

MathWorks AUTOMOTIVE  
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India

# Embedded AI for Body Applications with MATLAB and Simulink



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# Agenda

- Introduction, Current Area of Work
- Motivation behind AI-powered solutions
- Virtual Sensor model with Embedded-AI for Online Mass Flow estimation
- Development workflow
- Partnering with MathWorks to address challenges
- Results
- Key takeaways & Acknowledgement

# We are the Architects of the MB.OS platform -BODY & COMFORT

## Full control of development to deliver an Outstanding Luxury Product

- + BODY & COMFORT**
- INFOTAINMENT
- AUTOMATED DRIVING
- DRIVING & CHARGING
- DRIVING & CHARGING

Personalized luxury experience

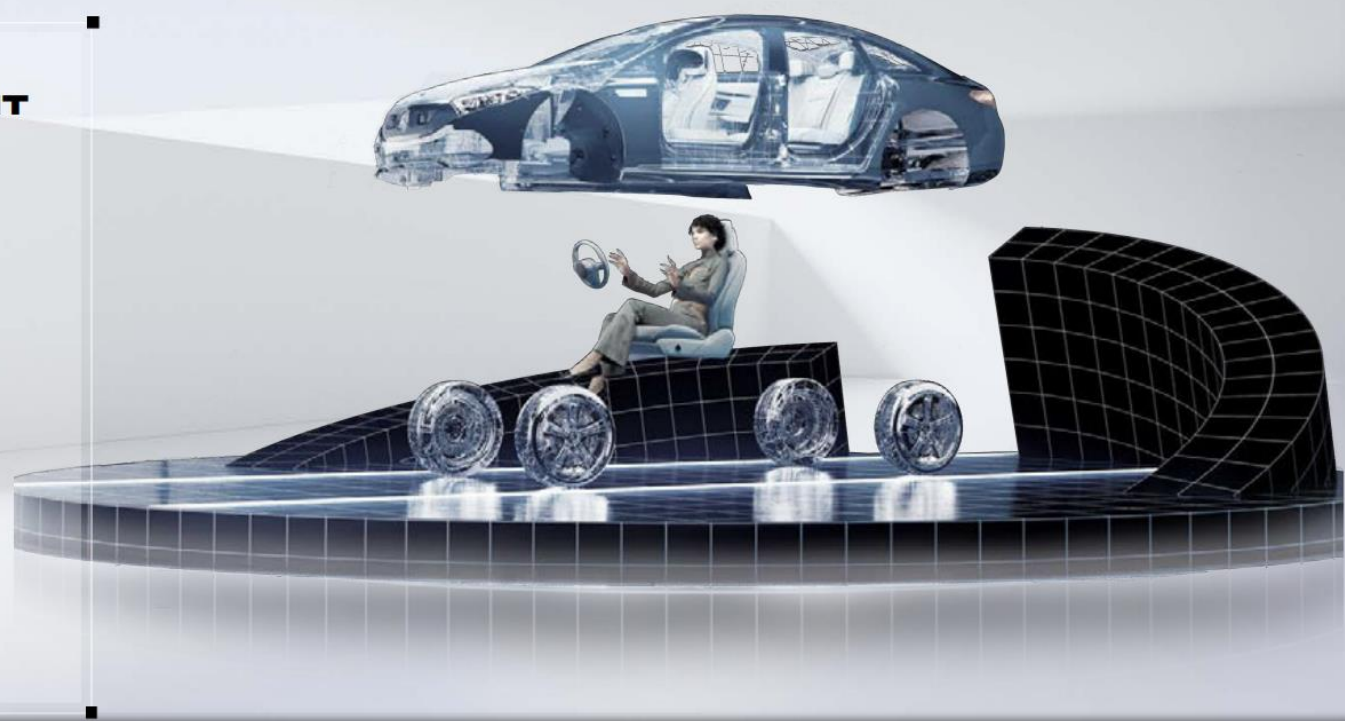
MB.OS will create an immersive multi-sensory experience  
We have control over all vehicle functions to deliver exceptional comfort

