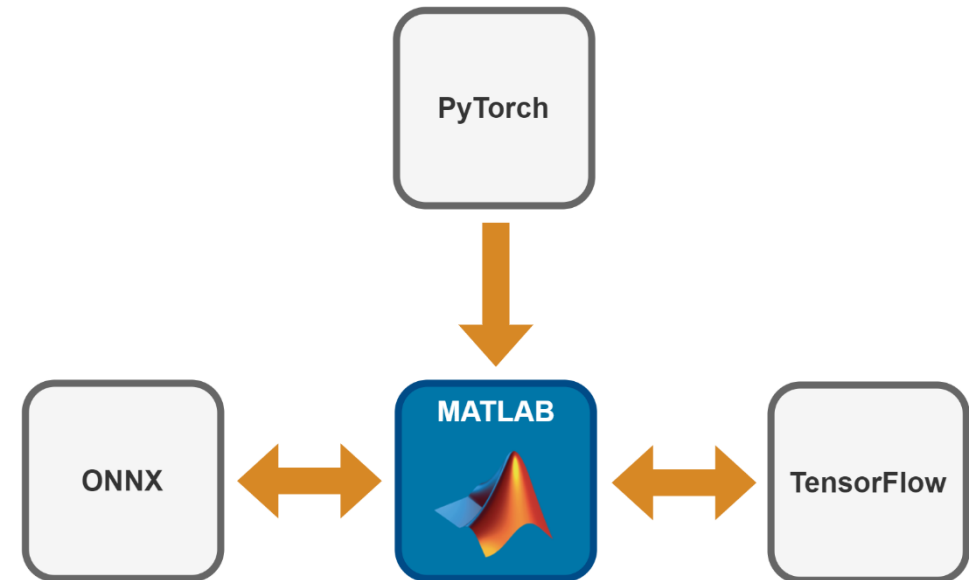
Automated workflow for deploying virtual sensors to powertrain ECU.

Use Deep Learning Toolbox, and Fixed-Point Designer to convert Python AI models into code that can be deployed to an automotive ECU.

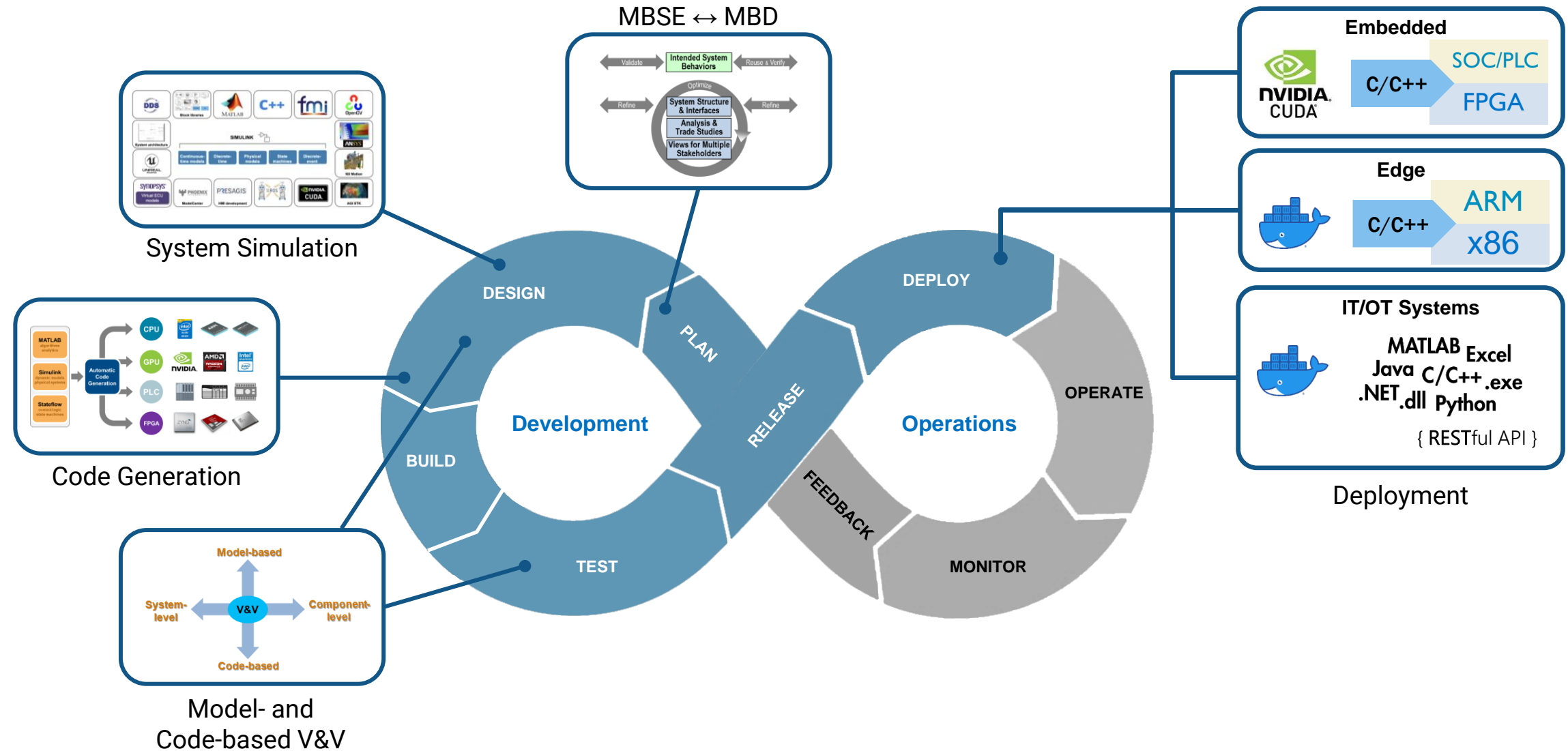
- CPU, memory, performance requirements met
- Flexible process established
- Development speed increased 600%

