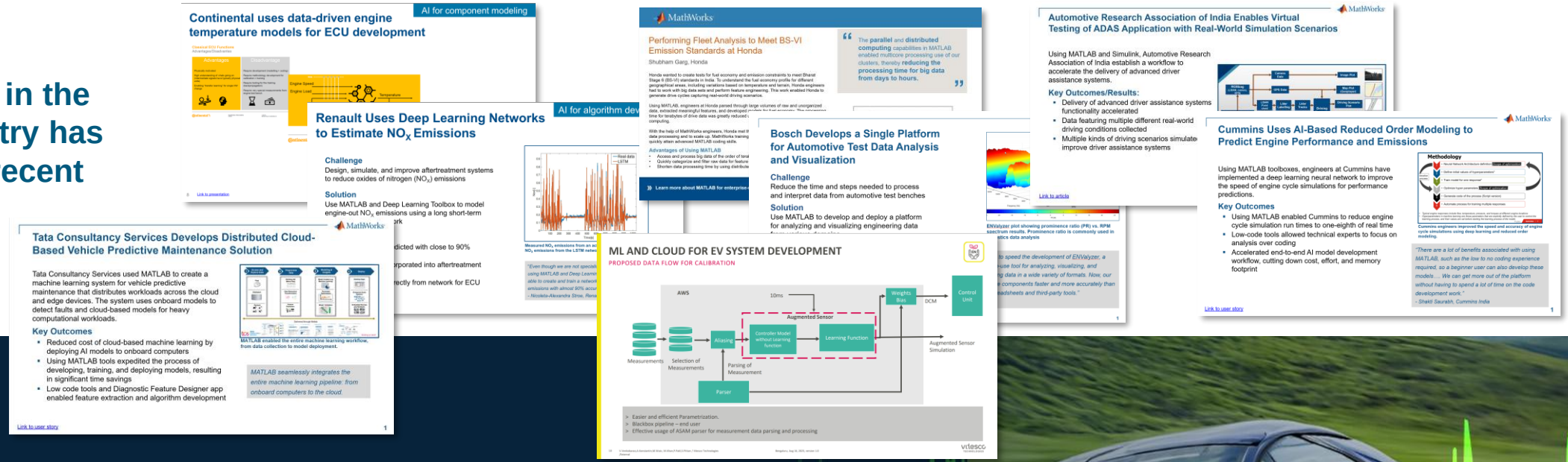
MathWorks
AUTOMOTIVE CONFERENCE 2024
India

19 November | Pune

Accelerating AI Adoption: From Design to Deployment in Mobility

MathWorks®

The traction of AI in the automotive industry has been growing in recent years.



AI in Mobility

These emerging trends also has development possibilities for developers and engineers.

- Core Technology Foundation
- Integration with Legacy Systems
- Deployment Challenges & Strategies
- Specialized Talents

Jayanth Balaji Avanashilingam

Senior Application Engineer, MathWorks

Koustubh Shirke

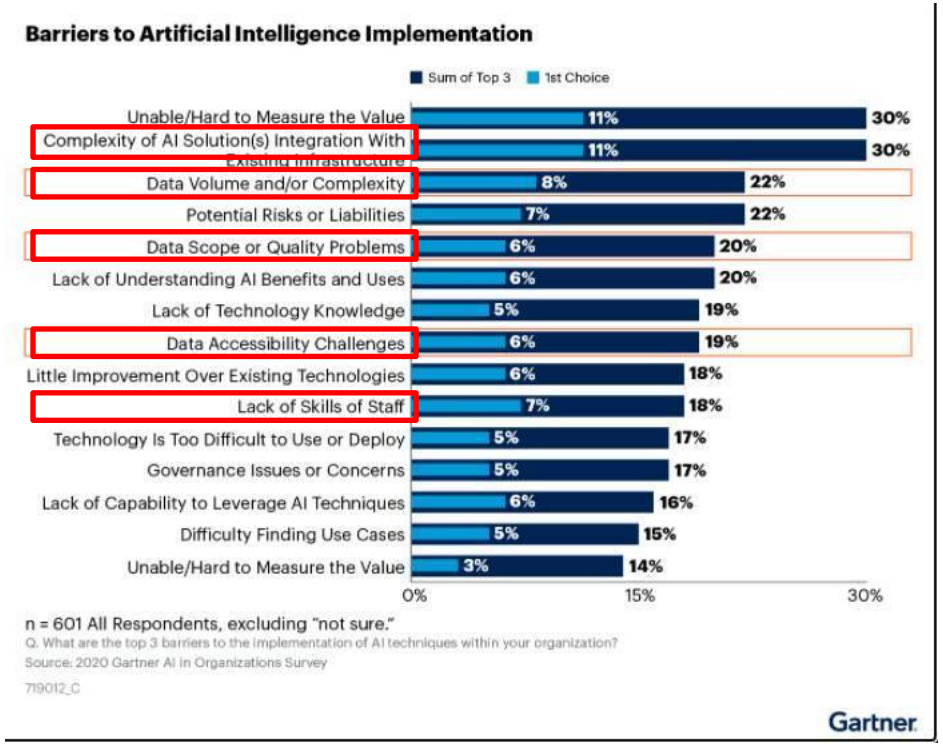
Senior Application Engineer, MathWorks

Nikita Pinto

Senior AI Academic Liaison, MathWorks

Integrating AI is a priority for companies today but…

Top Barriers to AI Implementation



Top barriers to successful adoption of AI

1. Integration with existing technology
2. Data Complexity/Quality
3. Lack of Skills

n = 601
Gartner Research Circle members, excluding "unsure"
Source: 2020 Gartner AI in Organizations Survey
Q: What are the top three barrier to the implementation of AI techniques within your organization? *Rank up to three.*
ID: 719012_C

- *Source: "" How to Build Knowledge Graphs That Enable AI-Driven*
- *Enterprise Applications" Gartner Research Note, <D#>, published 27 May 2020*

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These emerging trends also has development possibilities for developers and engineers.

Core Technology Foundation

Integration with Legacy Systems

Deployment Challenges & Strategies

Industry & Academia Collaboration

Data Preparation

- Data cleansing and preparation
- Human insight
- Simulation-generated data

AI Modeling

- Model design and tuning
- Hardware accelerated training
- Interoperability

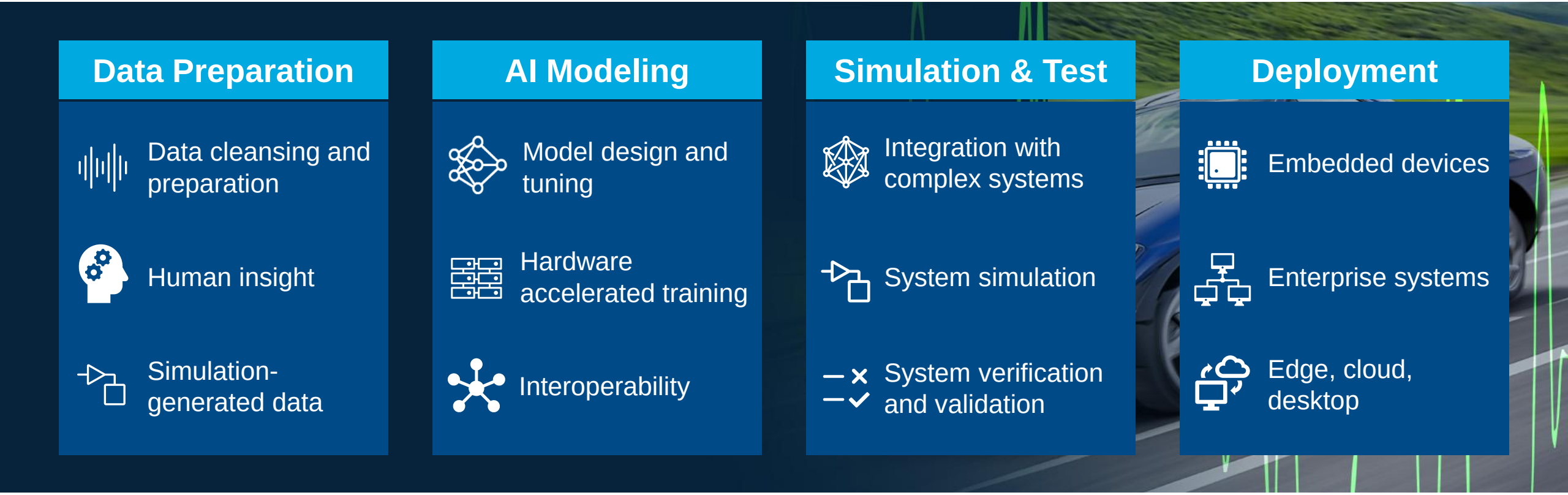
These emerging trends also has development possibilities for developers and engineers.

Core Technology Foundation

Integration with Legacy Systems

Deployment Challenges & Strategies

Industry & Academia Collaboration



Data Preparation

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AI Modeling

- Model design and tuning
- Hardware accelerated training
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Simulation & Test

- Integration with complex systems
- System simulation
- System verification and validation

Deployment

- Embedded devices
- Enterprise systems
- Edge, cloud, desktop

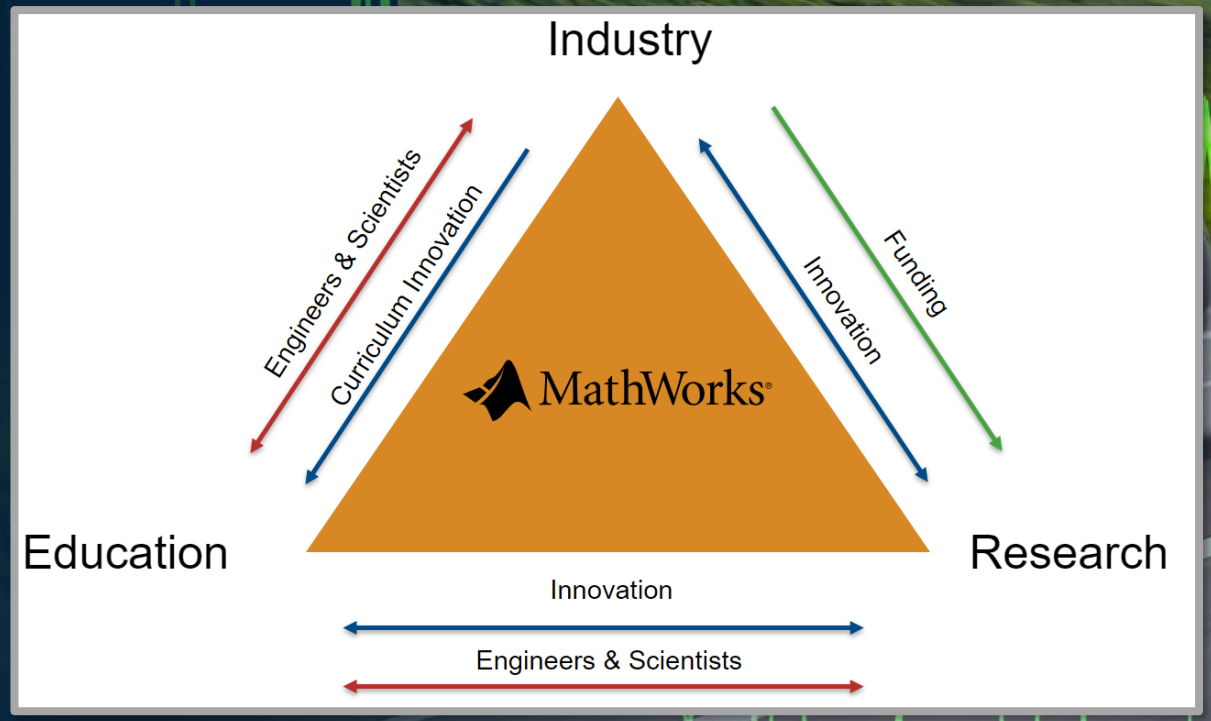
These emerging trends also has development possibilities for developers and engineers.