### IMMERSIVE ENTERTAINMENT

- ▶ Video
- ⌂ Motion
- 💡 Light
- 🌡️ Climate control**
- 🌸 Fragrance

Energizing comfort to wearables

Digital Vehicle Key for smartphones



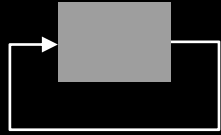




# How can we make our Real-Time Control algorithms Smarter to deliver an Outstanding Luxury Product?

## Control System Design Approaches

### A Case study



### Embedded AI

Deployment of AI applications into resource constrained devices like ECUs enabling real-time data processing without cloud connection



Accuracy



### Classical Physics-based Modeling

These models leverage established physical laws and equations to predict the behavior of a system



- Need for Real-time execution
- Recent Car to Cloud Data Transfer Regulations

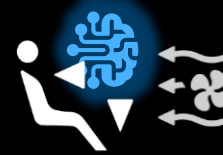


### AI Modeling

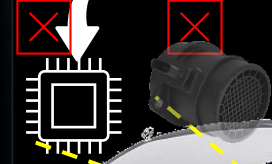
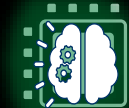
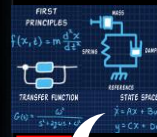
Traditional AI modeling leveraging cloud computing infrastructure and AI algorithms



# An Experimental Research of AI-powered Real-time Controls with Virtual Sensor to deliver an Outstanding Cabin Comfort



AI-powered Virtual Mass Flow Sensor for Air-distribution controls



Climate control flaps  
Stepper positions

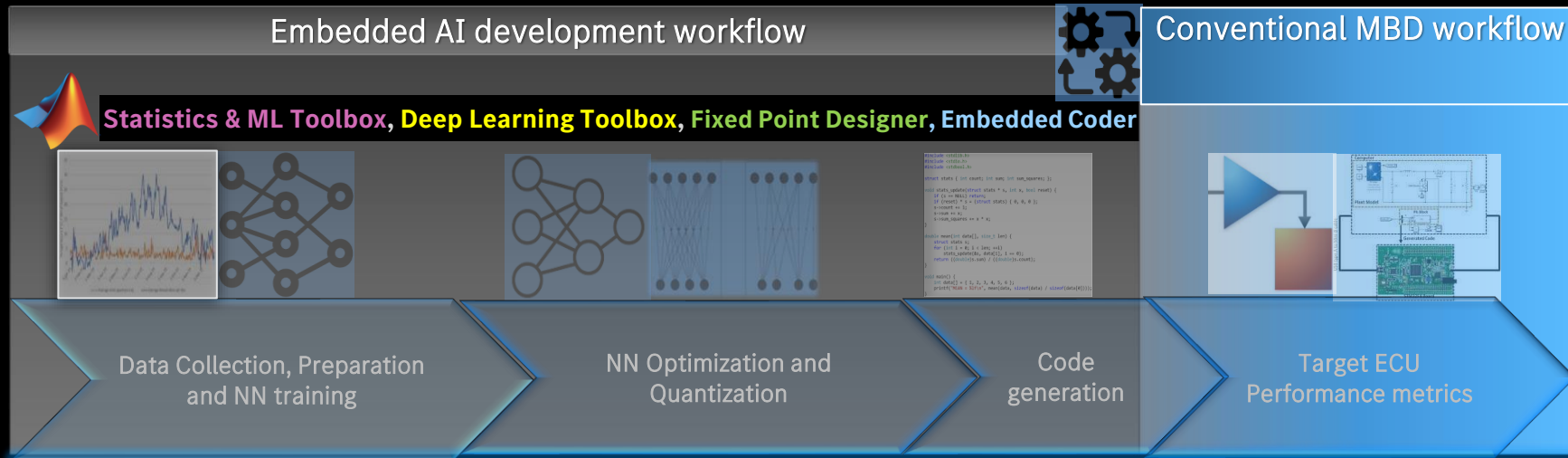
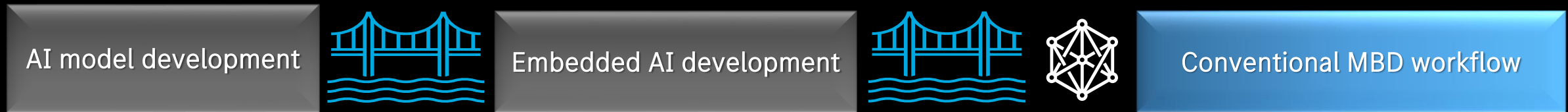