Continued investment into importing and exporting AI models into MATLAB and Simulink

TensorFlow-Keras Import	R2017b
ONNX Converter (Import & Export)	R2018a
TensorFlow Converter (Import)	R2021a
TensorFlow Converter (Export)	R2022b
PyTorch Converter (Import)	R2022b



Integrate AI with Software Development Workflows

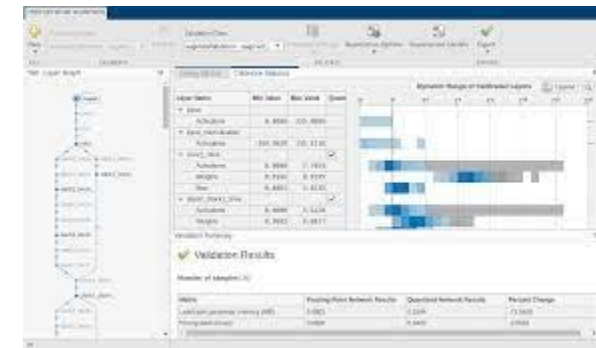
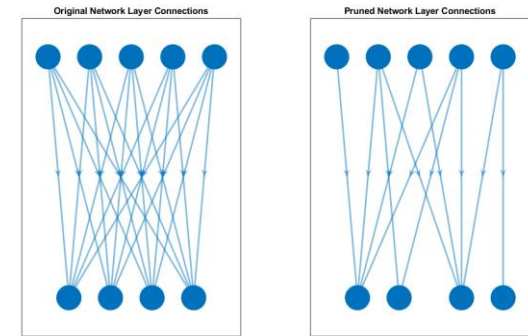
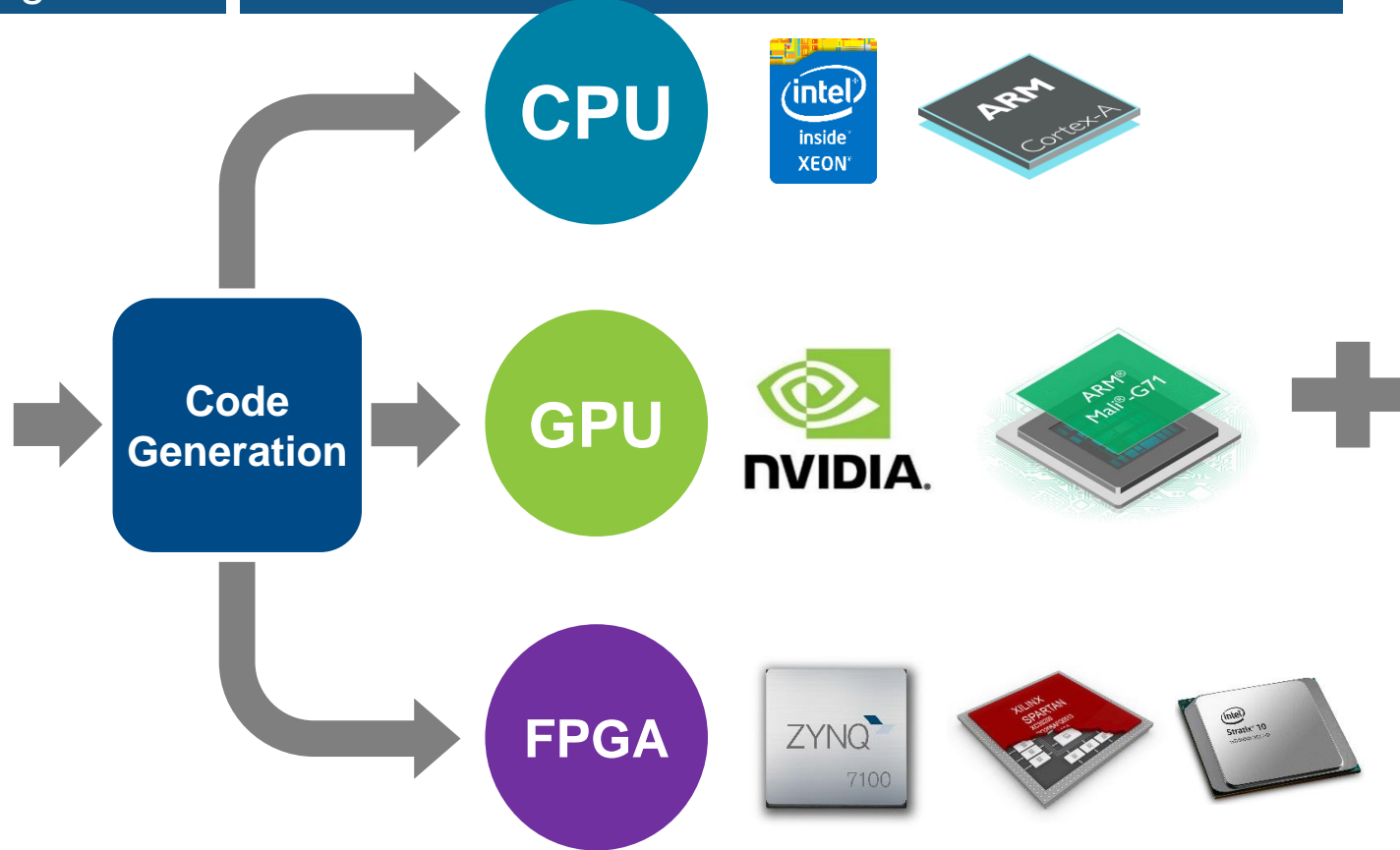
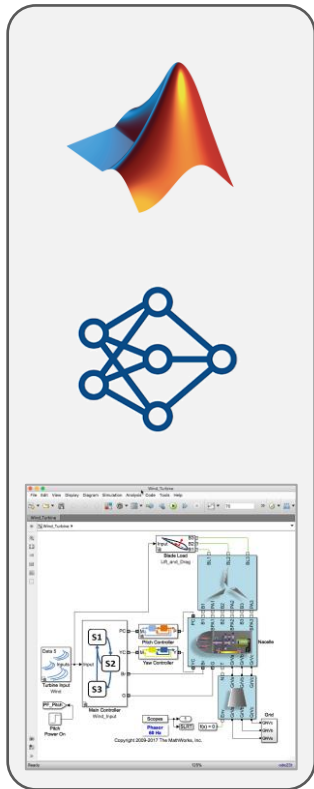


