EVolve Mobility:

Critical Elements for Excelling in Electric Powertrain Development and Testing

Dr. Gerald Sammer

Today’s Presenter

Dr. Gerald Sammer

Principal Business Field Owner, Battery & BEV.

M.Sc. in computer science and a Ph.D. in economics.

30+ years professional experience in computer science.

25+ years experience in automotive technologies.

AVL representative in the technical steering committee of the ASAM standardization group for automotive standards.

Happy EV drivers expect ...

- Latest innovations
- Long range & fast charge
- A hassle-free car
- Continues improvements

but OEMs are facing issues

- Development time is too long and HW prototypes are cost drivers
- Battery performance must improve along with reduced time-to-market
- OEMs are facing high warranty cost due to many product re-calls
- Many OEMs are challenged with complex and slow software releases

*) Picture created with OpenAI

We will show …

How to save 50% of test time and 40% of time for model integration	1	Development time is too long and HW prototypes are cost drivers
How to move battery validation to the lab and improve health prediction with AI	2	Battery performance must improve along with reduced time-to-market
How to save hundreds of millions of $ in repair costs for OEMs using AI	3	OEMs are facing high warranty cost due to many product re-calls
How to manage and shorten the SW update release cycle from months to days	4	Many OEMs are challenged with complex and slow software releases

We will show …

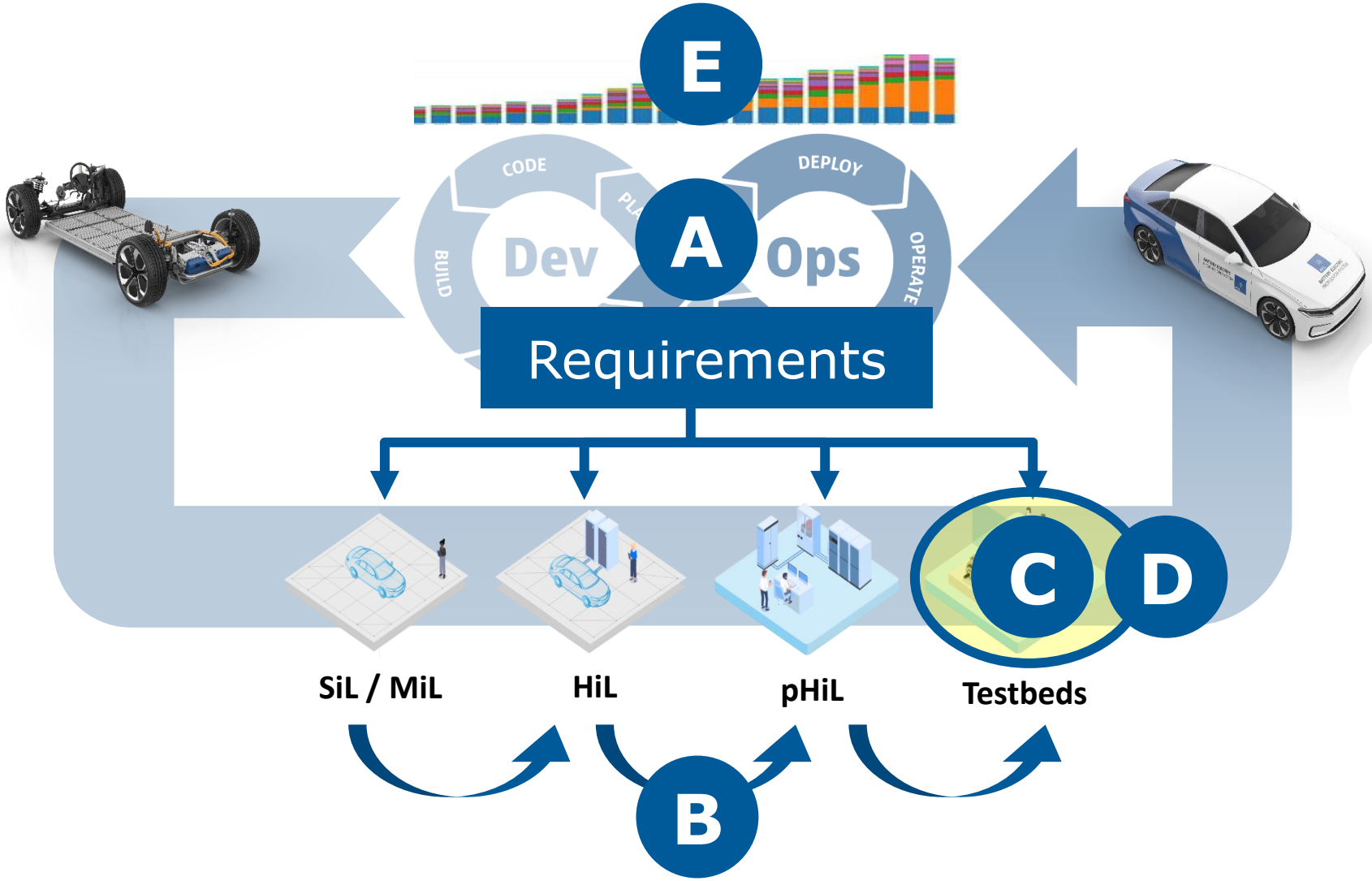
How to save 50% of test time and 40% of time for model integration	Deep Dive Webinar available from 30th June
How to move battery validation to the lab and improve health prediction with AI	Deep Dive Webinar available from 06th November
How to save hundreds of millions of $ in repair costs for OEMs using AI	Deep Dive Webinar available from 18th September
How to manage and shorten the SW update release cycle from months to days	Deep Dive Webinar available from 08th May

