IMPLEMENTATION OF A VIRTUAL SENSOR ON AN ECU (POWERTRAIN CONTROLLER) USING RECURRENT NEURAL NETWORKS

MathWorks Automotive Conference

20.10.2022

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AGENDA

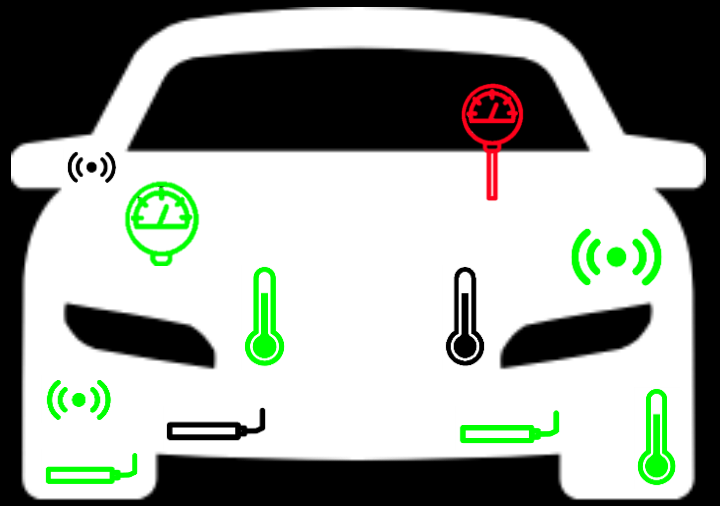
1 VIRTUAL SENSORS

2 RECURRENT NEURAL NETWORKS

3 ECU (POWERTRAIN CONTROLLER)

CAN WE USE ARTIFICIAL INTELLIGENCE TO IMPROVE OUR POWERTRAIN FUNCTIONS?

WHY REPLACE SENSORS ?

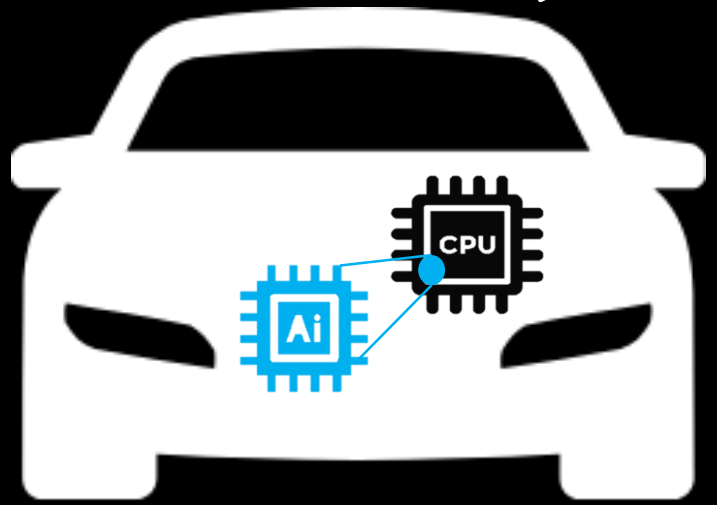


- In **test vehicles** there are many sensors available, that aren‘t in the series vehicles.
- Sensors can be expensive and can fail.
- In our specific use case, **there is no efficient, conventional software solution available** for replacing the physical sensor used by **powertrain functions.**

WHY REPLACE SENSORS ?

Many powertrain functions run in **realtime**:

Thus, we can‘t outsource those **time sensitive** calculations in the cloud. These functions must be executed in the vehicle – **embedded in the powertrain controller.**



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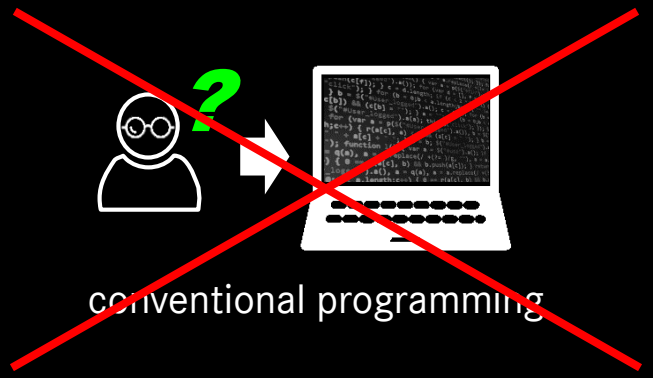

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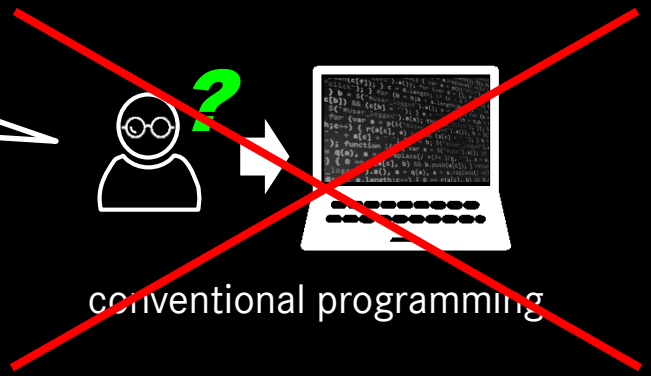
WHY NEURAL NETWORKS ?

reasons e.g.
- bad cost-benefit ratio
- complex state space
- various dependencies
- non-linearities



conventional programming

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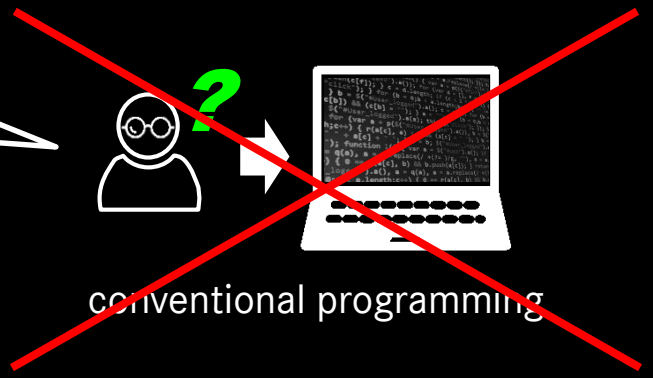
WHY NEURAL NETWORKS ?