Leveraging 30 years of code generation experience for AI workflows

Generate code for AI model + pre- and post-processing

Performant multi-processor deployment

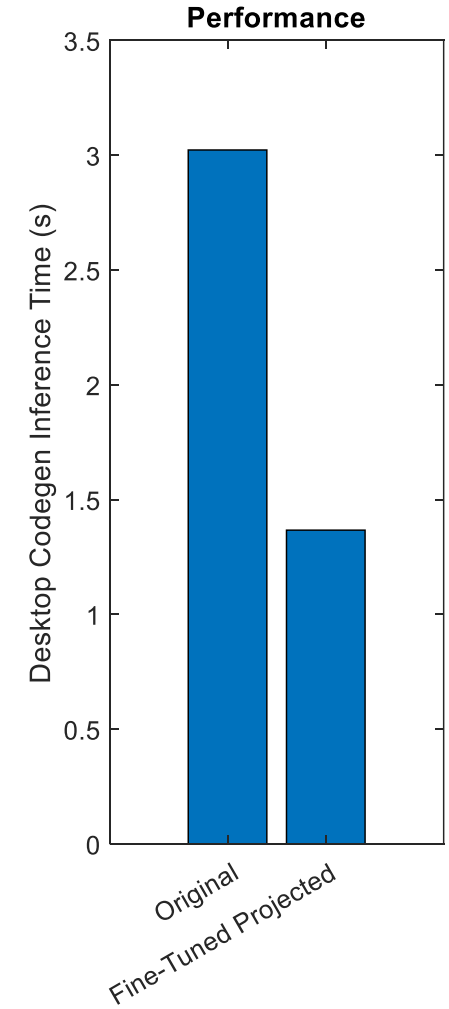
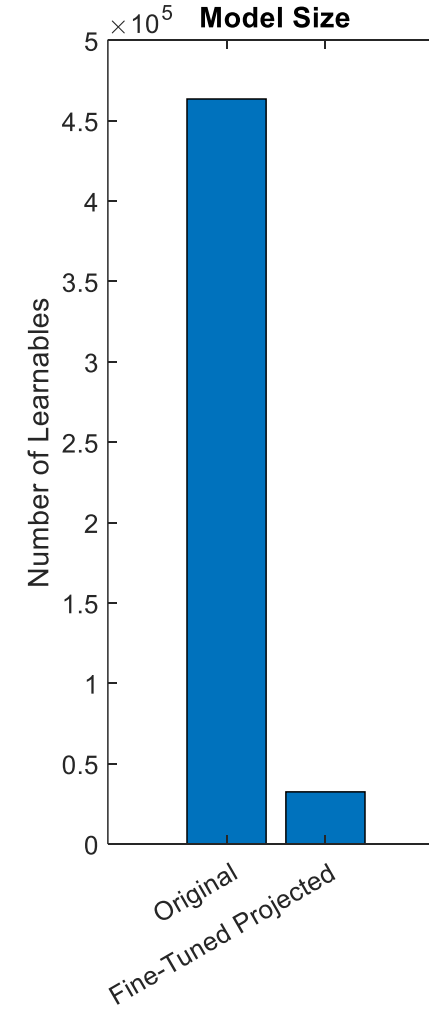
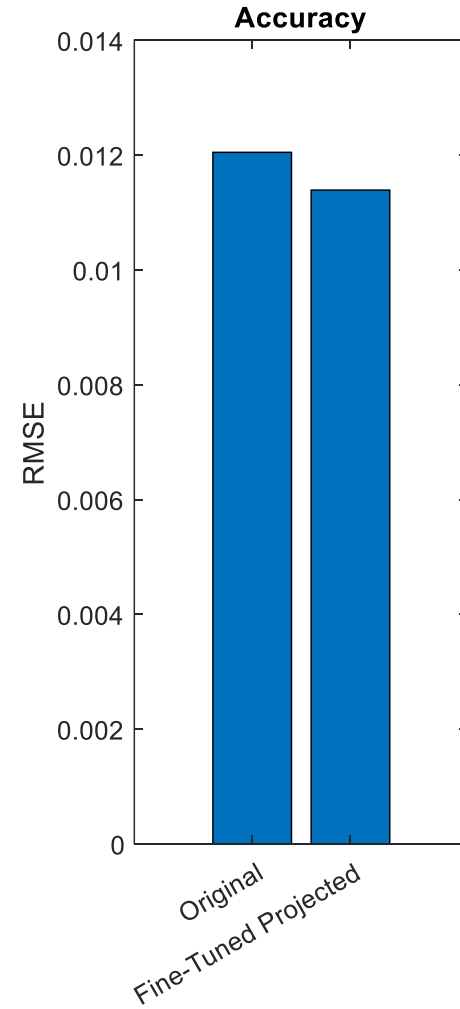
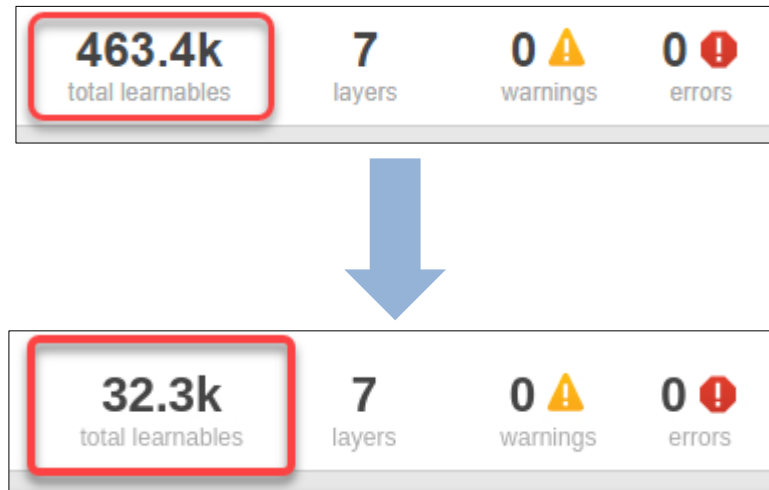
Pruning and quantization



Manage AI tradeoffs for your system

Battery SOC Estimation

Model Compression Using Projection: 93% size reduction with 2x speedup



Market trends driving AI in Automotive Development

1. AI improves existing systems and processes

2. Integration of AI with automotive software development process

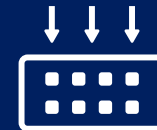
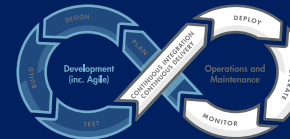
3. Government regulation and certification efforts

4. Shift from general-purpose AI to solving domain-specific problems using AI

MathWorks Response



AI in Simulink



Interoperability & DevOps

Code generation

Trend #3

Increase in government regulation and certification efforts


THE AI ACT

About The Act Assessment Analyses Developments Contact

The Artificial Intelligence Act

What is the EU AI Act?

The AI Act is a proposed European law on artificial intelligence (AI) – the first law on AI by a major regulator anywhere. The law assigns applications of AI to three risk categories. First, applications and systems that create an **unacceptable risk**, such as government-run social scoring of the type used in China, are banned. Second, **high-risk applications**, such as a CV-scanning tool that ranks job applicants, are subject to specific legal requirements. Lastly, applications not explicitly banned or listed as high-risk are largely left unregulated.