Core Technology Foundation

Integration with Legacy Systems

Deployment Challenges & Strategies

Specialized Talents- *Industry & Academia Collaboration*



Typical Data Driven Workflow

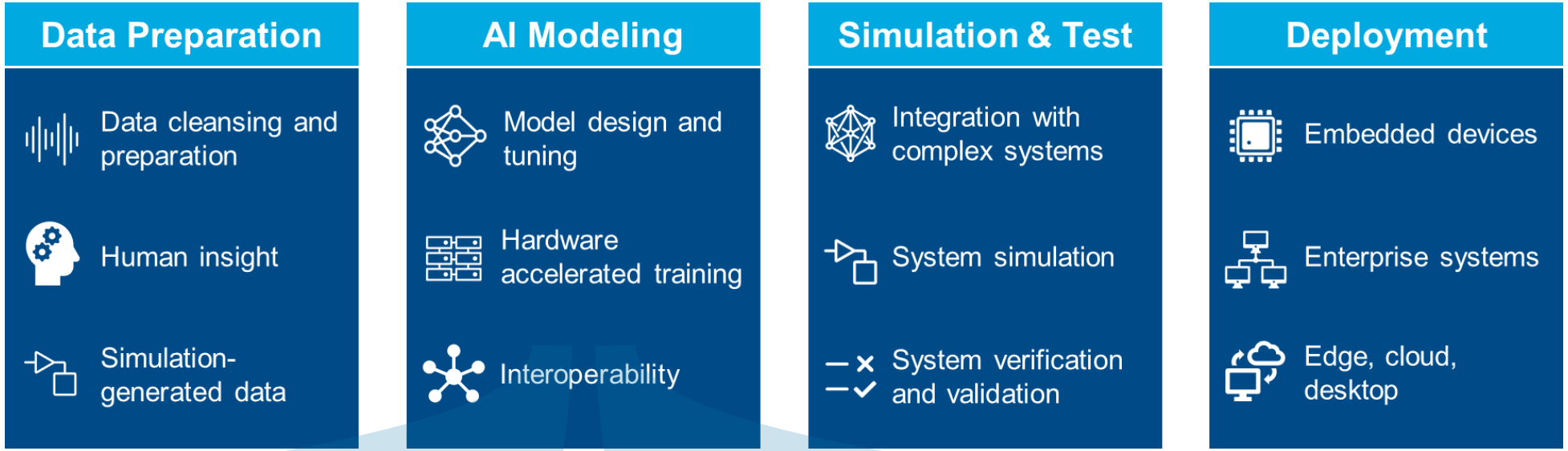
From data preparation to deployment

Domain Experts
From data to deployment, overseeing the entire AI workflow in MATLAB

Embedded Software Engineers
Implementing and optimizing AI models on edge hardware, collaborating seamlessly with data science teams

Data Preparation | **AI Modeling** | **Simulation & Test** | **Deployment**

Leveraging AI-driven Automotive Application design



AI for component modeling

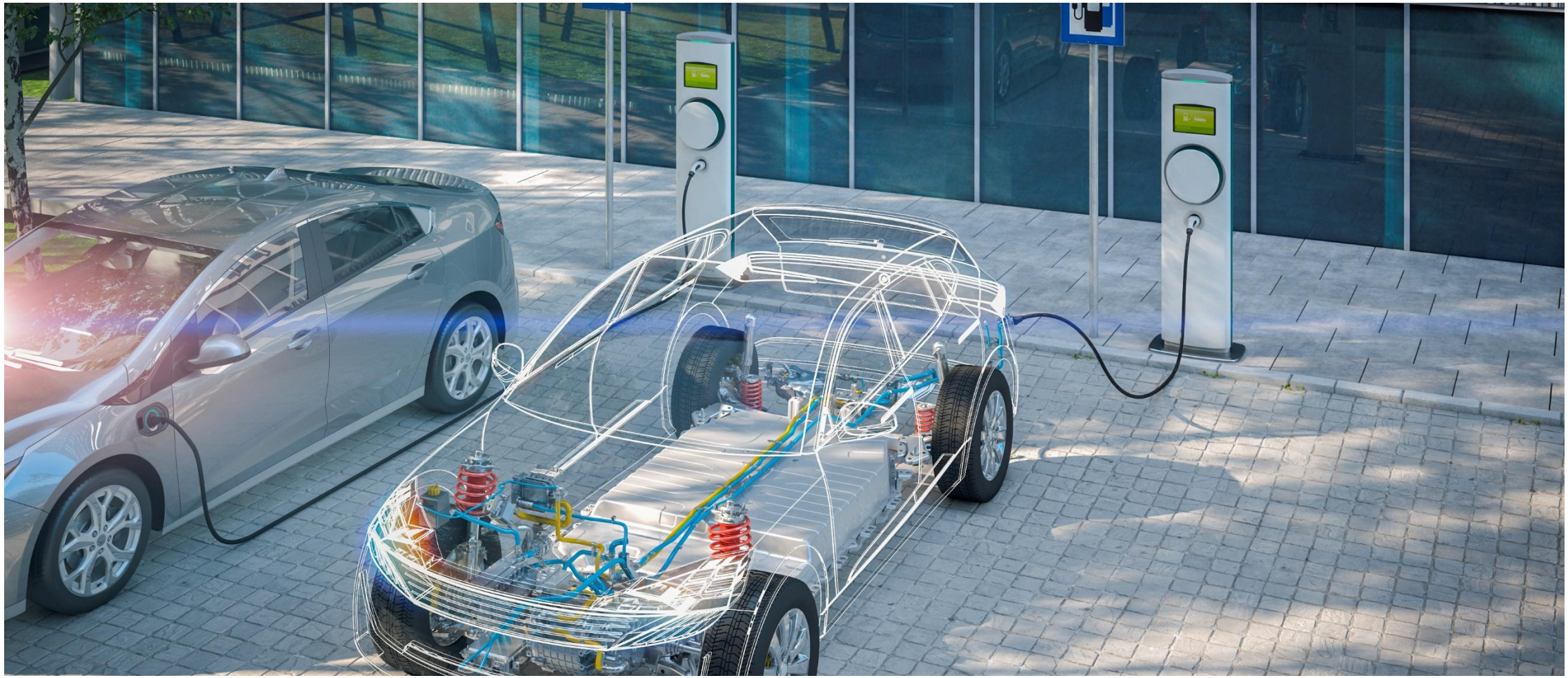
- Speeding up desktop and HIL simulations
- Modeling component dynamics from data when first-principles models cannot be obtained

AI for Algorithm development

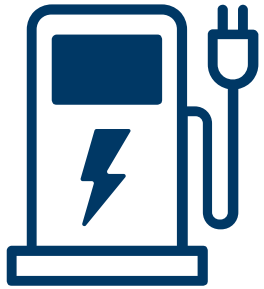
- Virtual sensor modeling
- Sensor fusion
- Object detection
- Remaining Useful Life Estimation/Predictive Maintenance

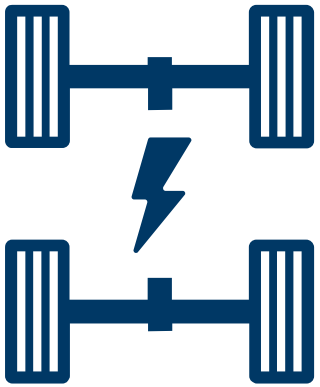
Leveraging Data Driven Application Software Development

Power Converters: Driving the Future of Electrification



Predictive Maintenance of Power Converters





Is my machine operating normally?	Anomaly Detection
Why is my machine behaving abnormally?	Fault Detection (Diagnostics)
How much longer can I operate my machine?	Remaining Useful Life Estimation (Prognostics)

I need help.

Phase Fault? Or Leg Fault?

I will shut down your line in 15 hours.

Test_3Ph_Inverter_Predictions * - Simulink

SIMULATION DEBUG MODELING FORMAT APPS

New Open Save Print — FILE
Library Browser — LIBRARY
Log Signals Add Viewer Signal Table — PREPARE
Stop Time 0.095 Normal Fast Restart
Step Back Run Step Forward Stop — SIMULATE
Data Inspector Logic Analyzer Bird's-Eye Scope Simulation Manager — REVIEW RESULTS

Test_3Ph_Inverter_Predictions

Test_3Ph_Inverter_Predictions

Dashboard

AH BH CH AL BL CL

Mild Moderate Healthy Extreme

Sign of Aging

Asset

Vd_ref (pu) Vabc_inv Vabc (pu) Voltage regulator
1 Vref (pu)
1/380
500VDC 500VDC1 f(x) = 0
G + - a b c Inverter
A B C a b c LC Filter
a1 b1 c1 a2 b2 c2 V I A V Measure
a b c n 50 kW 380 Vrms 60 Hz
[Vabc] [Iabc]

Three-Phase Inverter Voltage Control

Predictive Maintenance using Machine Learning

[Vabc] [Iabc] From1
Vabc labc output Subsystem
1

Daihatsu Uses AI to Classify Engine Sounds

Challenge

Develop an AI solution that can judge the level of engine knocking sound, which only skilled workers could judge

Solution

Create classification models and easy-to-use interface with MATLAB, making it possible to examine features multiple times

Key Outcomes

- Performed knocking sound analysis with the same accuracy as skilled workers
- Increased AI expertise through MATLAB training
- Promoted visualization of AI and increased awareness of AI

Daihatsu used AI to identify knocking sounds from its engines.