prediction of measured sensor signals is a multivariate time series forecasting problem → recurrent neural networks fit perfectly



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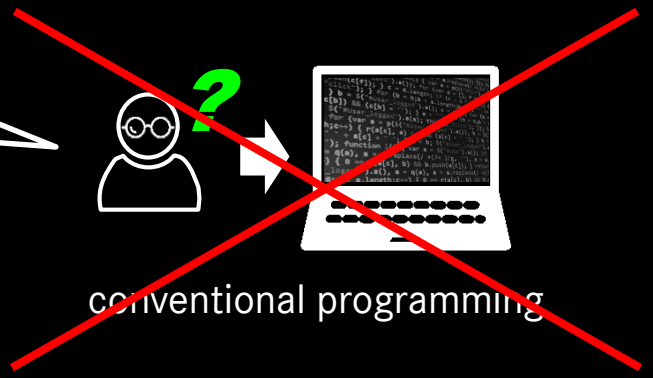

- The potential of machine learning helped us find an **efficient solution by using recurrent neural networks** (e.g. LSTMs)
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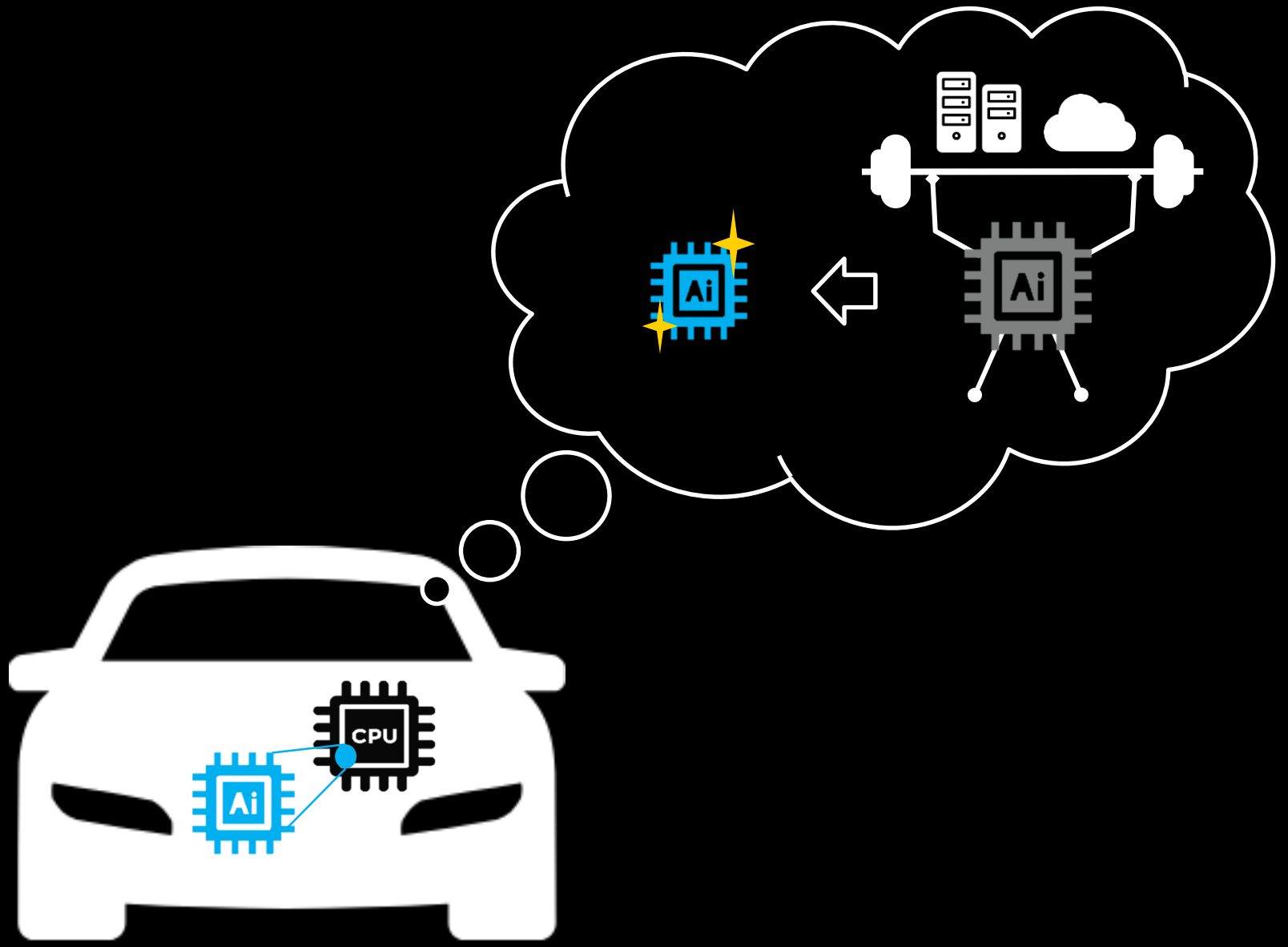
HOW TO IMPLEMENT NNS ON THE ECU?