Today's Overview Webinar

We will show …

How to save 50% of test time and 40% of time for model integration	1	Development time is too long and HW prototypes are cost drivers
How to move battery validation to the lab and improve health prediction with AI	2	Battery performance must improve along with reduced time-to-market
How to save hundreds of millions of $ in repair costs for OEMs using AI	3	OEMs are facing high warranty cost due to many product re-calls
How to manage and shorten the SW update release cycle from months to days	4	Many OEMs are challenged with complex and slow software releases

1 Development time is too long and HW prototypes are cost drivers



A Current test environments lack SW pipeline integration, causing manual effort and delaying releases.

B Separate e-motor models for HiL and Power-HiL cause extra effort with complex integration of own models.

C High pressure to optimize e-drive efficiency and calibrate maps in short time due to limited testbed time.

D Low test equipment utilization

E Lack of product maturity progress tracking across the development process.

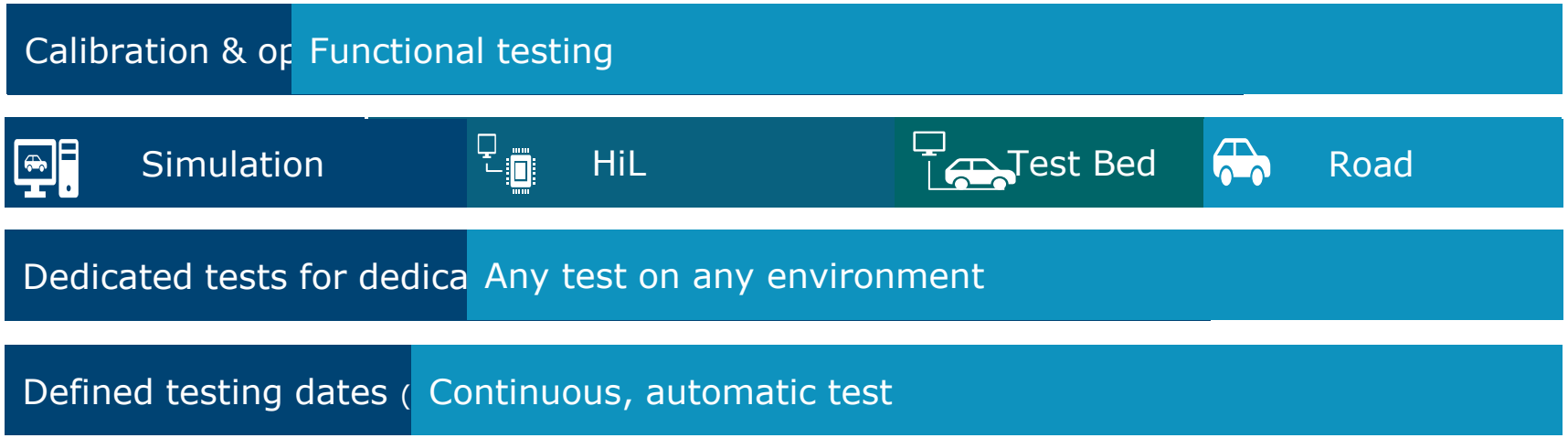
1 Development time is too long and HW prototypes are cost drivers