"Although we tried other programming languages, it was hard to implement. We decided to use MATLAB, which allows us to easily import the necessary data by dragging and dropping, and we could easily see the result by ourselves."

- Takuya Kumagae, Daihatsu Motor Co., Ltd.

Link to case study

Challenges in AI Model Development

Accuracy	• Balancing precision with real-world applicability
Development Time	• Time to market
Effective Testing	• Ensuring reliable model behavior
Compatibility	• Integration with the production systems
Maintainability	• Efficient model updating
Robustness	• Maintaining consistent performance in diverse situation
Latency	• Meeting real-time processing

Hands-on learning: IIT Madras and HAW Hamburg

[MATLAB and Simulink Challenge Projects]

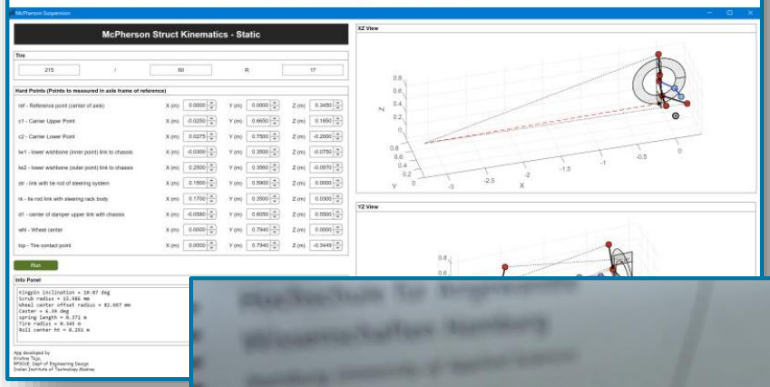
Dr. V Krishna Teja Mantripragada (He/Him) • 1st
Tyre & Vehicle dynamics, JK Tyres | Adjunct Faculty, IIT Madras
2w • Edited •

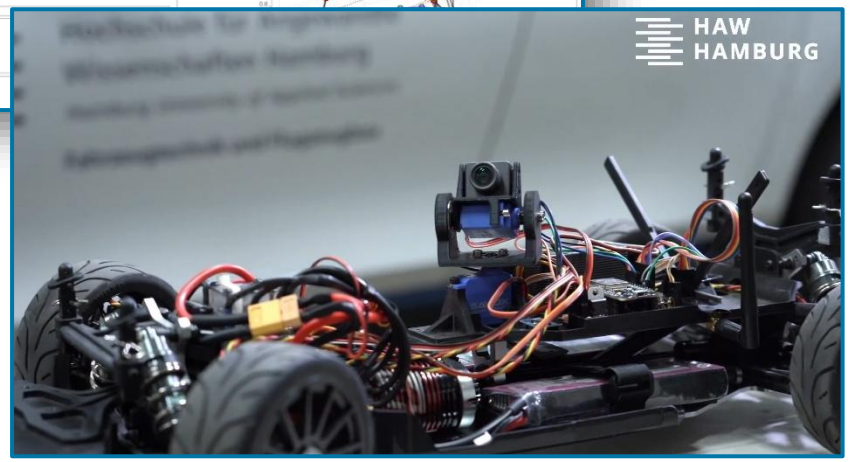
Hey Automotive Enthusiasts!

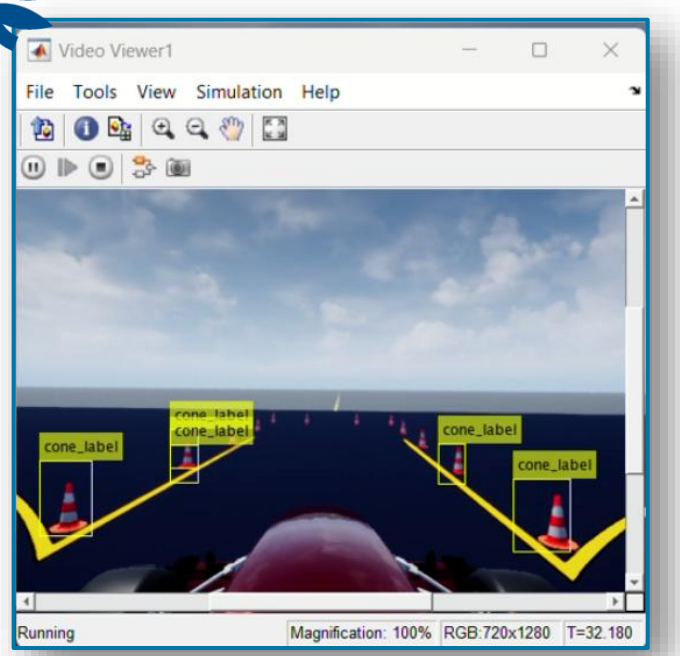
Ever wondered about so many buzz words in suspension tuning that makes your vehicle ride and handling smooth...
Here is a simple #MATLAB app that I created during my university days for quickly visualising McPherson suspension and calculating some important metrics. The app can be downloaded from Mathworks FileExchange
https://lnkd.in/gNfudcN6

Feel free to customise as needed!
Share your insights on suspension optimization and tuning experiences...

#AutomotiveEngineering #vehicledynamics #engineering #design #vehicledesign #students #formulastudent #modelling #simulation