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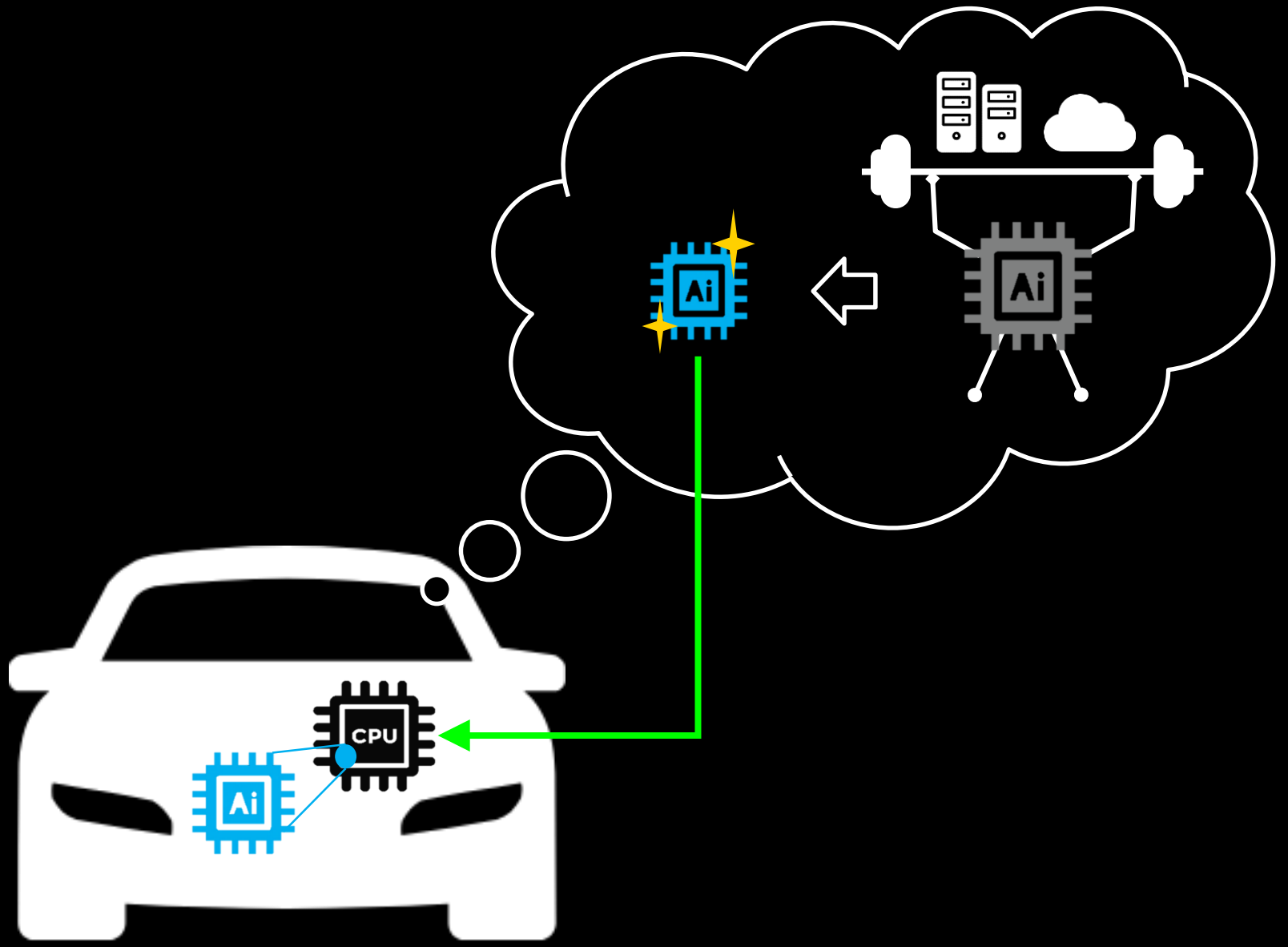


HOW TO IMPLEMENT NNS ON THE ECU?