Automated Vehicles for Safety

The Topic ▾

NHTSA In Action

Resources

NHTSA IN ACTION

NHTSA is dedicated to advancing the lifesaving potential of new vehicle technologies

NHTSA demonstrates its dedication to saving lives on our nation's roads and highways through its approach to the safe development, testing, and deployment of new and advanced vehicle technologies that have enormous potential for improving safety and mobility for all Americans.

NHTSA supports the Safe System Approach, a data-driven, holistic, and equitable method to roadway safety that fully integrates the needs of all users. As part of this approach, vehicle safety technologies offer unique opportunities to reduce traffic deaths, injuries, and harm.

In 2021, NHTSA issued a [Standing General Order](#) that requires manufacturers and operators of automated driving systems and SAE Level 2 advanced driver assistance systems equipped vehicles to report crashes to the agency.

In 2020, NHTSA launched [Automated Vehicle Transparency and Engagement for Safe Testing](#). As part of the AV TEST initiative, states and companies can voluntarily submit information about testing of automated driving systems to NHTSA, and the public can view the information using NHTSA's interactive tool.

In September 2016, NHTSA and the U.S. Department of Transportation issued the Federal Automated Vehicles Policy, which sets forth a proactive approach to providing safety assurance and facilitating innovation. Building on that policy and incorporating feedback received through public comments, stakeholder meetings, and Congressional hearings the agency issued [Automated Driving Systems: A Vision for Safety](#).

Trend #3

Increase in government regulation and certification efforts

Impact on MATLAB and Simulink Users



Increased interest in explainable AI & certification



**XAI &
Certification**



**Scenario-based
Testing**



Significant progress in Robustness: AI Verification & Certification

- Released Support Package in October 2022



Neural
Network



Road 
No road 



Deep Learning Toolbox Verification Library

by MathWorks Deep Learning Toolbox Team **STAFF**

Test robustness properties of deep learning networks

 MathWorks Optional Feature

- Released techniques focusing on fairness: bias detection and mitigation
- Engagement with certification bodies and working groups



Test AI based systems with scenario-based testing

The screenshot displays the MathWorks RoadRunner R2022a simulation environment. The main window shows a 3D perspective view of a street scene with a red car, a white car, a white truck, and a yellow car. The interface includes a menu bar (File, Edit, View, Tools, Assets, Window, Help) and a toolbar with navigation icons. The bottom-left corner shows the '2D Editor | Logic Playback' window, which contains a logic flow diagram with various car and hatchback objects and their associated properties. The bottom-right corner shows the 'Simulation' control panel with buttons for Pause, Step Forward, and Stop, along with a time display (0.140 s) and a speed control slider (0.05x to 20x). A 'Variables' table is also visible, listing simulation parameters.

SpeedBump Actions.rsscenario | 22a Project | MathWorks RoadRunner R2022a

File Edit View Tools Assets Window Help

Scenario Editing

Simulation

Simulation Controls

Pause Step Forward Stop

Time: 0.140 s

Enable Pacing to Slow Down Simulation

Slower Faster

0.05x 1x 20x

Simulation Properties

Step Size: 0.02000 s Max Time: 1000.000

Camera

Camera View Default editor camera

2D Editor | Logic Playback

Variables

	Name	
1	Hatchback_InitialSpeed	14
2	Car_NumLanesToChange	2
3	Car_LaneChangeDirection	LeftOf
4	Car_DistanceBehindSpeedBump	-18

Simulation Tool

Attributes Metadata Simulation

MathWorks

Simulate Complex Logic In-Editor

Test AI based systems with scenario-based testing

The screenshot displays the MathWorks RoadRunner R2022a interface, which is used for scenario-based testing of autonomous systems. The interface is divided into several key sections:

- Simulation View (Top):** A 3D rendering of a road intersection with a white car (the ego vehicle) on the left side of the road. The interface includes a menu bar (File, Edit, View, Tools, Assets, Window, Help) and a 'Scenario Editing' dropdown.
- Simulation Controls (Right Panel):** A panel for managing the simulation. It includes:
 - Simulation Controls:** Buttons for Pause, Step Forward, and Stop.
 - Time:** Current simulation time is 1.160 s.
 - Enable Pacing to Slow Down Simulation:** A checkbox to control simulation speed.
 - Speed Control:** A slider ranging from 0.05x (Slower) to 20x (Faster), currently set at 1x.
 - Simulation Properties:** Fields for Step Size (0.02000 s) and Max Time (1000.000).
 - Camera:** A dropdown menu for Camera View, currently set to 'Default editor camera'.
- 2D Editor | Logic Playback (Bottom Left):** A logic editor showing two 'Ego' blocks connected in a sequence. The first block is green and labeled 'Ego' with a speed of 5.0 m/s. The second block is orange and labeled 'Ego' with a speed of 15.0 m/s and a duration of 'Over 10 s'. A clock icon is positioned to the right of the second block.
- Variables (Bottom Center):** A table showing the current state of variables in the simulation.