Blower speed

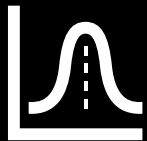
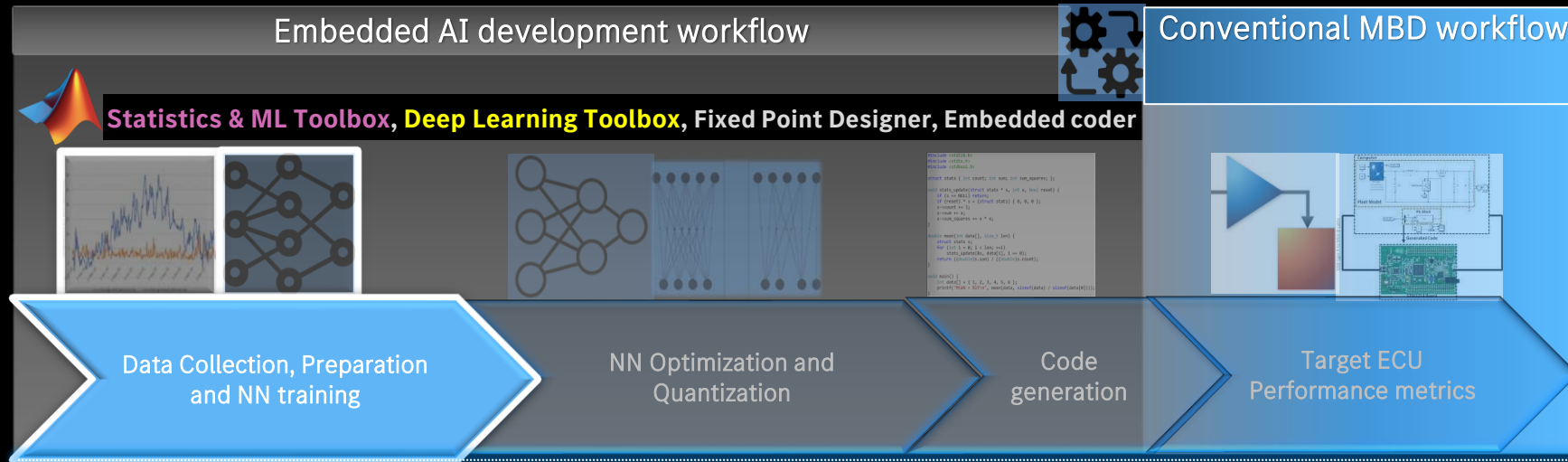
# Adaption of MathWorks Toolchain for AI-powered Virtual Sensor



In collaboration with MathWorks, we established a comprehensive Embedded AI development pipeline, starting from initial ML concept design → code generation and → deployment on the ECU for our pilot use case

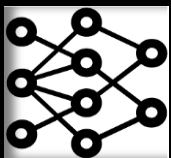


# Embedded AI Development Workflow



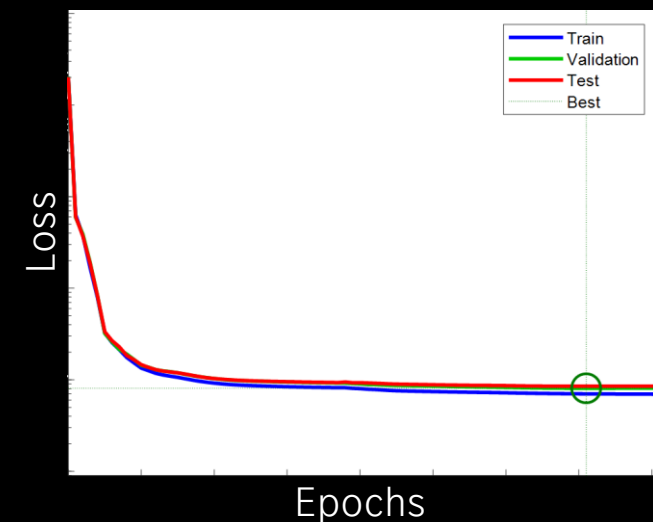
## ❑ Experiment Input data Generation:

- Generating Samples with proper distribution over input range(method: LHS)
- Input Normalization for better Neural network generalization.