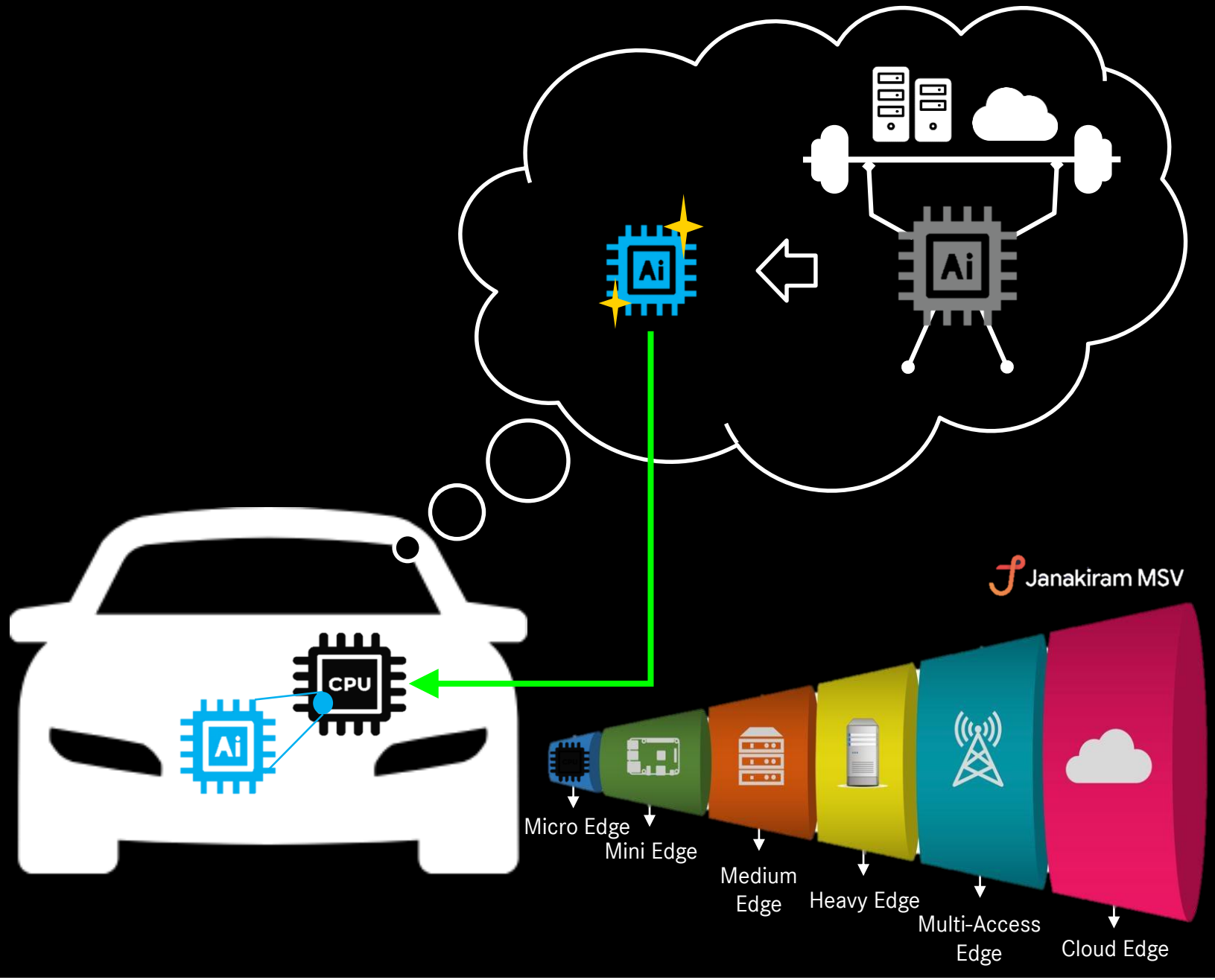
REQUIREMENTS / CHALLENGES

general

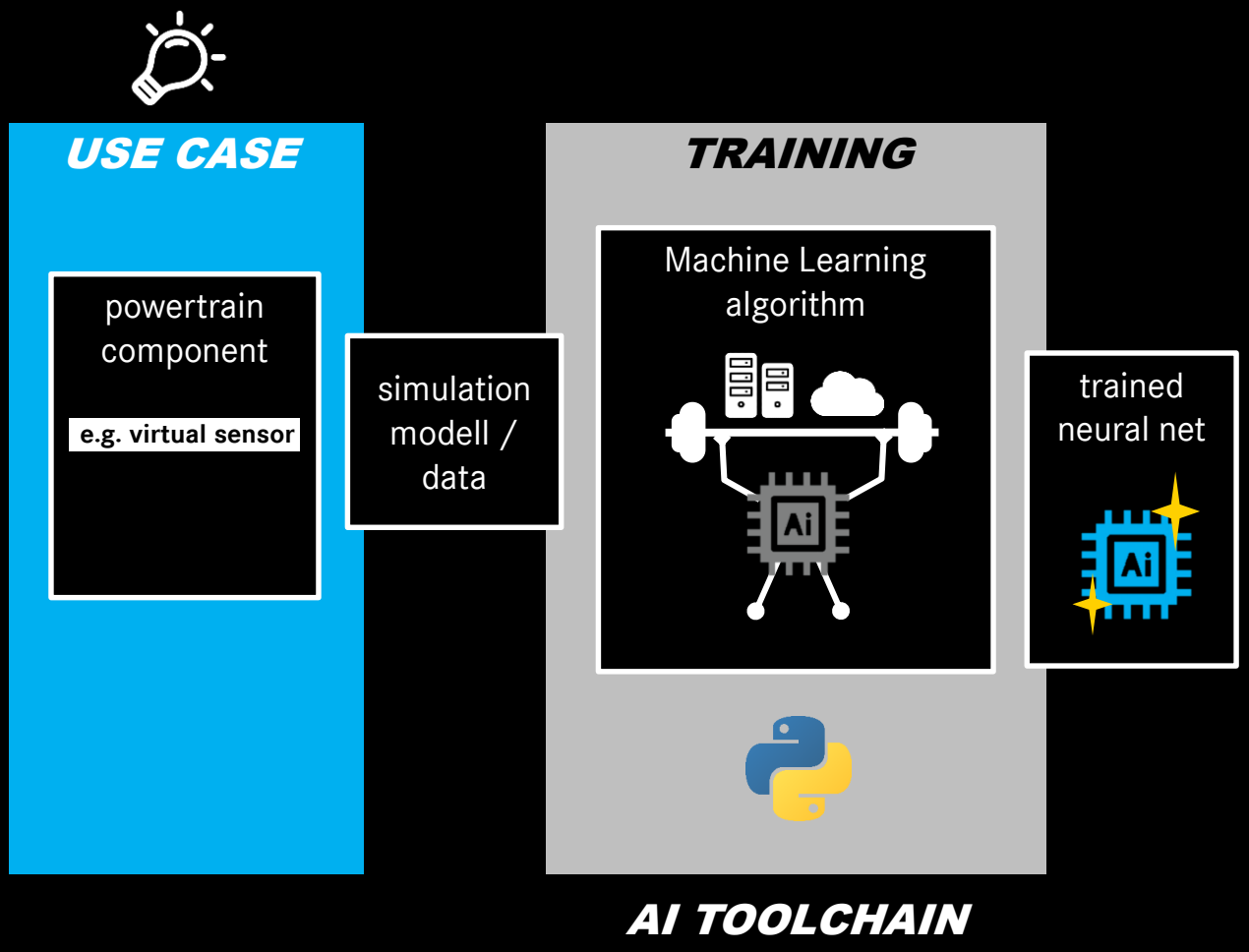
- limited ECU resources
- real-time requirements
- huge NNs for complex tasks
- safety / security requirements