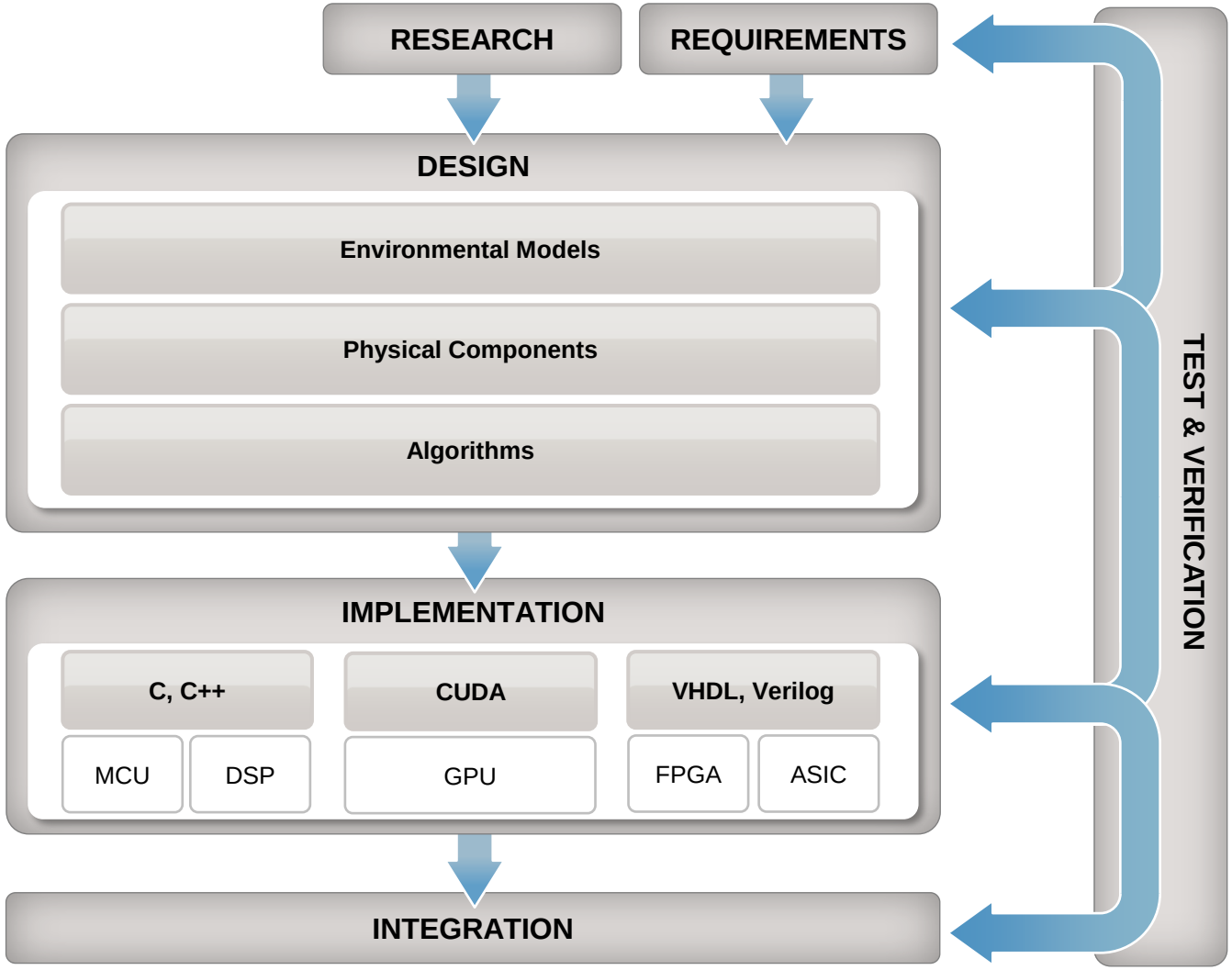


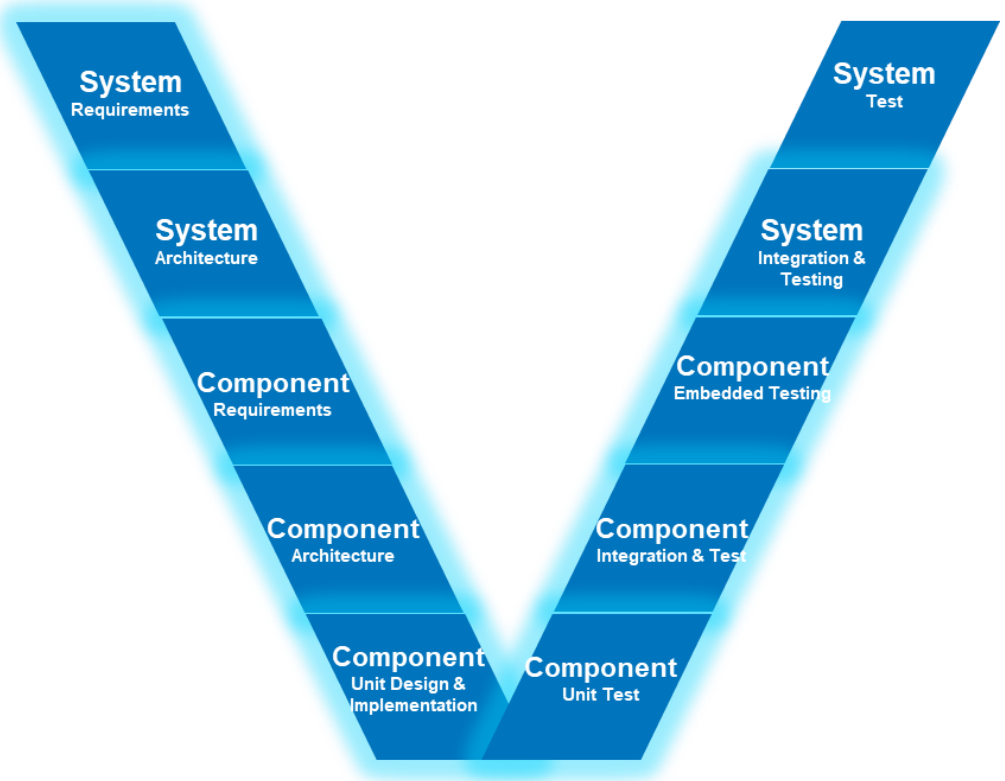


Student competitions – TUM at the Indy Autonomous Challenge

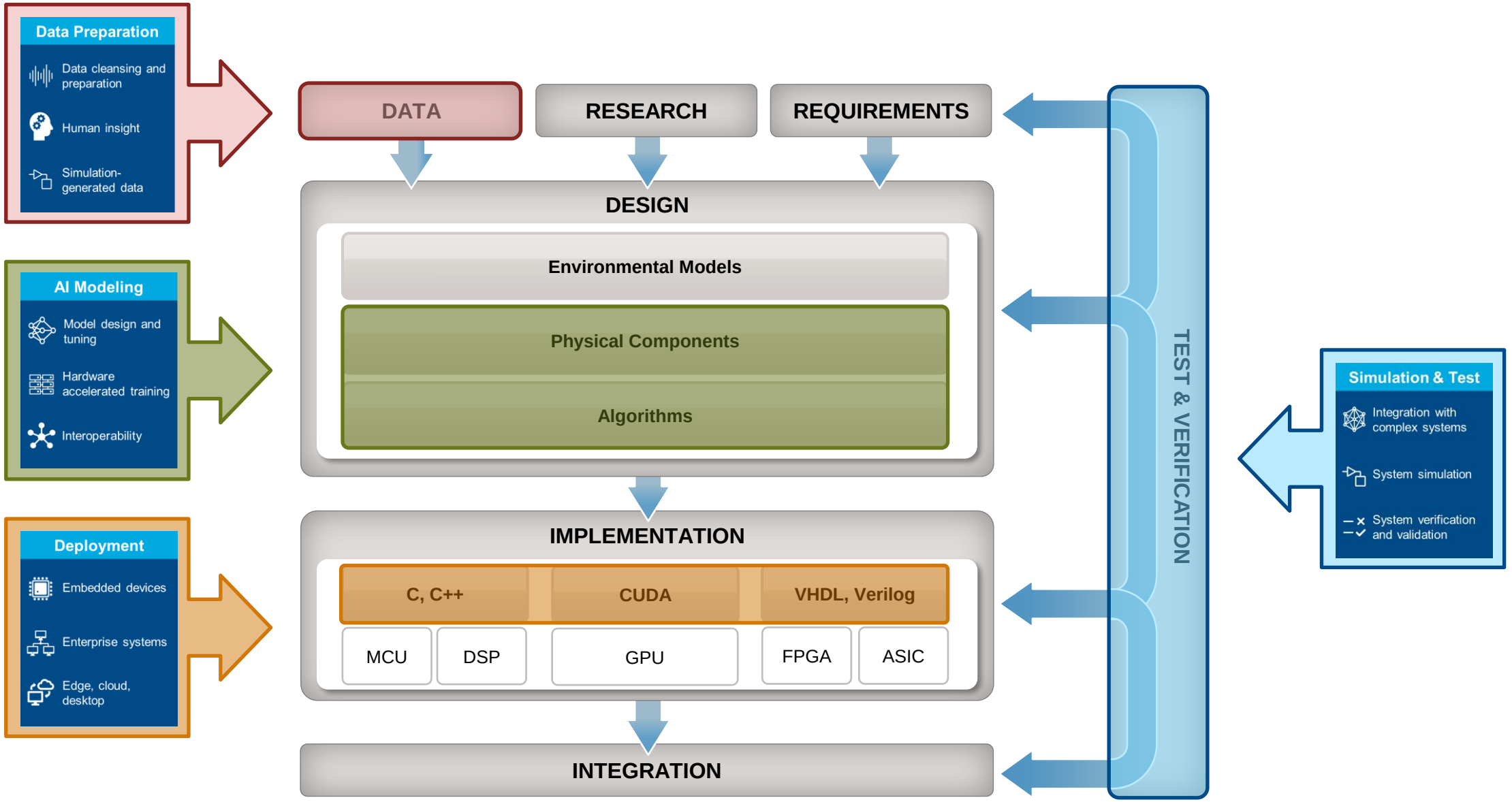
Audience Question

Application Development workflow with Model-Based Design





Integrating AI in Model-Based Design



Use AI to improve engine control unit development efficiency

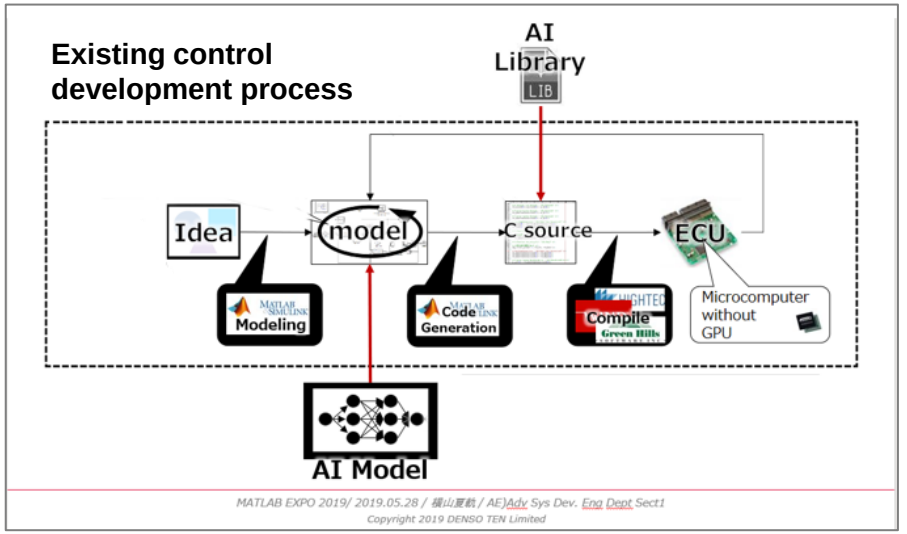
DENSO TEN

- Used Deep Learning to formulate a model for complex vehicle control issues
- Applied model-based development to integrate AI model into existing control model
- Developed a pathway to c-code generation for ECU implementation

"A model-based development workflow is essential in order to use AI for control ECUs. Combining the existing control model and the AI model enables us to establish a simulation environment and accelerate product development."

- Natsuki Yokoyama, Denso Ten

Model-Based Development Workflow



Verification and Validation of AI Model

		Model-Based Design	AI Models
Verification	**Correctness of Algorithm**	Ensuring algorithms represent the intended physical or logical system accurately	Verifying model training aligns with intended objectives.
	Chances of Error	Errors stem from incorrect logic, parameter values, or design mistake.	Errors may arise from data quality, hyperparameters, or learning process
Validation	**Purpose**	Ensure the system performs as intended under real-world scenarios	Ensure the AI model generalizes well to unseen data and meets real-world requirements
	Testing Scenarios	Relies on diverse and representative datasets for validation	Uses predefined scenarios based on design requirements and physical constraints

Explainability

Rigor & Trust

Robustness

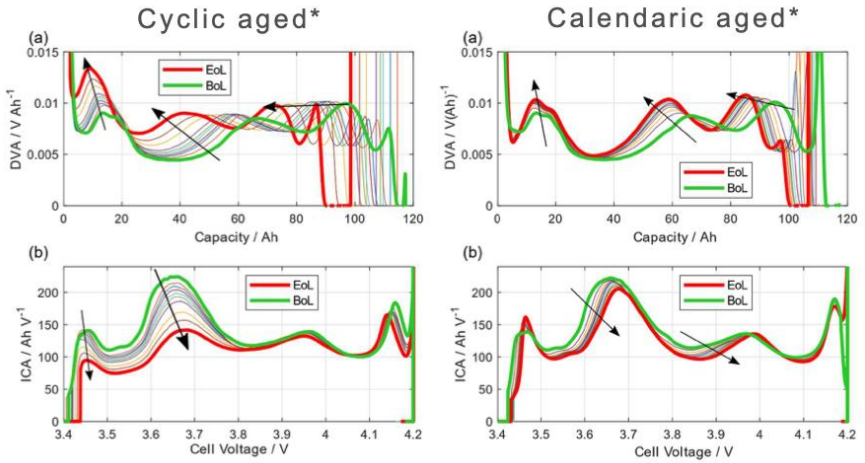
Real – World scenarios

Developing Onboard SOH Estimation Using DVA and ICA for LFP Batteries

Gotion

Challenge

Li-on Batteries suffer from a variety of degradation mechanisms that lead to either capacity fade or power fade. Techniques like Incremental Capacity Analysis and Differential Voltage Analysis can be used to estimate DQ and DV curves but inferring battery State of Health (SOH) from these curves still requires domain expertise.



Solution

Gotion used MATLAB to develop feature extraction methods that detect the most important features in DQ and DV curves, then trained a linear regression model that correlates these features with capacity fade. This regression model was then used alongside temperature data in a 2-D look-up table that estimates SOH. The solution was implemented in Simulink for testing, requirements validation, and certification.