Name	Value
1 egoBehavior	
- Simulation Tool (Bottom):** The MATLAB R2022a environment. The Command Window shows the following text:


```

% |rrSim| is the |Simulink.ScenarioSimulation| object. Use this object to
% set variables and to read scenario-related information.
%% Simulate RoadRunner Scenario
% When |egoBehavior| is unspecified, the ego vehicle uses the built-in
% behavior of the RoadRunner scenario. Clear the |egoBehavior| variable
% use the built-in behavior.

rrApp.setScenarioVariable("egoBehavior", " ");
Connection status: 1
Connected to RoadRunner Scenario server on localhost:49327, with client
fx >>

```

 The Editor window shows the MATLAB script for the scenario:


```

TrajectoryFollowerWithRRScenarioExample.m
146 rrSim.set("SimulationCommand","Start");
147 while strcmp(rrSim.get("SimulationStatus"),"Running")
148     pause(1);
149 end
150 %%
151 % Use the |helperVisualizeVelocityProfile| function to visualize the
152 % velocity profile using the SDI. The |helperVisualizeVelocityProfile|
153 % function also plots lane centers and the ego vehicle trajectory. The
154 % |helperVisualizeVelocityProfile| function takes |rrSim|, the ego actor
155 % ID, and the signal name for SDI as inputs.
156
157 helperVisualizeVelocityProfile(rrSim,1,"Built-in")
158 hFigSDI = Simulink.sdi.snapshot;
159 %%

```

Market trends driving AI in Automotive Development

1. AI improves existing systems and processes

2. Integration of AI with automotive software development process

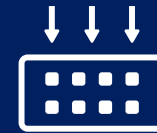
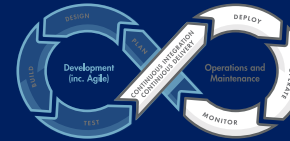
3. Government regulation and certification efforts

4. Shift from general-purpose AI to solving domain-specific problems using AI

MathWorks Response



AI in Simulink



Interoperability & DevOps Code generation



XAI & Certification



Scenario-based Testing

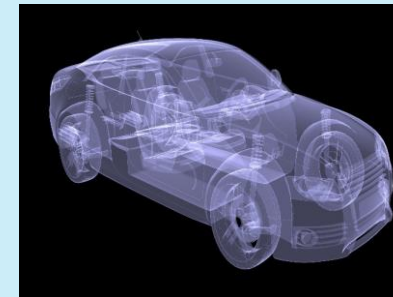
Trend #4

Industry shift from investing in general-purpose AI to solving domain-specific problems using AI

General Purpose



Domain Specific



Automotive controls



Predictive maintenance



NVH



Road Condition Estimation with AI at Mahindra Truck and Bus



- Built model that estimates road condition from existing vehicle sensors
- Integrated with other control algorithms to improve fuel economy

mahindra

Trend #4

Industry shift from investing in general-purpose AI to solving domain-specific problems using AI

Impact on MATLAB and Simulink users

- Reduced interest in *learning AI*
- Increase in interest to *apply AI* for specific applications
- Focus shift from model-centric to data-centric AI



Verticals & Data-centric AI

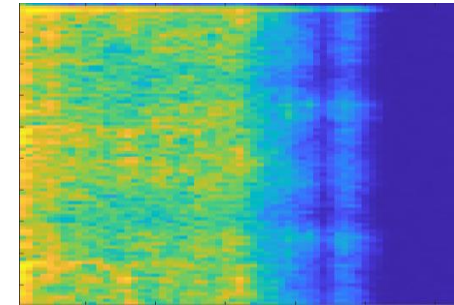
Data-centric AI investments span many teams, data-types and domains



Data Synthesis

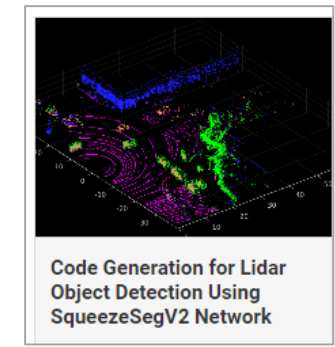
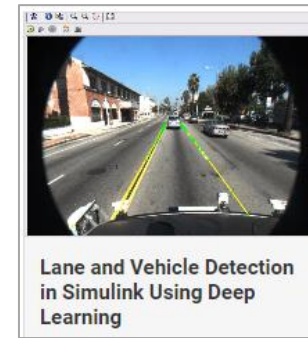
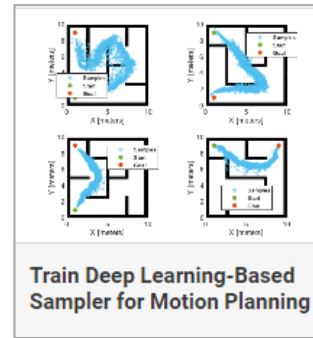