our specific use case

- fixed point datatypes
- embed into existing workflows



AUTOMATED WORKFLOW



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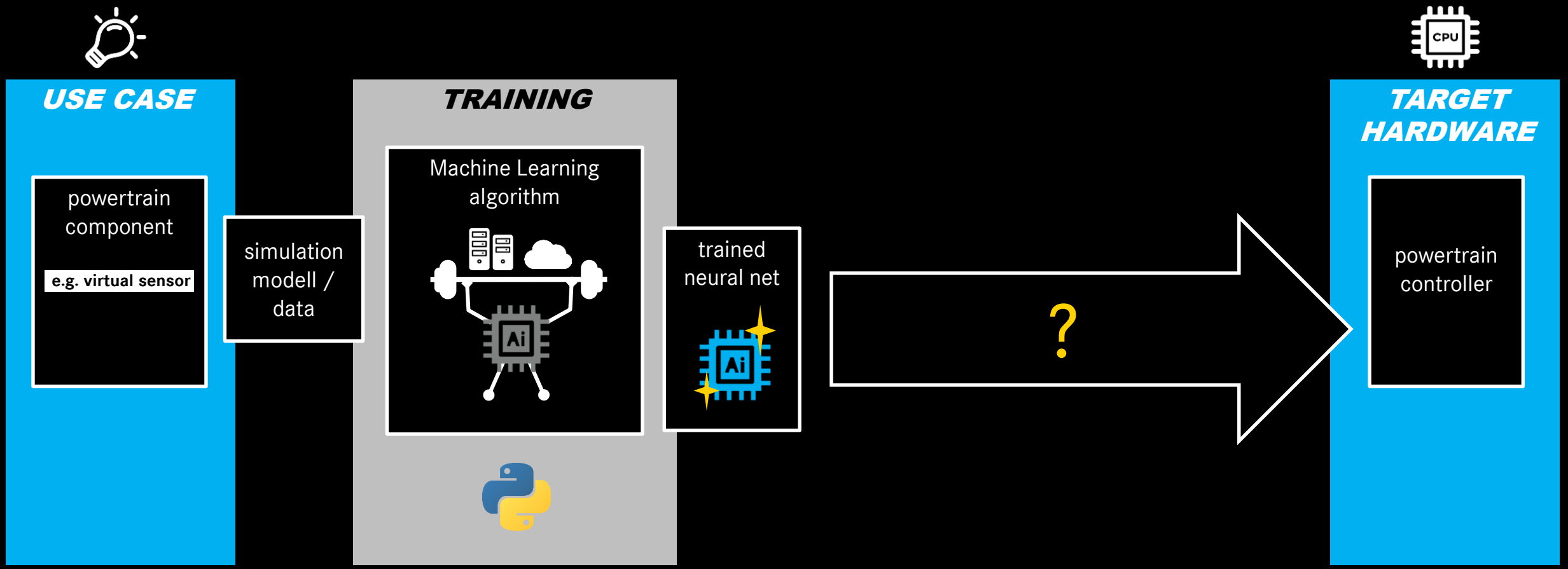

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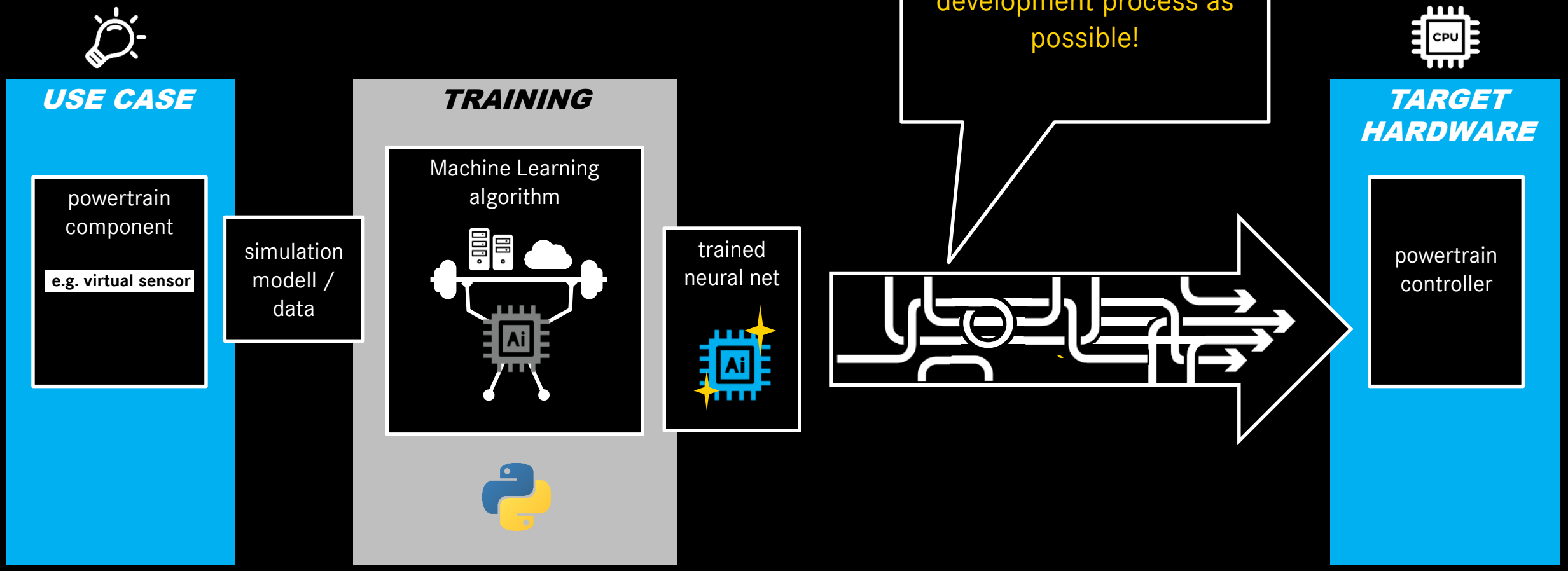