Benefits of using MATLAB and Simulink

- Easy data analysis for visualization and identification of key trends in battery aging
- Built-in tools to extract meaningful features from differential voltage curves (peak detection)
- V-diagram workflow support including requirements management, automatic code generation, and ISO 26262/IEC 61508 certification

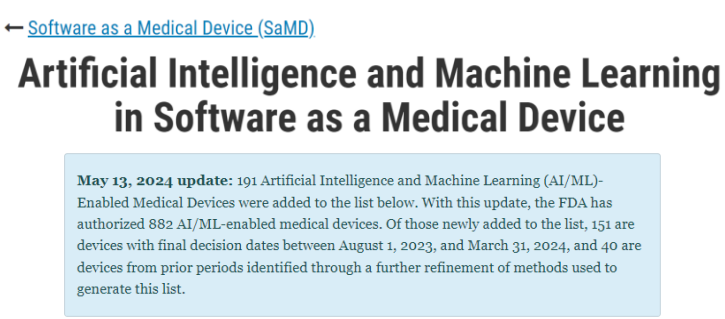
Link to MathWorks Automotive Conference slides
Link to MathWorks Automotive Conference recording

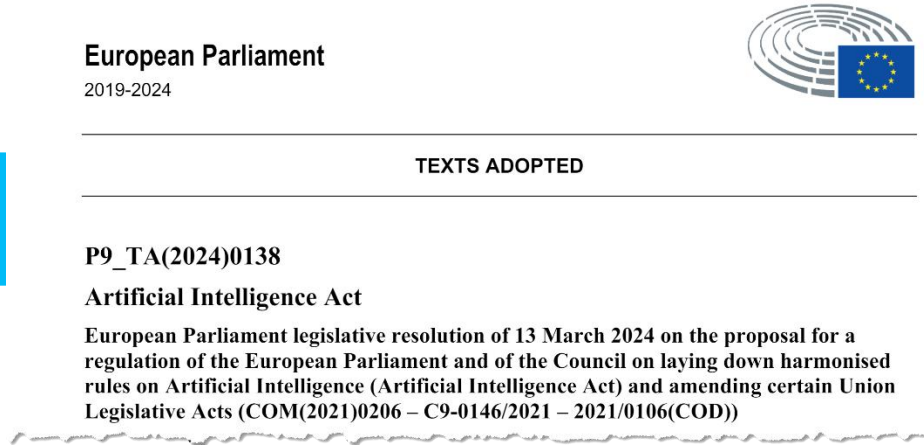
There is an increased focus in government **regulation and certification** efforts

Automotive

Aerospace

Medical Devices



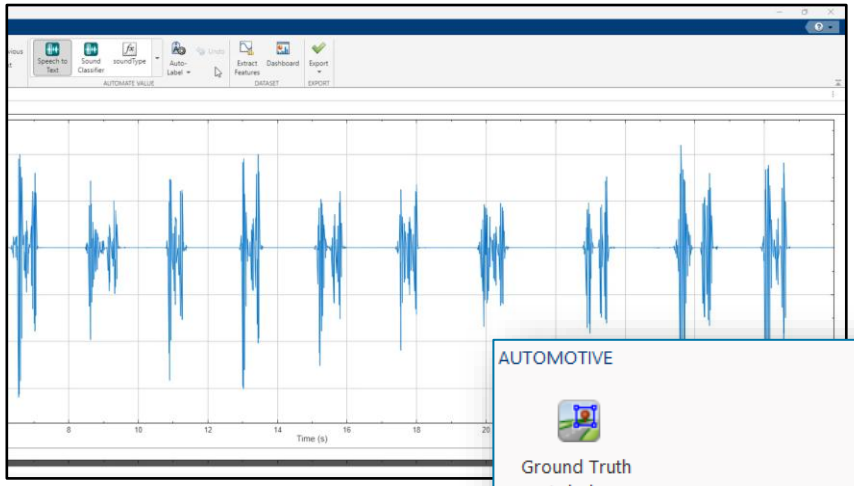


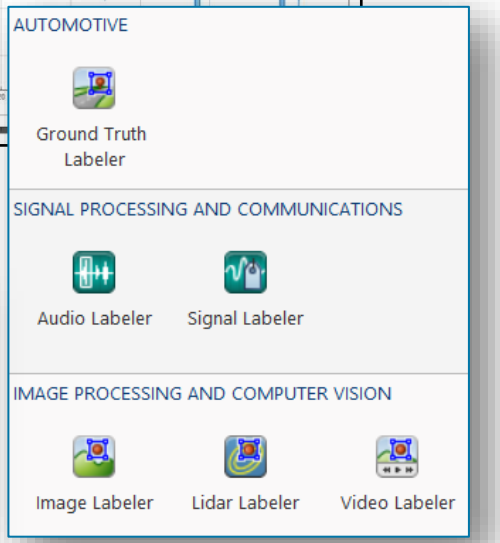
Requirements and Data Management

Define Requirements for end-to-end AI workflows

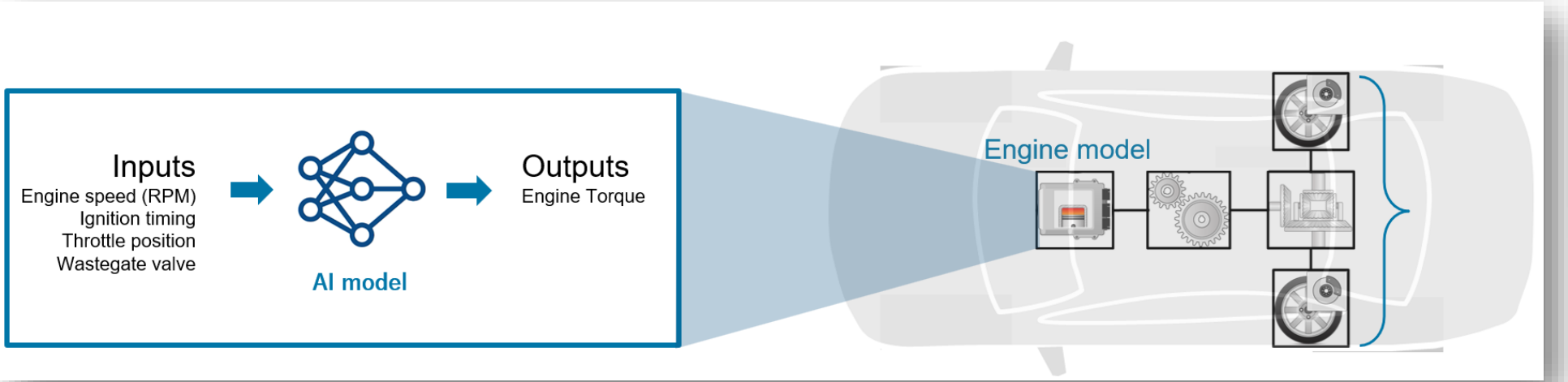
Summary	Implemented	Verified
Battery SOC data temperature: -10 degrees C		
Battery SOC data temperature: 0 degrees C		
Battery SOC data temperature: 10 degrees C		
Battery SOC data temperature: 25 degrees C		
Data Justifications		

Automate Data Labeling



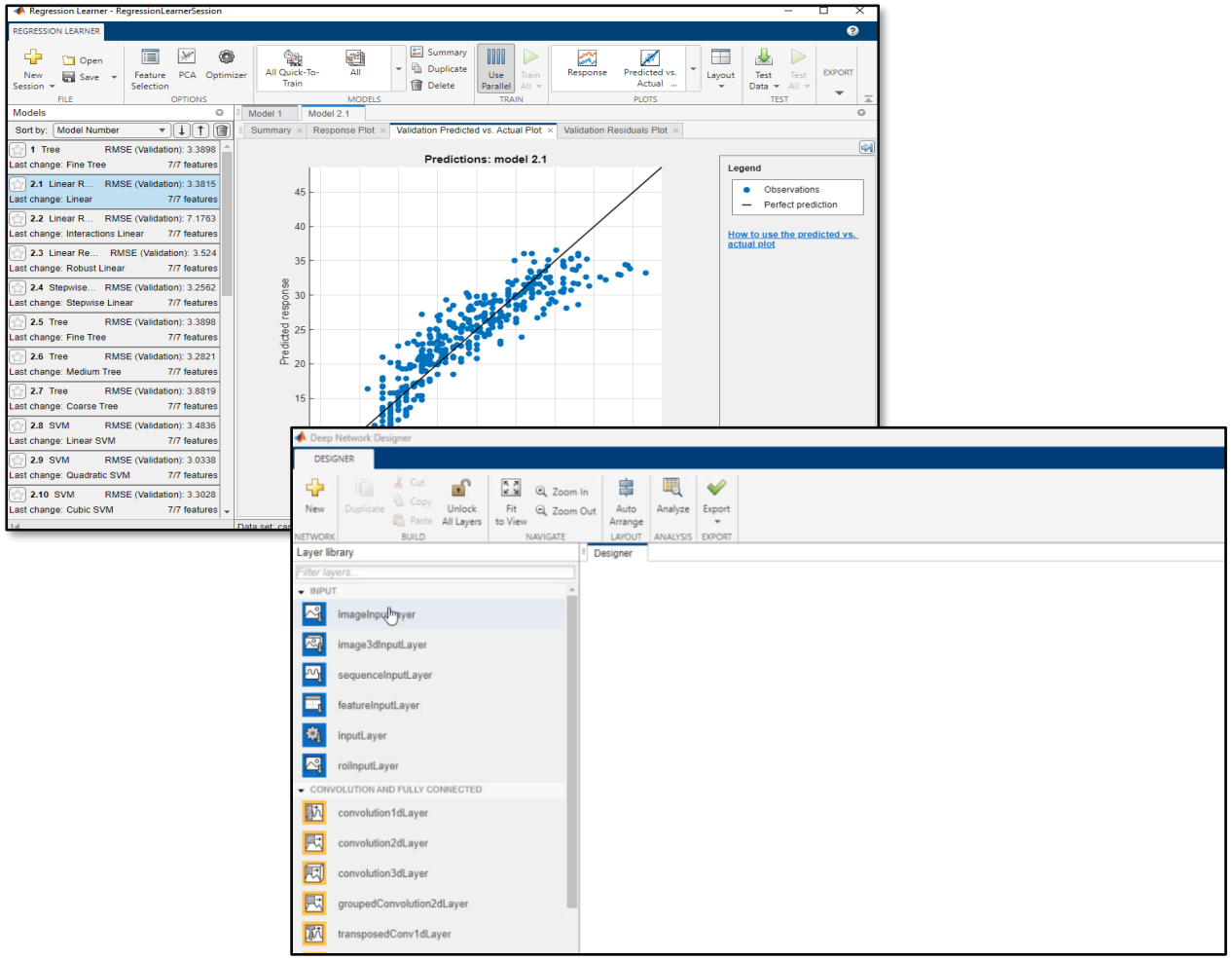


Generate data for AI models (e.g. using ROM)