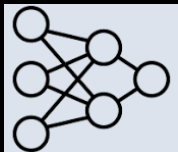
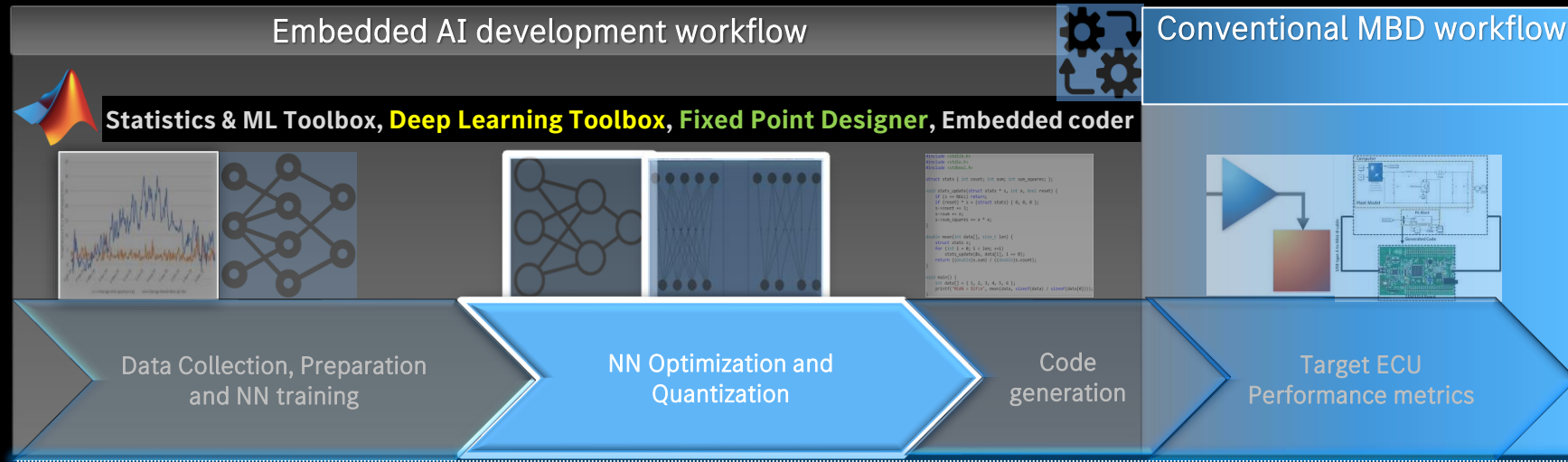
## ❑ Neural Network(NN) training:

- NN Architecture Design using Deep network designer or programmatical approach.
- Validating model performance