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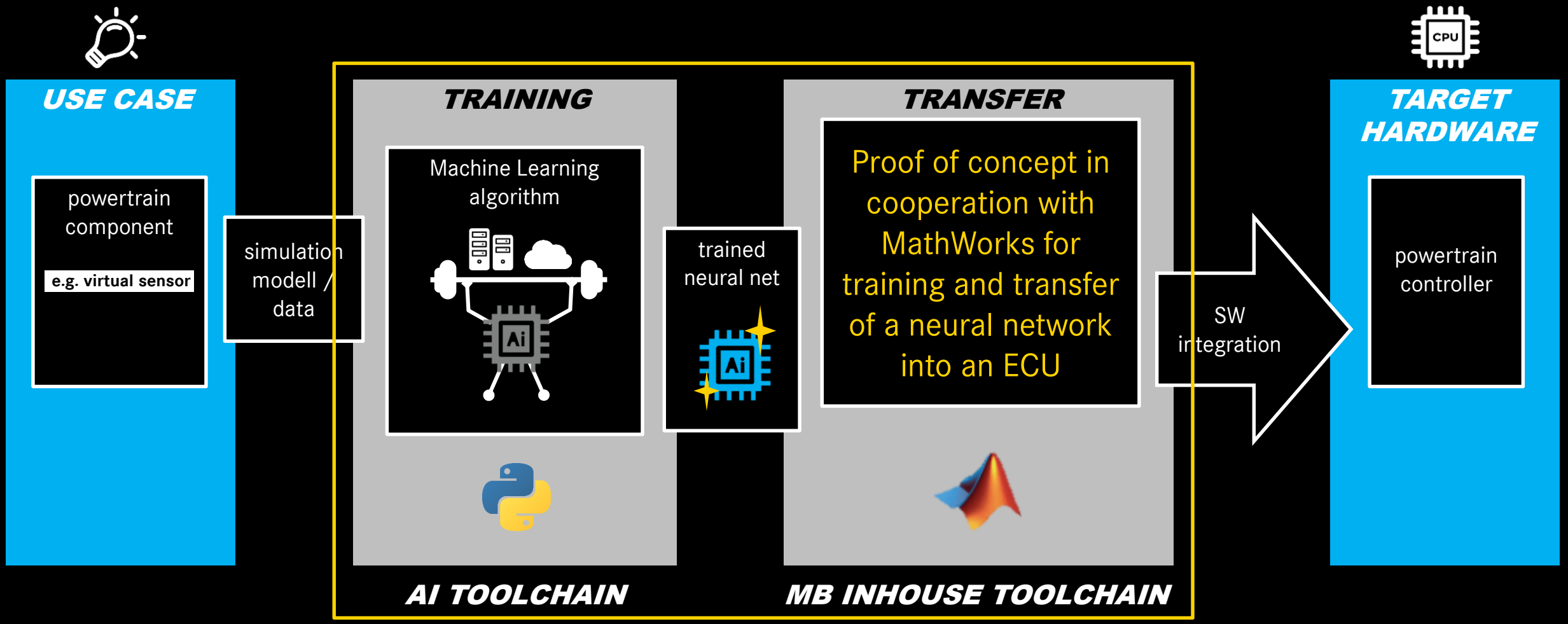
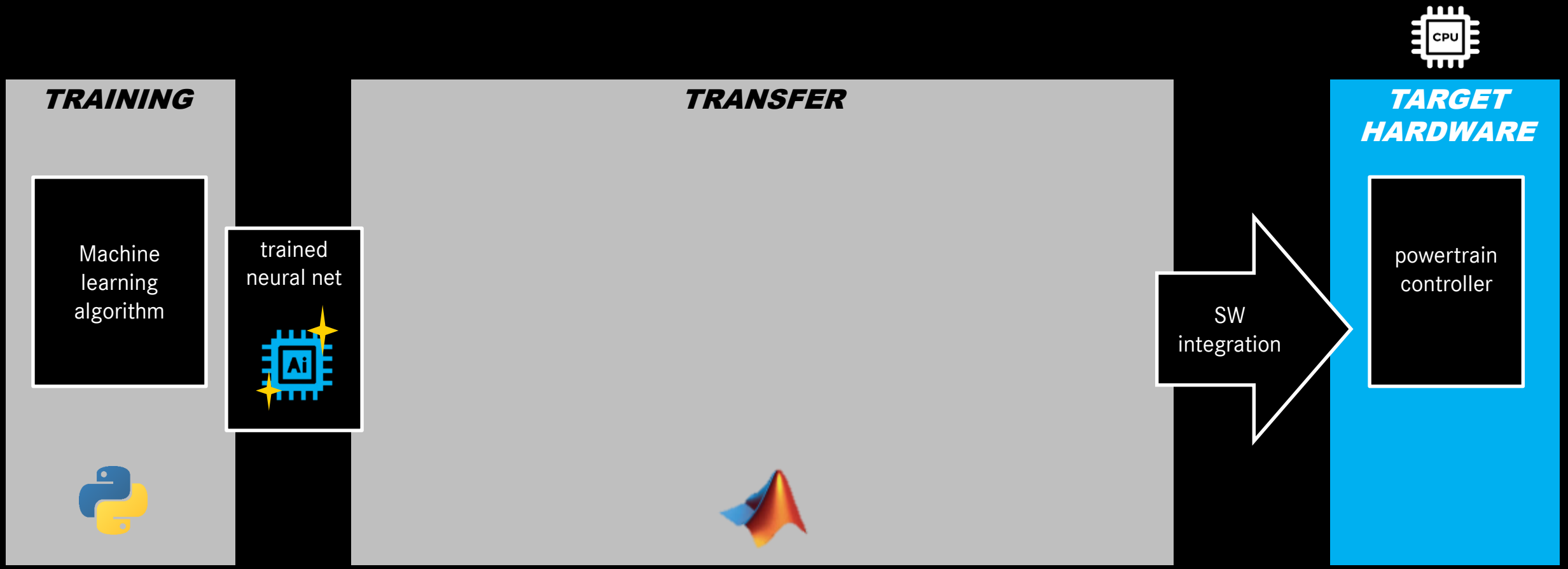