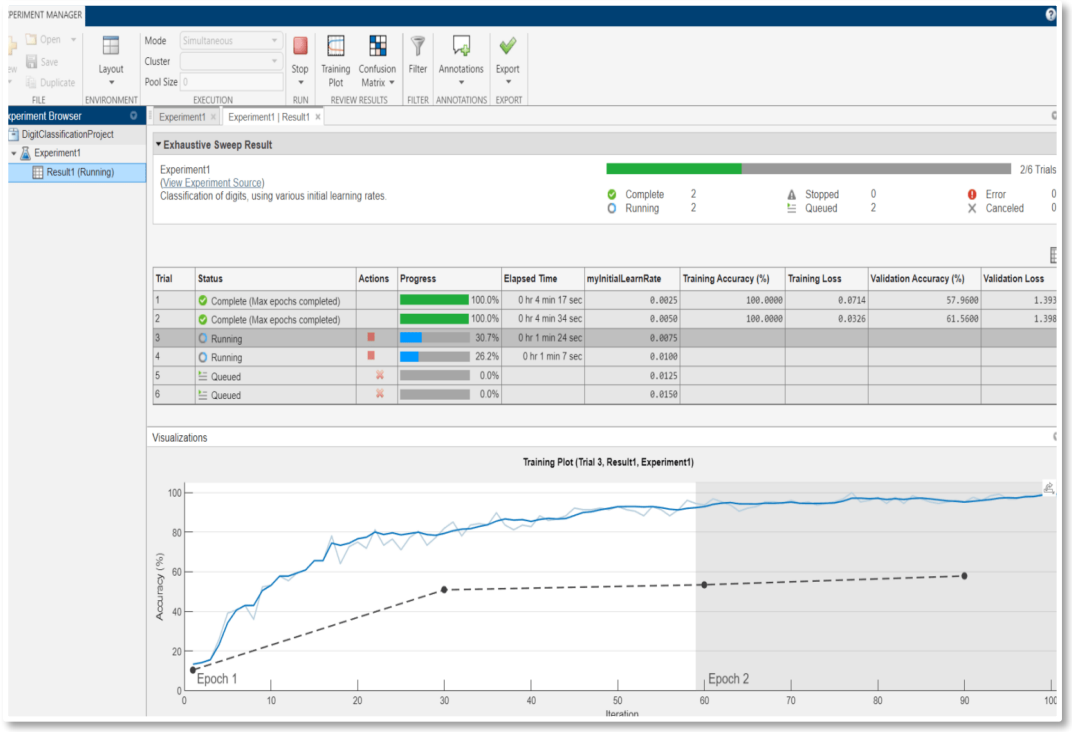


Learning Process - AI Modeling, Hyperparameters & Experimentation

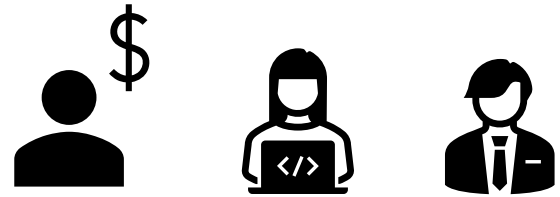
Design & Train Deep Learning, Machine Learning models



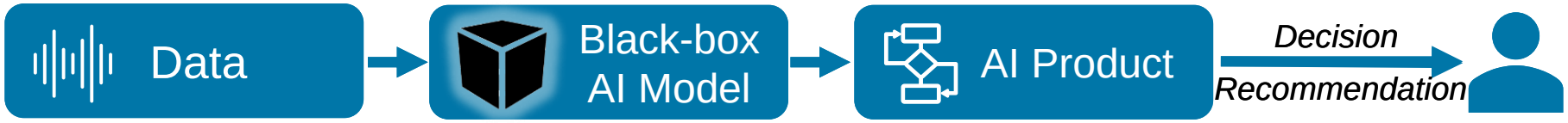
Experiment over models, hyperparameters



Explainability of AI components

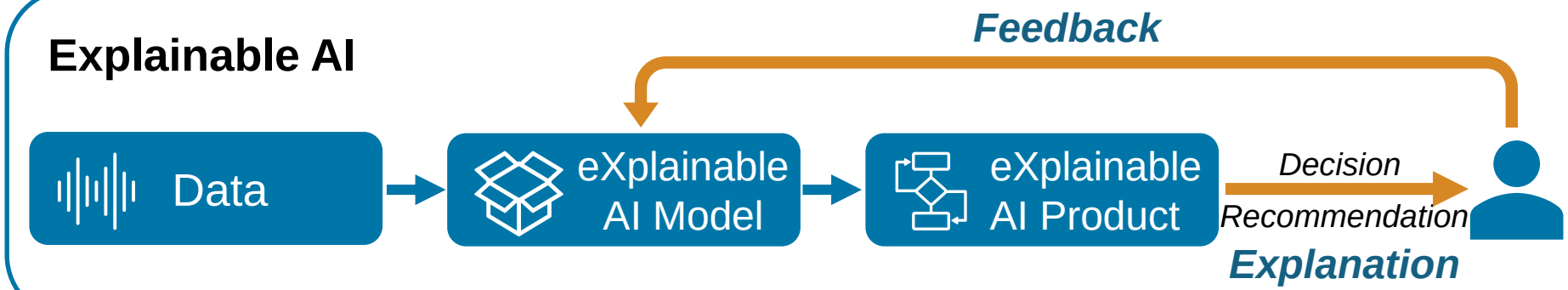


Unexplainable AI



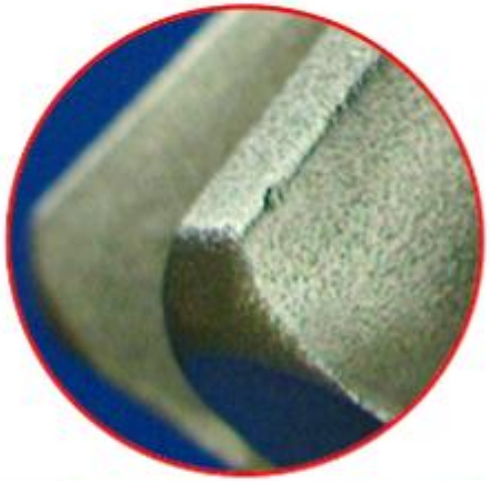
- Why did you do that?
- Why did you not do that?
- When do you succeed or fail?
- When can I trust you?
- How do I correct an error?

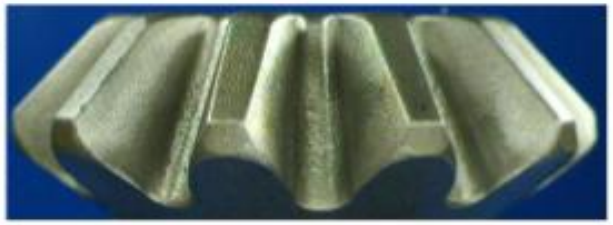
Explainable AI



- I understand why
- I understand why not
- I know why you succeed or fail
- I know when to trust you
- I know why you erred

Musashi Seimitsu Industry Uses Deep Learning for Visual Inspection of Automotive Parts



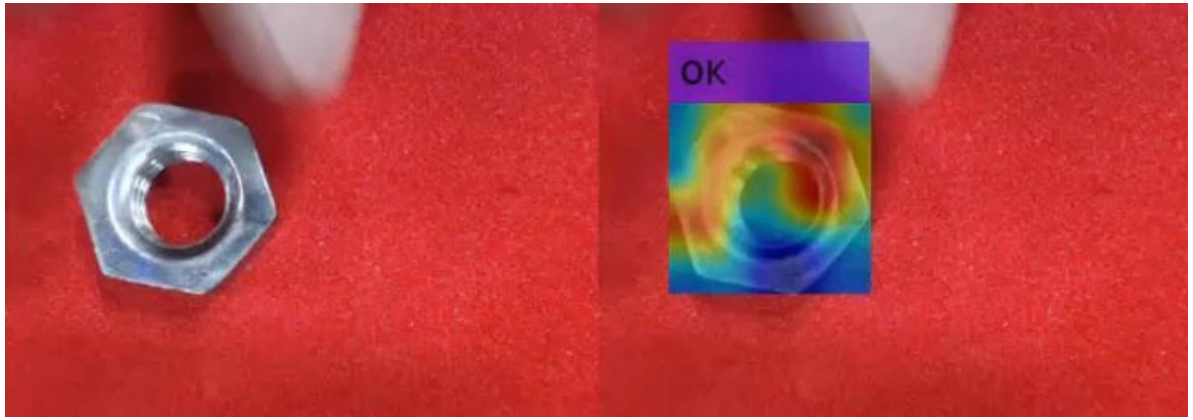


> *Using camera connection, preprocessing, and various pretrained models in MATLAB enabled us to work on the entire workflow. Through discussions with consultants, our team gained many tips for solving problems, growing the skills of our engineers.*

How XAI was used:

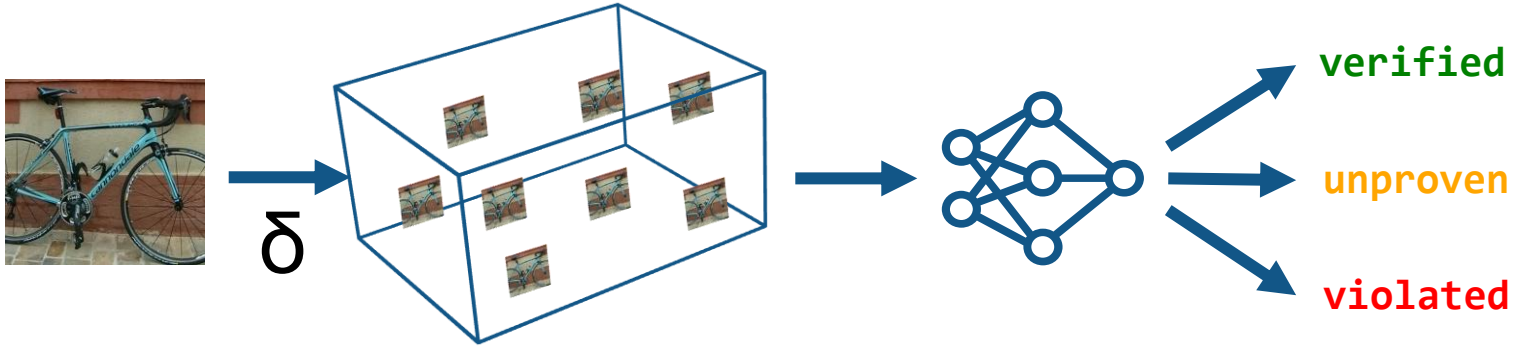
Estimate and visualize the defect area using Class Activation Mapping