# Embedded AI Development Workflow



## □ NN Optimization

- Hyper parameter tuning using experiment designer
- NN projection



Limited Processing power and Memory capacity

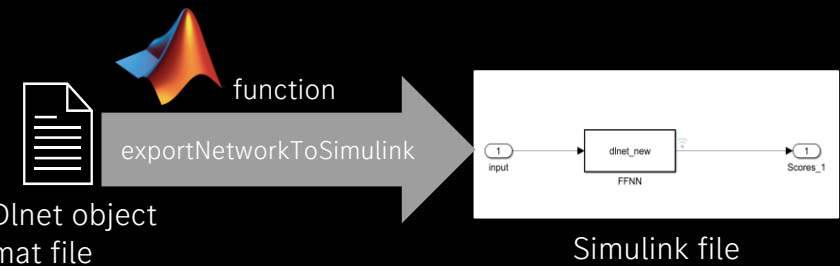


## □ Quantize model parameters

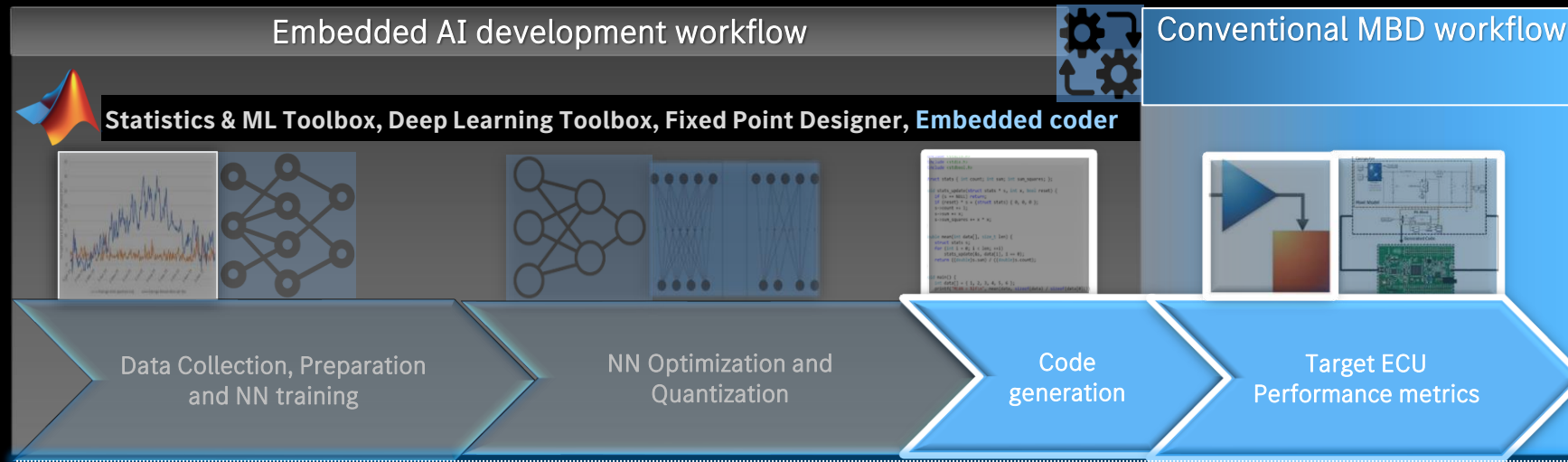
- Conversion of dlnet object('.mat') to Simulink blocks using Layer to block function: "exportNetworkToSimulink"
- Quantizing to fixed point datatype



Limited Floating-point operations support on ECUs for high precision AI models



# Embedded AI Development Workflow

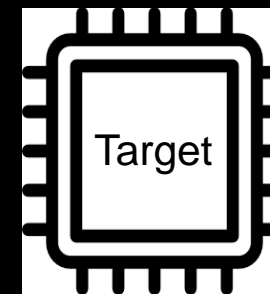


## Code Generation

- Algorithm Code Generation using Embedded Coder



Integrating the AI software with Existing Development toolchain



Library Free  
C/C++

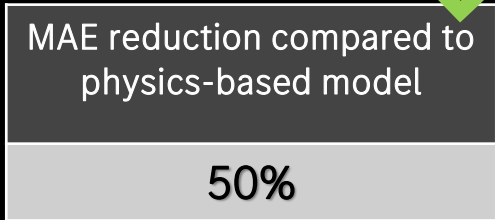
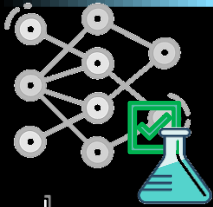
## Target ECU Performance metrics