AUTOMATED WORKFLOW - TRANSFER



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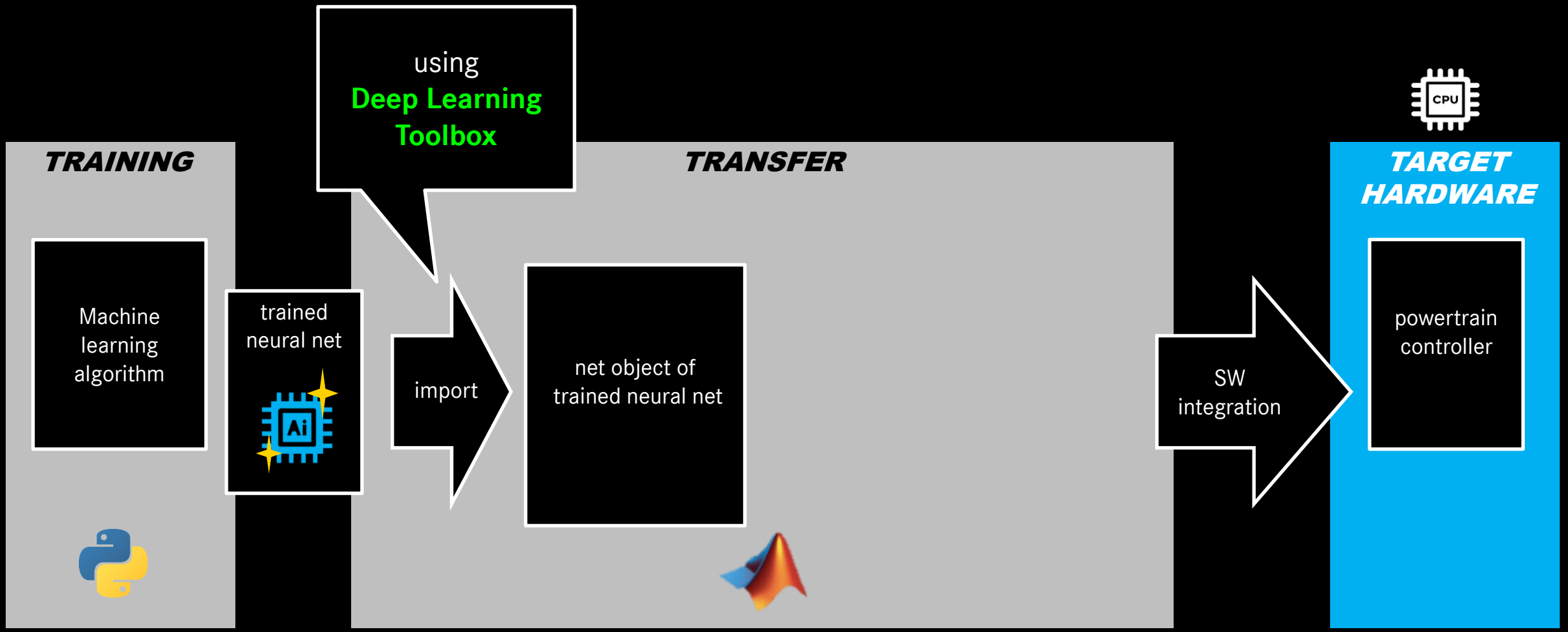

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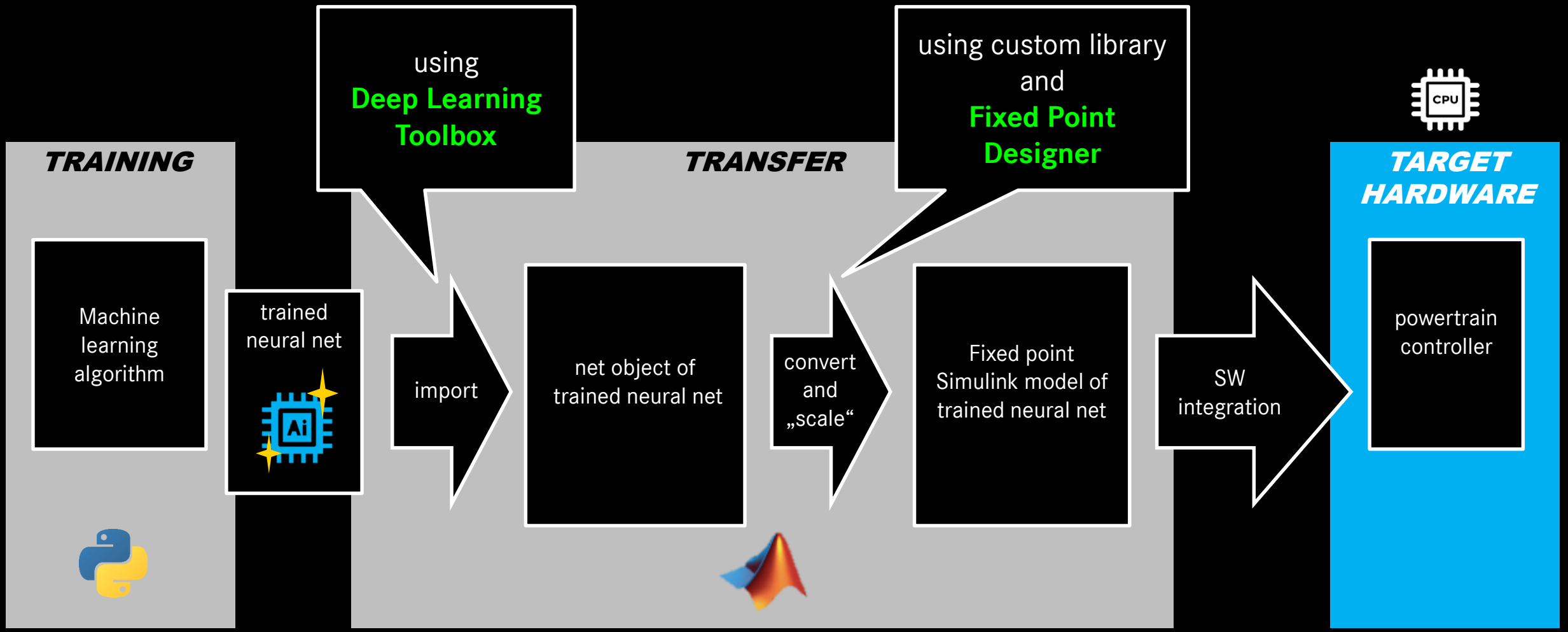