Class Activation Mapping

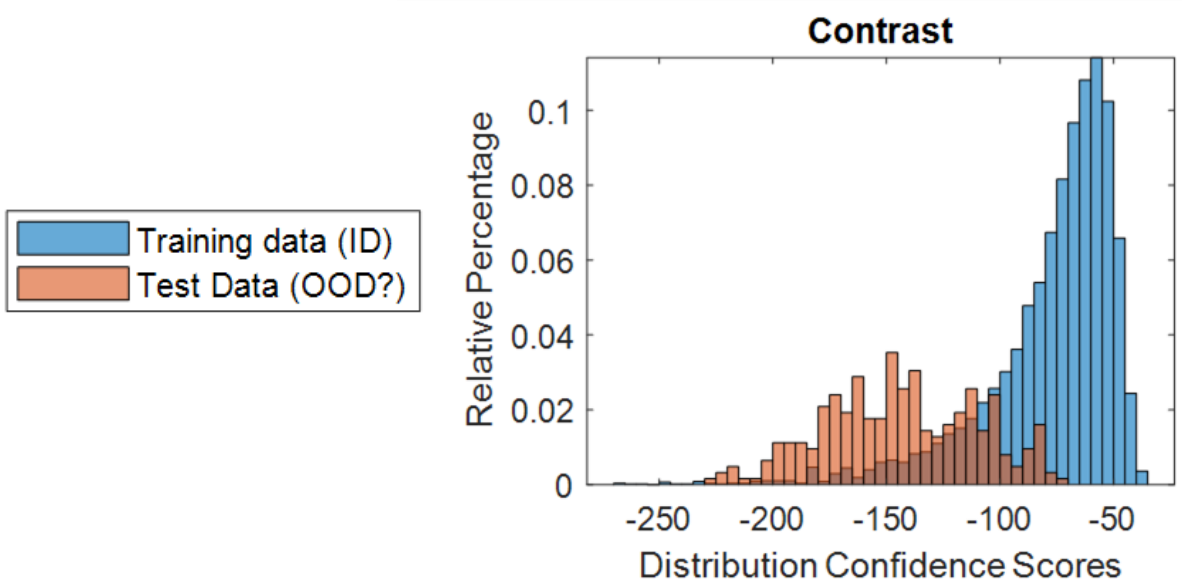


Robustness and Out of Distribution Detection

Is the AI model robust against small input changes?



Can the AI model reliably detect unknown samples?

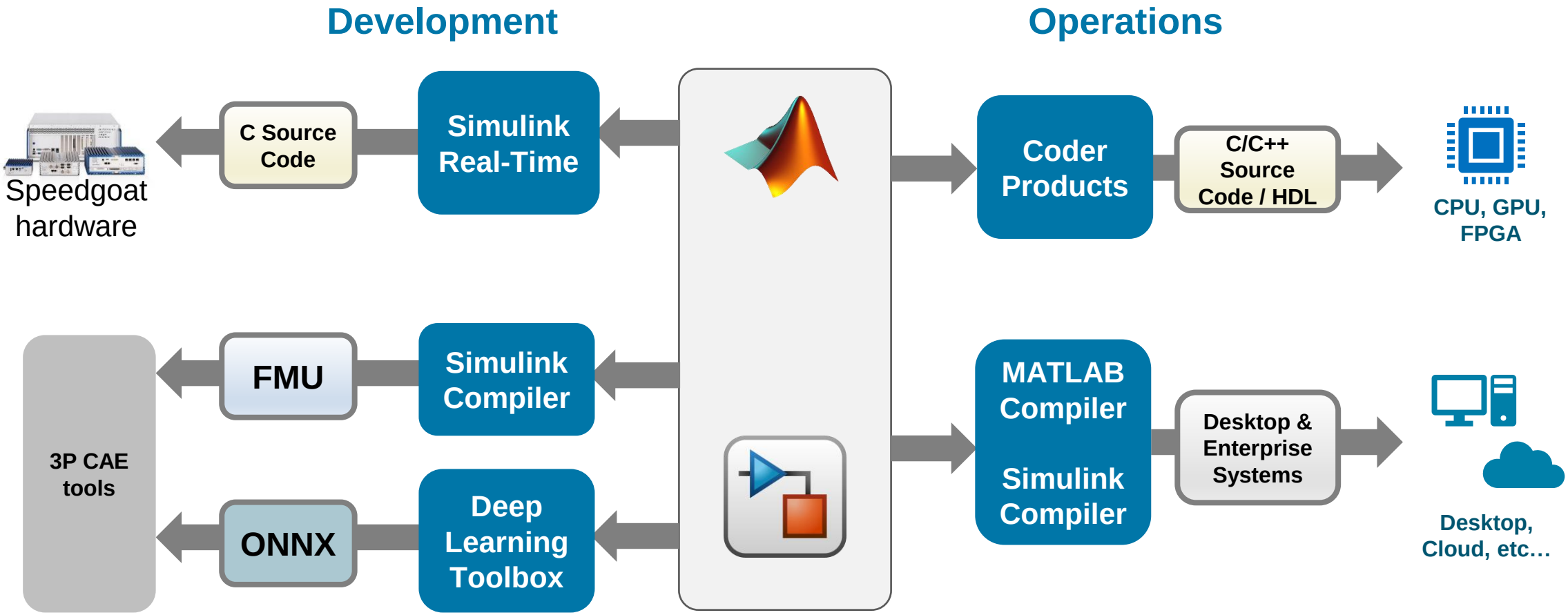


Deep Learning Toolbox Verification Library

by MathWorks Deep Learning Toolbox Team STAFF

Verify and test robustness of deep learning networks

Deploy to your choice of embedded hardware, or integrate with a variety of platforms in the cloud



Operationalize Embedded AI with On-Device Learning

Domain Experts
From data to deployment, overseeing the entire AI workflow in MATLAB

Embedded Software Engineers
Implementing and optimizing AI models on edge hardware, collaborating seamlessly with data science teams

Data Preparation | **AI Modeling** | **Simulation & Test** | **Deployment**

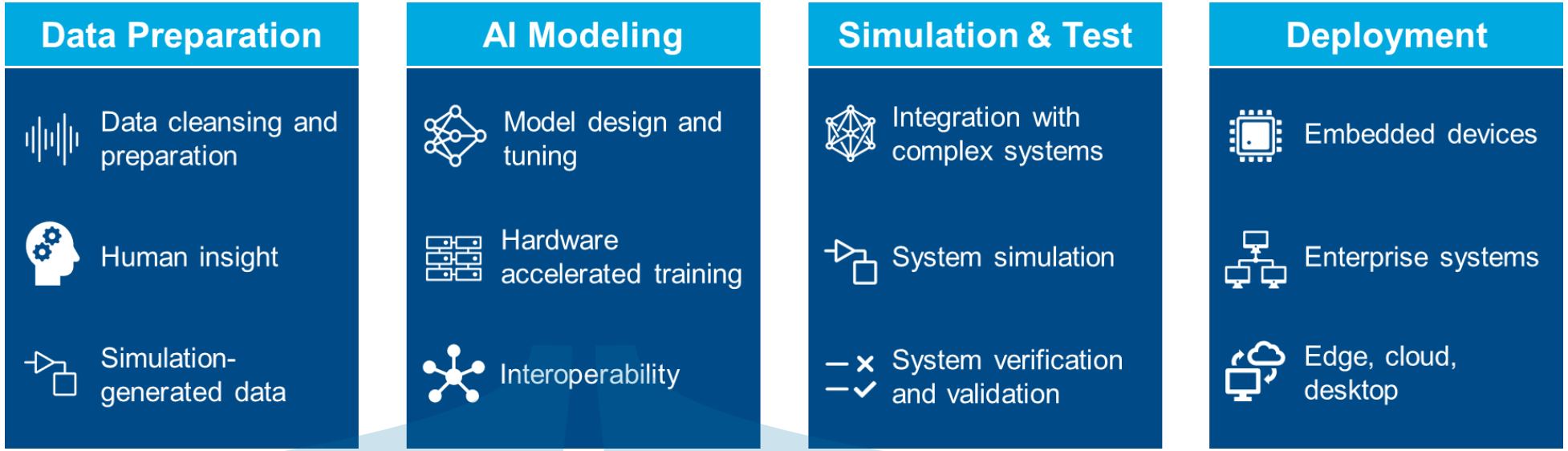
Workflow for Embedded AI

Data Preparation | **AI Modeling** | **Simulation & Test** | **Deployment** | **Keeps Learning**

Incremental Learning Blocks

Workflow for On-Device Learning

Leveraging AI-driven Automotive Application design



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AI for Algorithm development

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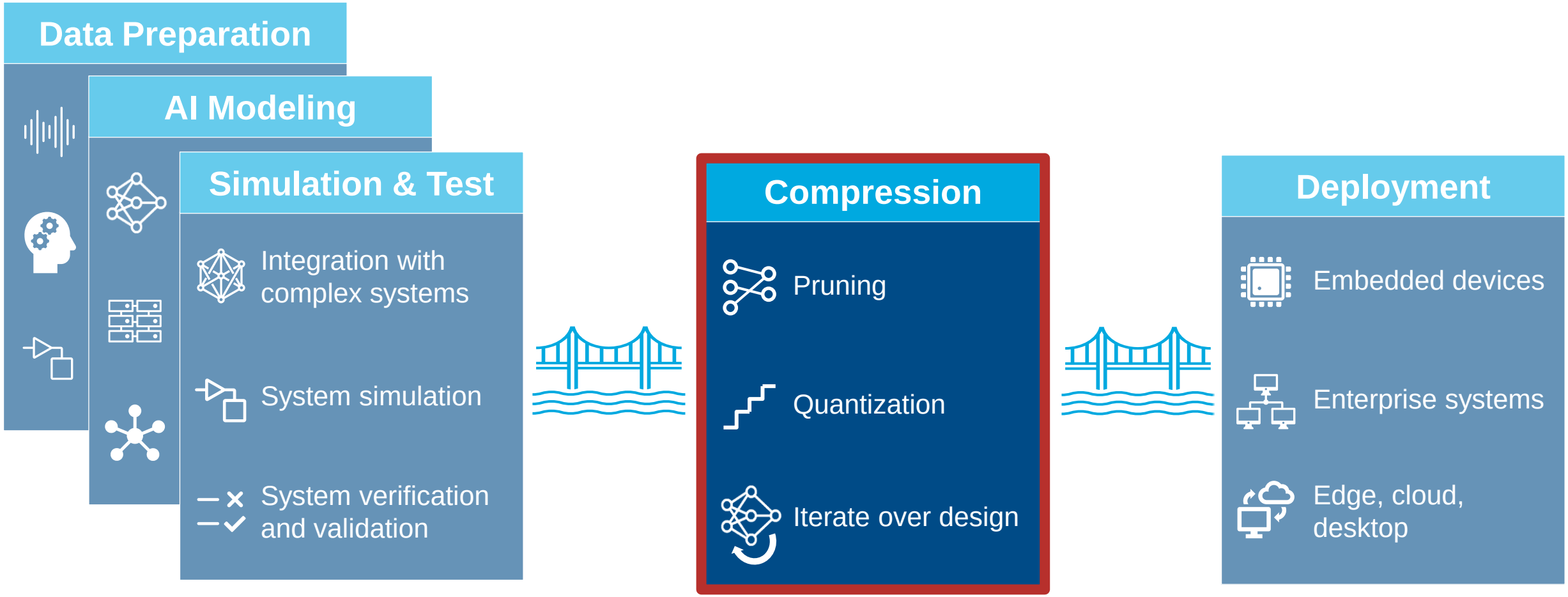
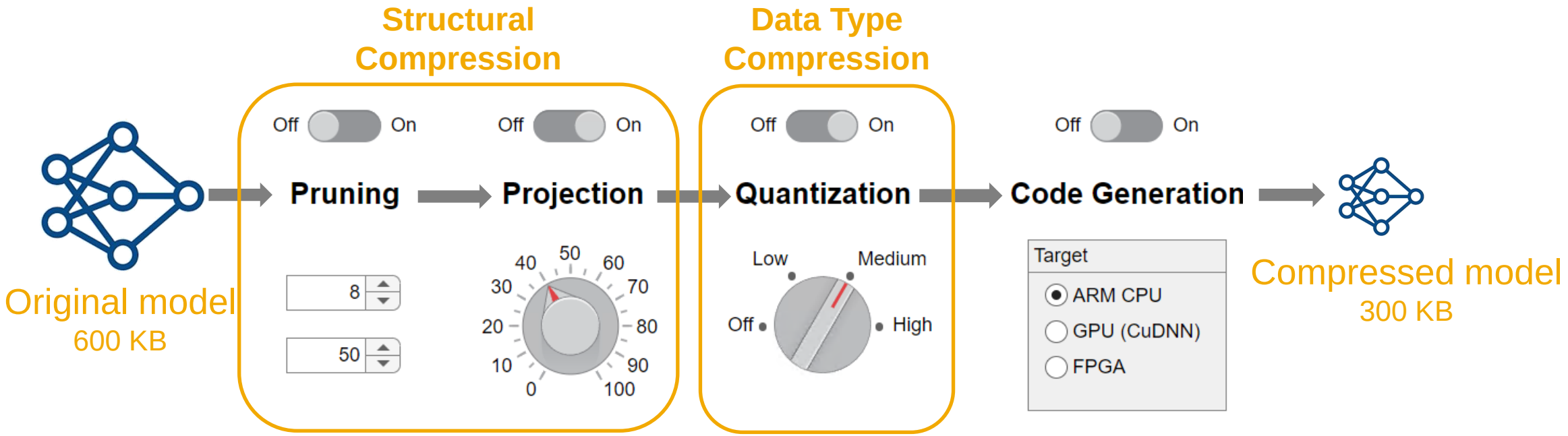
Leveraging Data Driven Application Software Development