A Current test environments lack SW pipeline integration, causing manual effort and delaying releases.

1 Development time is too long and HW prototypes are cost drivers

Hardware-centric development process

Software-centric development process (DevOps)



A

Current test environments lack SW pipeline integration, causing manual effort and delaying releases.

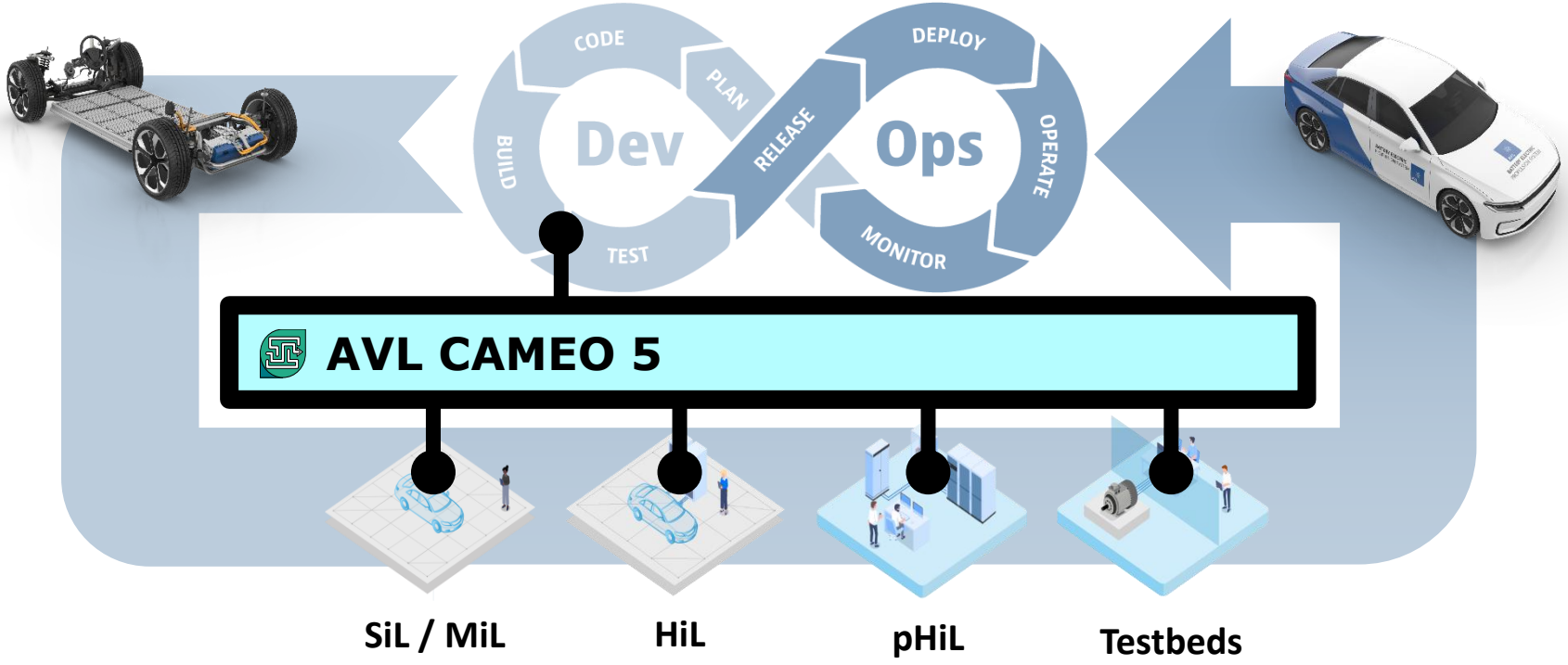
The Challenge:

- Increasing need for functional, continuous testing
- Example: Functional safety requires about 1800 individual tests
- Manual test case implementation is slow and error prone
- 60% of a typical project of 18 months is dedicated to test case implementation

1 Development time is too long and HW prototypes are cost drivers

A

Current test environments lack SW pipeline integration, causing manual effort and delaying releases.



60% of overall project effort can be automated

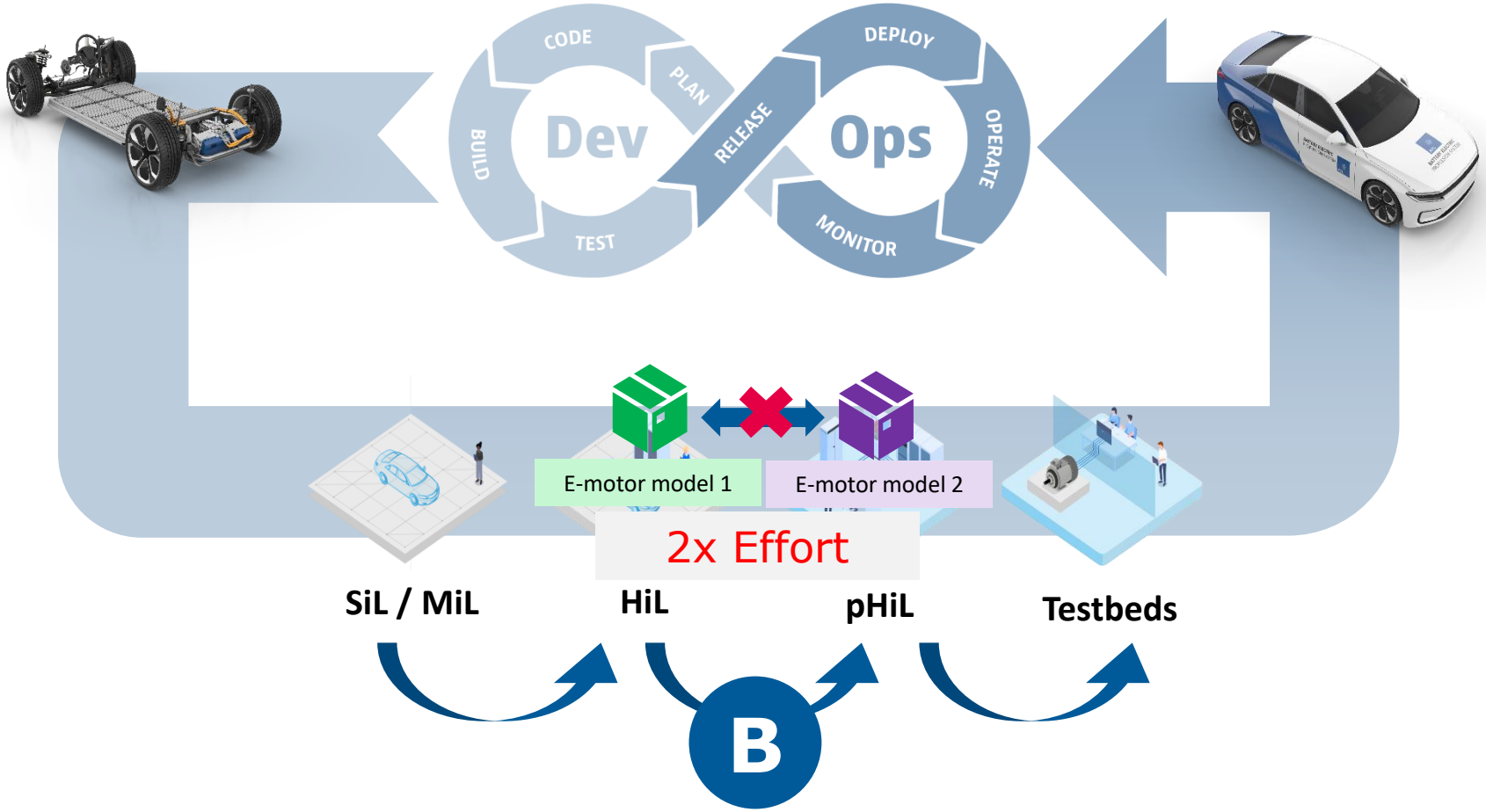
The Solution:

- Test cases are automatically read from the lifecycle management tool
- Tests are automatically triggered by the pipeline and executed; no manual intervention
- Full traceability as results and reports are sent back to the lifecycle management tool

1 Development time is too long and HW prototypes are cost drivers

B

Separate e-motor models for HiL and Power-HiL cause extra effort with complex integration of own models.

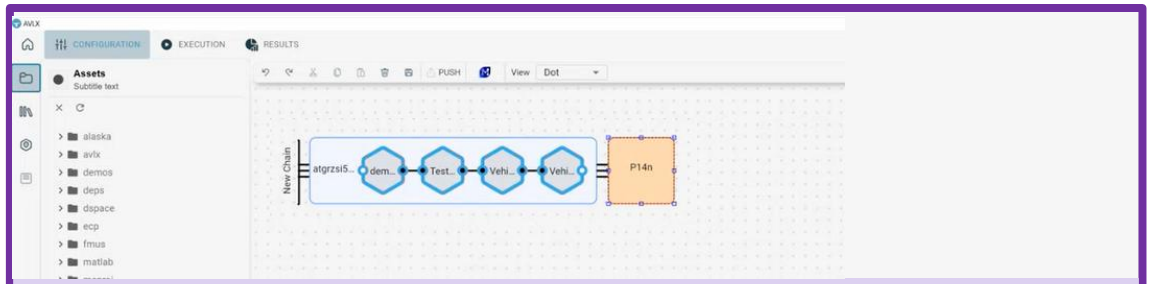


The Challenge:

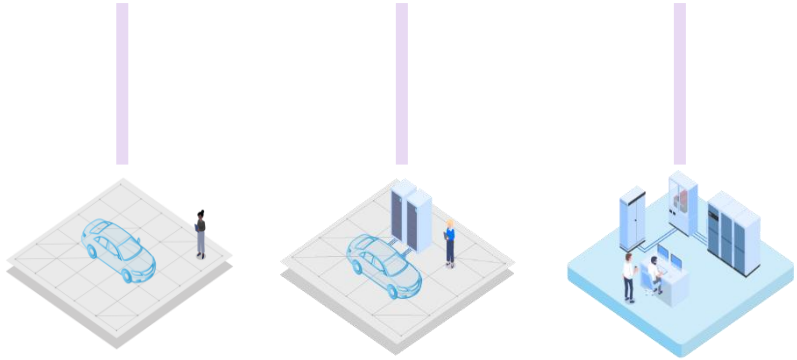
- SiL limitations drive preference for HiL/pHiL with complex integration.
- Separate HiL/pHiL models cause redundant parametrization.
- Integration complexity slows down e-drive development.