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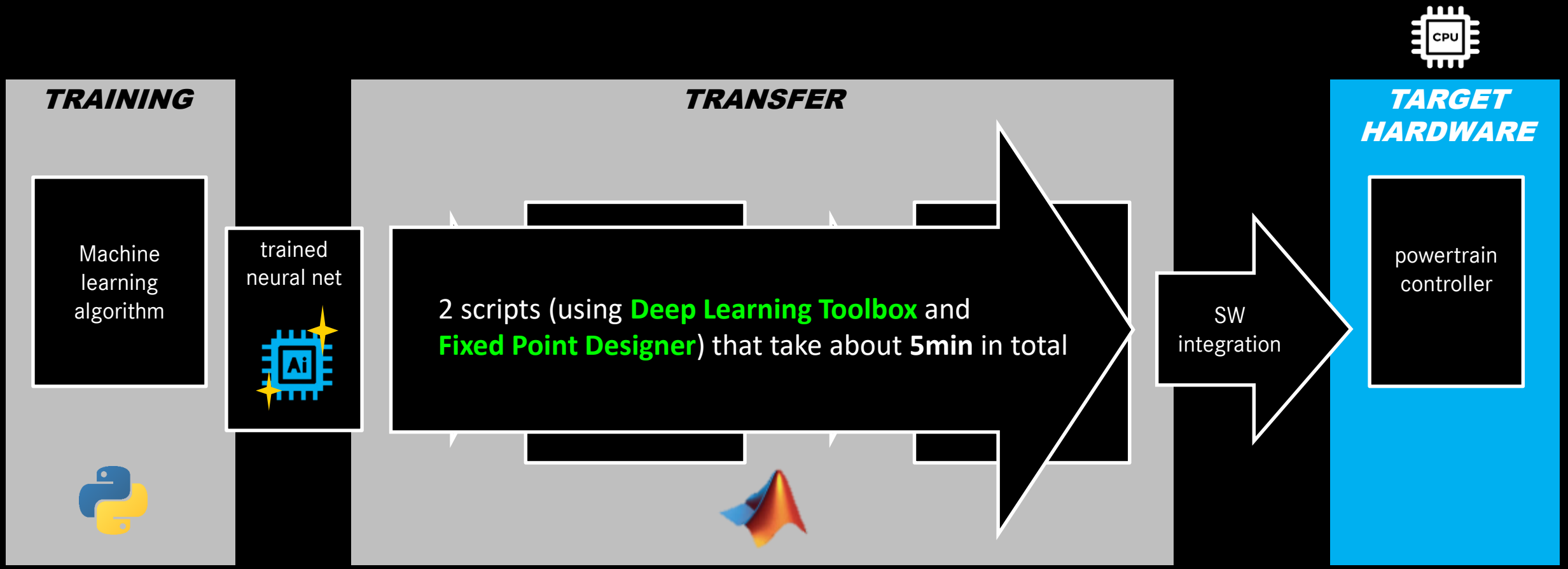

AUTOMATED WORKFLOW - TRANSFER

We were able to speed up the process sixfold

TRAINING

Machine learning algorithm

trained neural net

TRANSFER

2 scripts (using **Deep Learning Toolbox** and **Fixed Point Designer**) that take about **5min** in total

SW integration

TARGET HARDWARE

CPU

powertrain controller

CAN WE USE ARTIFICIAL INTELLIGENCE TO IMPROVE OUR POWERTRAIN FUNCTIONS?

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ARTIFICIAL INTELLIGENCE TO IMPROVE OUR
POWERTRAIN FUNCTIONS?

YES WE CAN!
BY USING THE POTENTIAL OF NEURAL
NETWORKS AND THE AUTOMATED WORKFLOW
FOR IMPLEMENTING THEM IN OUR EXISTING
POWERTRAIN TOOLCHAIN!

THANK YOU!!

BACKUP

NEXT STEPS

SHORT TERM

- we **extended the workflow** by using other neural network architectures
- **transfer** of the workflow to other projects successfully implemented
- series colleagues are validating the current results of the virtual sensor **for use in series**

LONG TERM

- finding a use case where it‘s possible to **compare the conventional solution of a virtual sensor with the solution found by AI** regarding memory/performance footprint on the target hardware, robustness, accuracy, cost-benefit ratio...
- hand over the completed workflow to the software development colleagues **to increase usage of artificial intelligence** in the powertrain development