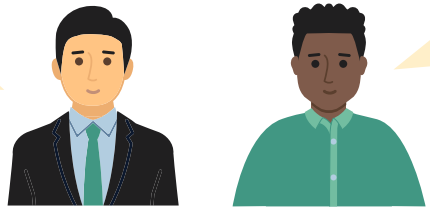
Model compression can bridge the gap between AI modelling and embedded deployment



Reduce model footprint and accelerate inference of DL models for deployment to the edge



*"original [network] was 40MB, was told needed to be **less than 10MB to fit**."*



*"model is 600kb and want to **reduce it to 300kb**. if I'm not fitting it in, I don't have a working solution"*

Challenges in AI Model Development

Accuracy	• Learning Verification • Hyper parameter tunning
Development Time	• Streamlined AI Workflow – 4 bucket
Effective Testing	• AI V&V
Compatibility	• Integrated AI with MBD & Deployment portfolio
Maintainability	• On-Device Learning
Robustness	• Verification & Validation of AI Models • Tuning the models
Latency	• Model Compression

Learning Verification
Hyper parameter tunning

Accuracy

Streamlined AI Workflow – 4 bucket

Development Time

AI V&V

Effective Testing

Integrated AI with MBD

Compatibility

Maintainability

On-Device Learning

Robustness

Verification & Validation of AI Models
Tuning the models

Latency

Model Compression

Industry-Academia initiatives

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At Continental, we believe in the power of partnerships to shape the future of mobility. Our collaboration with Amrita Vishwa Vidyapeetham and MathWorks reflects our commitment to bridging the gap between academia and industry, ensuring that future engineers are equipped with both cutting-edge knowledge and industry readiness.

Through the Automotive Systems and Layered Architecture course, students gain exposure to advanced automotive technologies such as #AUTOSAR, a critical standard in the #industry. By combining academic expertise with Continental's industry insights, we are creating an environment where students can develop the skills needed to address real-world challenges in automotive engineering.

This #partnership is not just about #education —it's about creating future-ready professionals who will lead the way in innovation. We are proud to support initiatives like this that empower the next generation, preparing them for the dynamic demands of the #automotive world.

#Collaboration and #innovation are
smarter, safer #future for mobility at

#ContinentalIndia #India #bangalore

Bosch and National Institute of Technology Calicut Collaborate on EV Course to Prepare Students for Industry

Challenge

Address the shortage of automotive engineers with system engineering skills

Solution

Jointly create a new undergraduate course in model-based system engineering as part of a collaboration between academia and industry

Results

- Months of on-the-job training eliminated
- Enrollment increased by 250%
- 90%+ positive feedback received

Pradeep Kumar of Bosch India lighting the ceremonial lamp with Dr. Sivaji Chakravorti of NIT Calicut before signing the agreement.

"The collaboration between NIT Calicut, MathWorks, and Bosch narrowed the gap between academia and industry, producing an electric vehicle system engineering course that has been both well received by our students and highly useful for them as well."
- Dr. Kumaravel Sundaramoorthy, NIT Calicut

[Bosch and National Institute of Technology Calicut Collaborate on EV Course to Prepare Students for Industry]

Upcoming course on SDV

Course Outcomes:

By the end of this course, students will be able to:

1. Understand the architecture and evolution of software-defined vehicles and their role in the automotive industry.

2. Analyze the components, systems, and communication protocols central to software-defined vehicles.

3. Apply software development and validation techniques specific to automotive applications.

4. Explore trends and emerging technologies shaping the future of software-defined vehicles.

Module 1: Introduction to Software-Defined Vehicles
Definition, significance, SDVs - Evolution, automotive technology, software-centric systems - Software-defined architecture - vehicle design, functionality
Module 2: Fundamentals of SDV Architecture and Components
SDV architecture, embedded systems, ECUs - Software platforms, methodologies, SDVs - Software development lifecycle (SDLC) - automotive engineering
Module 3: Communication, Connectivity, and ADAS in SDVs
V2V, V2I, V2X communication - In-vehicle networking, CAN, Ethernet - Advanced Driver Assistance Systems (ADAS) - key features - autonomous driving
Module 4: Software Development, Validation, and Future Trends
Software development, validation, testing, simulation, ISO 26262 - Case studies, practical implementations - Future trends, OTA updates, cloud-based platforms and Role of AI in SDVs

Key Summary…

Core Technology Foundation

Automotive software development **steadily incorporates AI, focusing on security, safety, resources**, and **business necessities.**

Integration with Legacy Systems

AI-based development **can seamlessly integrate into the traditional Model-Based design workflow.**

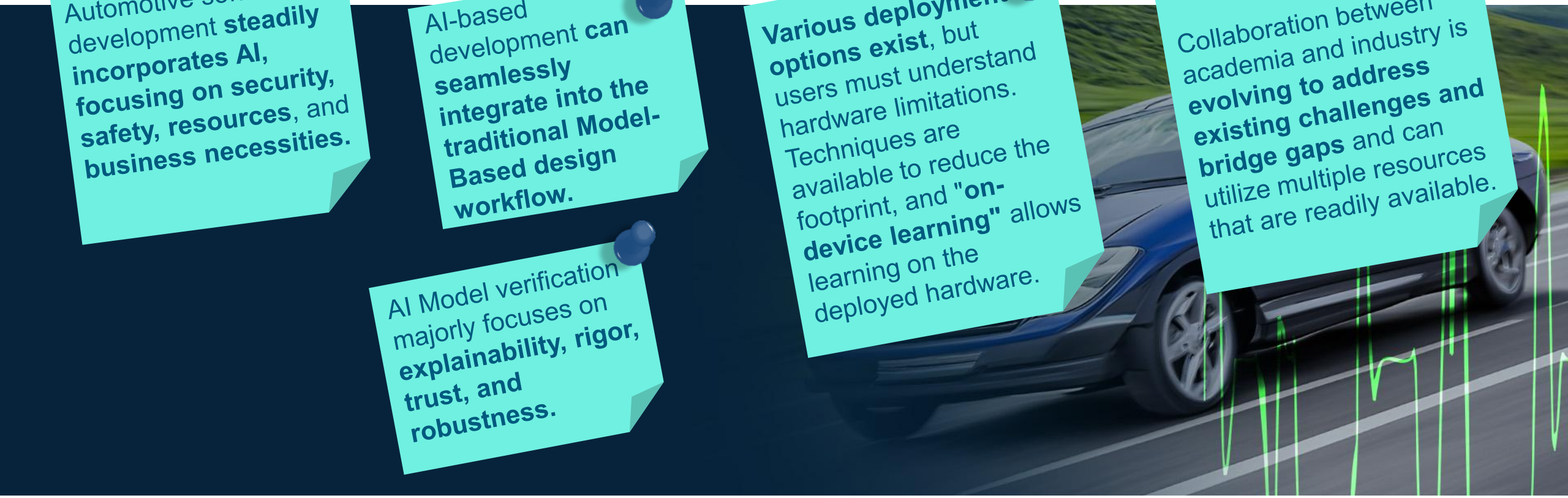
AI Model verification majorly focuses on **explainability, rigor, trust, and robustness.**

Deployment Challenges & Strategies

Various deployment options exist, but users must understand hardware limitations. Techniques are available to reduce the footprint, and **"on-device learning"** allows learning on the deployed hardware.

Industry & Academia Collaboration

Collaboration between academia and industry is **evolving to address existing challenges and bridge gaps** and can utilize multiple resources that are readily available.



Key Summary…

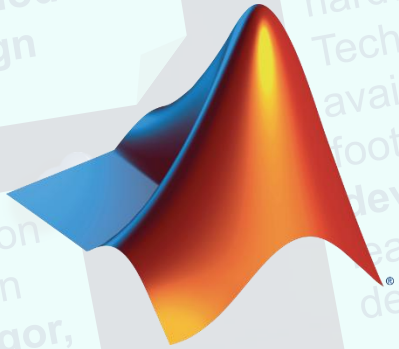
Core Technology Foundation

Integration with Legacy Systems

Deployment Challenges & Strategies

Industry & Academia Collaboration

Why not..! Start building your automotive software with AI models



We are open to collaborate and support in your journey

Audience Question