Labeling



Feature Engineering

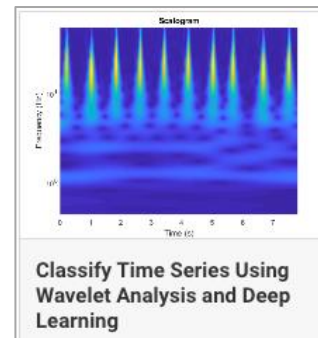
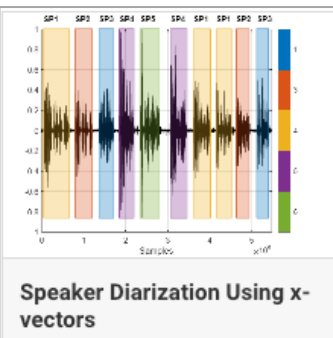
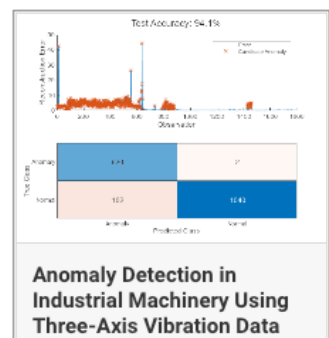
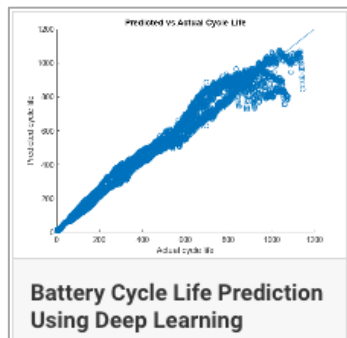
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Market trends driving AI in Automotive Development

1. AI improves existing systems and processes

2. Integration of AI with automotive software development process

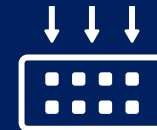
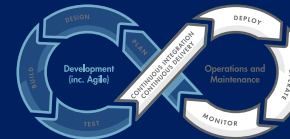
3. Government regulation and certification efforts

4. Shift from general-purpose AI to solving domain-specific problems using AI

MathWorks Response



AI in Simulink



Interoperability & DevOps Code generation



XAI & Certification

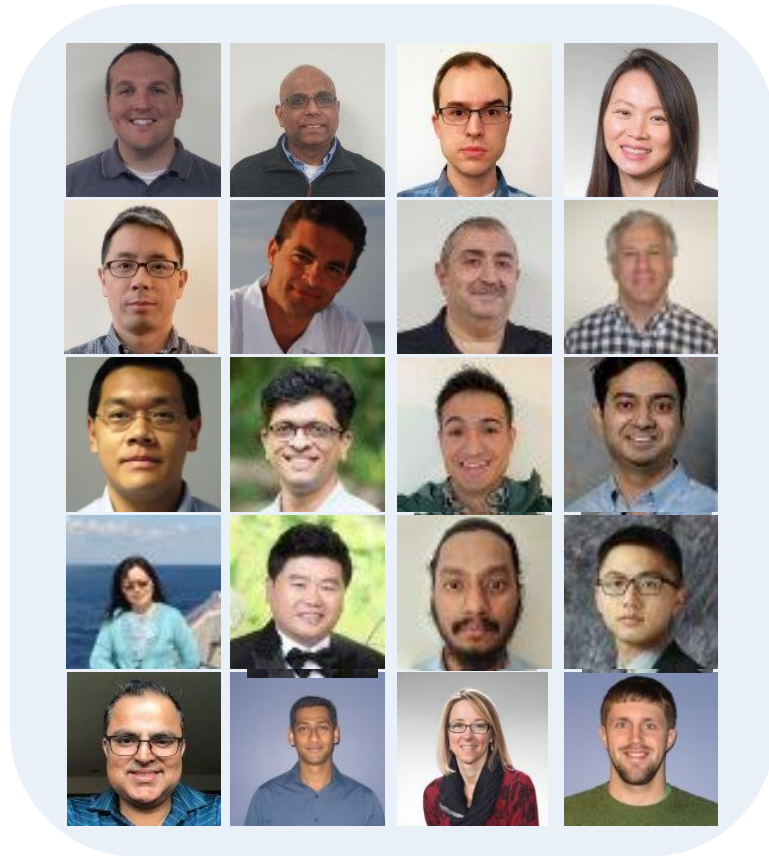


Scenario-based Testing



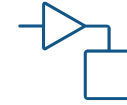
Verticals & Data-centric

MATLAB and Simulink for AI in Automotive Development

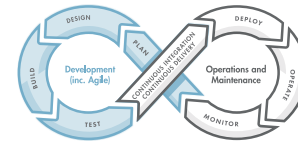


People

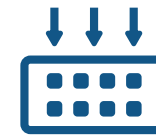
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AI in Simulink