- Flash the Integrated code onto the ECU
- Check the PIL/SIL performance



# Results

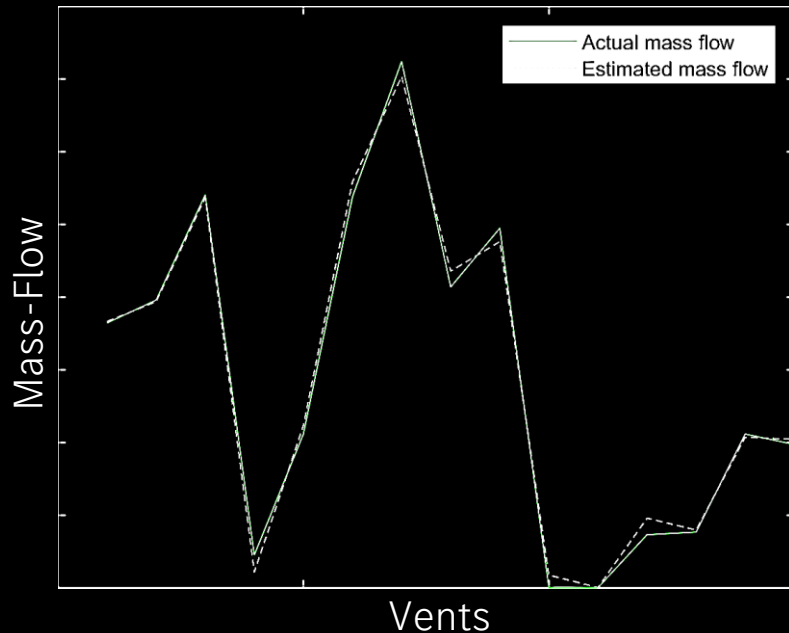
## Cabin mass flow estimation Neural Network Model Validation



Improved accuracy

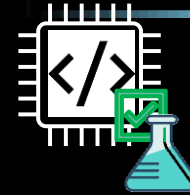
*\*Improved Thermal comfort due to accurate mass flow estimation*

Estimated and actual mass flow accuracy comparison plot



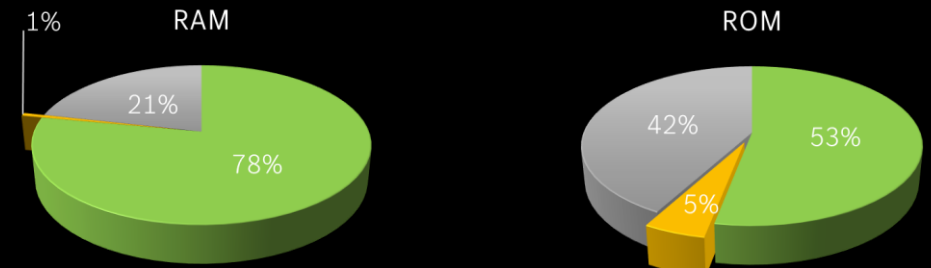
NEURAL NETWORK MODEL

## Neural Network(NN) based mass flow estimation Code: Resource utilization metrics



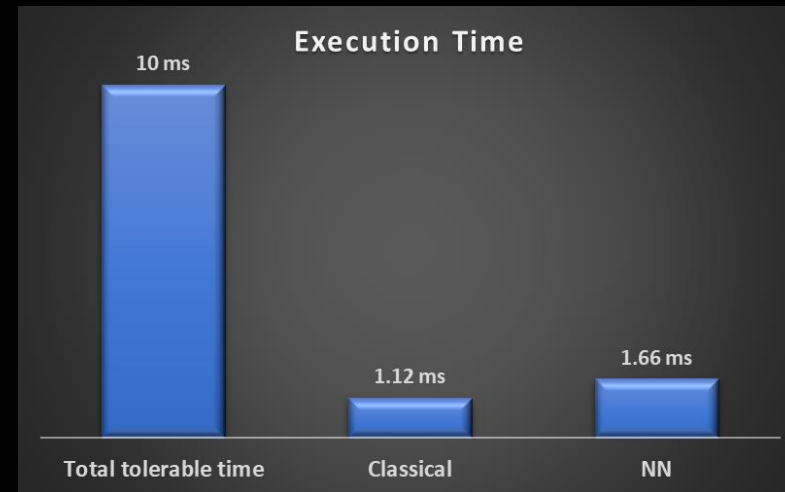
CPU, memory and performance requirements

Tolerable memory consumption



■ Classical ■ Increase due to NN ■ Unused memory

EMBEDDED CODE



Fixed-Point Operations

Floating-Point Operations



# Key Takeaways & Acknowledgement

- ❑ Less development time and easy deployment of AI models
- ❑ CPU, memory, and performance requirements are met for resource constrained ECUs
- ❑ Seamless integration to existing toolchain
- ❑ Real time processing capabilities and eliminates any kind of bandwidth requirements
- ❑ Compliance with Data transfer regulations due to local processing

## Acknowledgement

For the support offered and tailored solution offerings from MathWorks for our AI-powered Virtual Sensor use-case





# Q & A

Thank you