Interoperability & DevOps



Code generation



XAI & Certification



Scenario-based Testing



Verticals & Data-centric AI

Upskill in AI

Onramp Tutorials

- Machine Learning Onramp
- Deep Learning Onramp
- Reinforcement Learning Onramp
- Computer Vision Onramp

Training Courses

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- Machine Learning with MATLAB
- Signal Preprocessing and Feature Extraction with MATLAB
- Deep Learning with MATLAB
- Optimization Techniques in MATLAB
- Reinforcement Learning in MATLAB and Simulink
- Automated Driving with MATLAB
- Designing 3D Scenes with RoadRunner

coursera

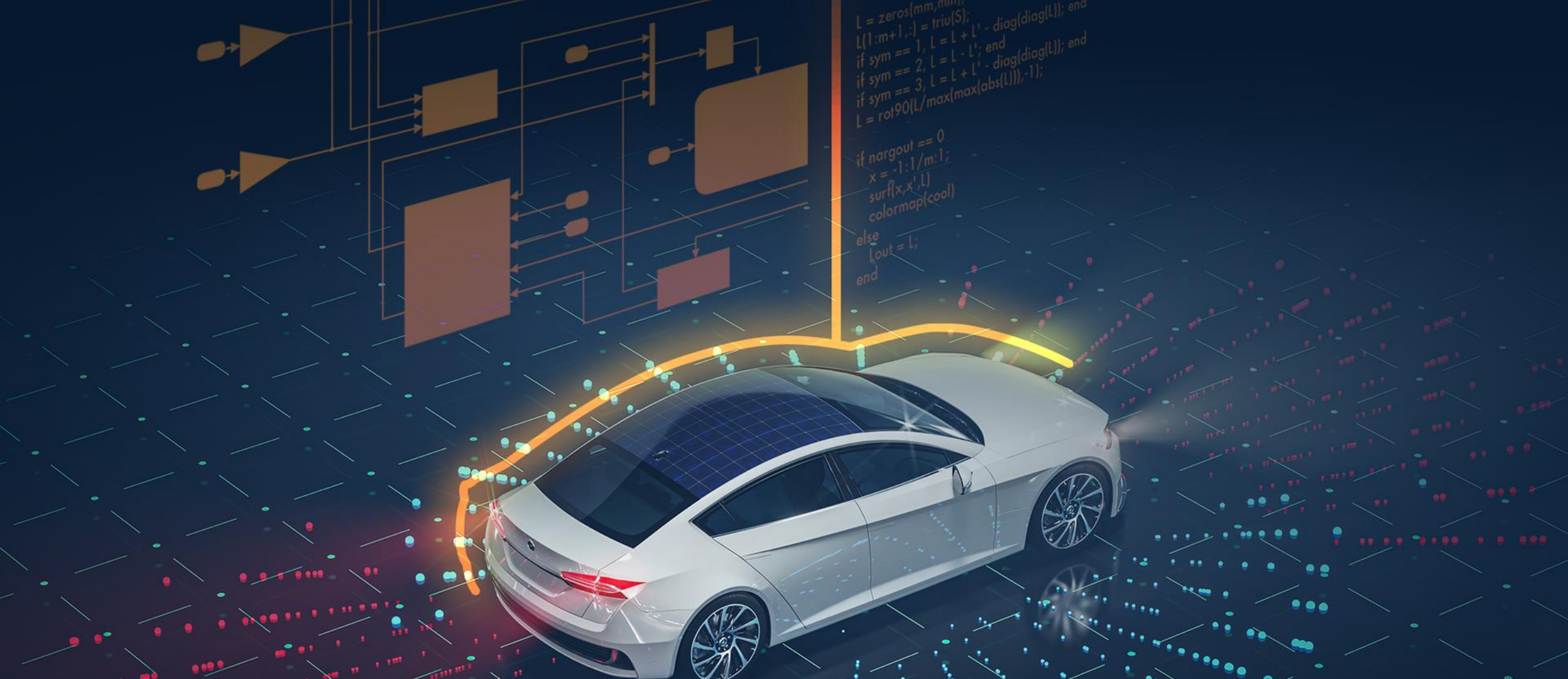
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```
L = zeros(m, m);  
L(1:m+1, :) = triu(S);  
if sym == 1, L = L + L' - diag(diag(L)); end  
if sym == 2, L = L - L'; end  
if sym == 3, L = L + L' - diag(diag(L)); end  
L = rot90(L / max(max(abs(L))), -1);  
  
if nargin == 0  
x = -1:1/m:1;  
surf(x, x', L)  
colormap(cool)  
else  
Lout = L;  
end
```

Enjoy the Conference!