1 Development time is too long and HW prototypes are cost drivers

B Separate e-motor models for HiL and Power-HiL cause extra effort with complex integration of own models.

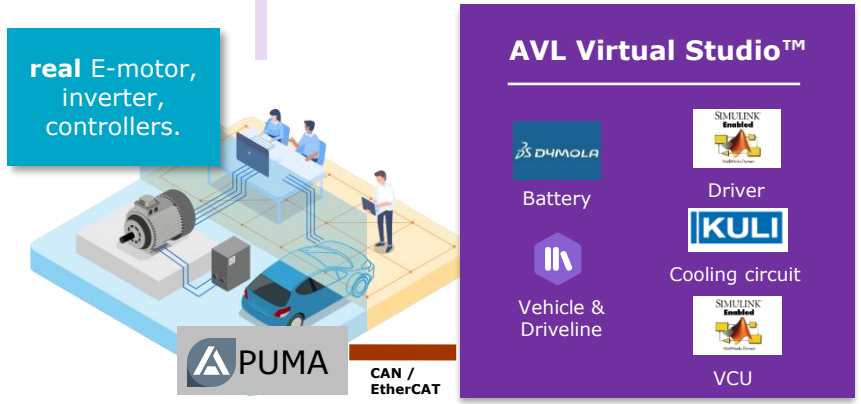


One configurator for all environments



SiL / MiL | HiL | pHiL

VECTOR | synopsys | dSPACE | MicroNova Software und Systeme



AVL Virtual Studio™

- Battery
- Driver
- Cooling circuit
- Vehicle & Driveline
- VCU

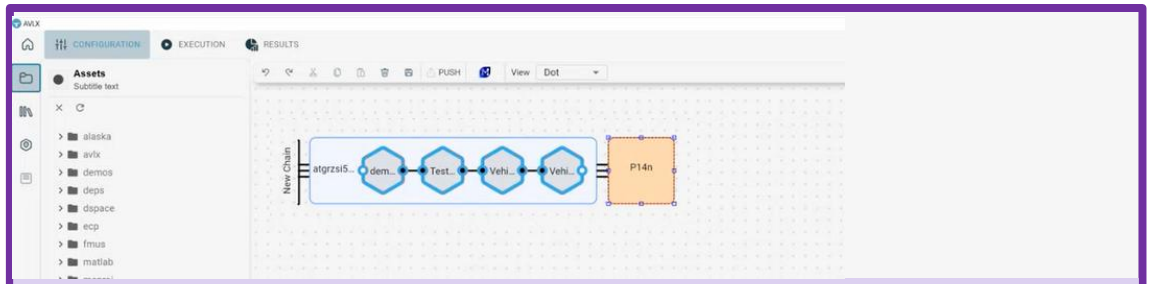
simulated vehicle

The Solution:

- Automatic pHiL model parametrization based on customer data
- Re-use of models in different test environments for less modelling and integration work
- Easier configuration as the models can be replaced with HW in later phases

1 Development time is too long and HW prototypes are cost drivers

B Separate e-motor models for HiL and Power-HiL cause extra effort with complex integration of own models.



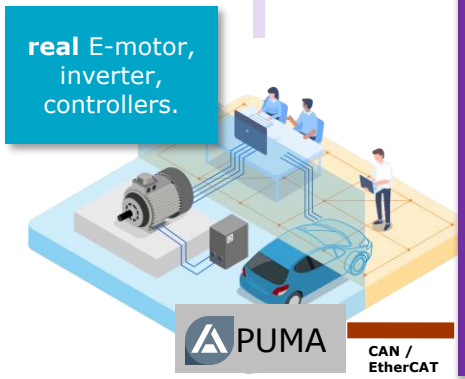
One configurator for all environments

SiL / MiL

HiL

pHiL

VECTOR synopsys dSPACE MicroNova Software und Systeme



AVL Virtual Studio™

- Battery
- Driver
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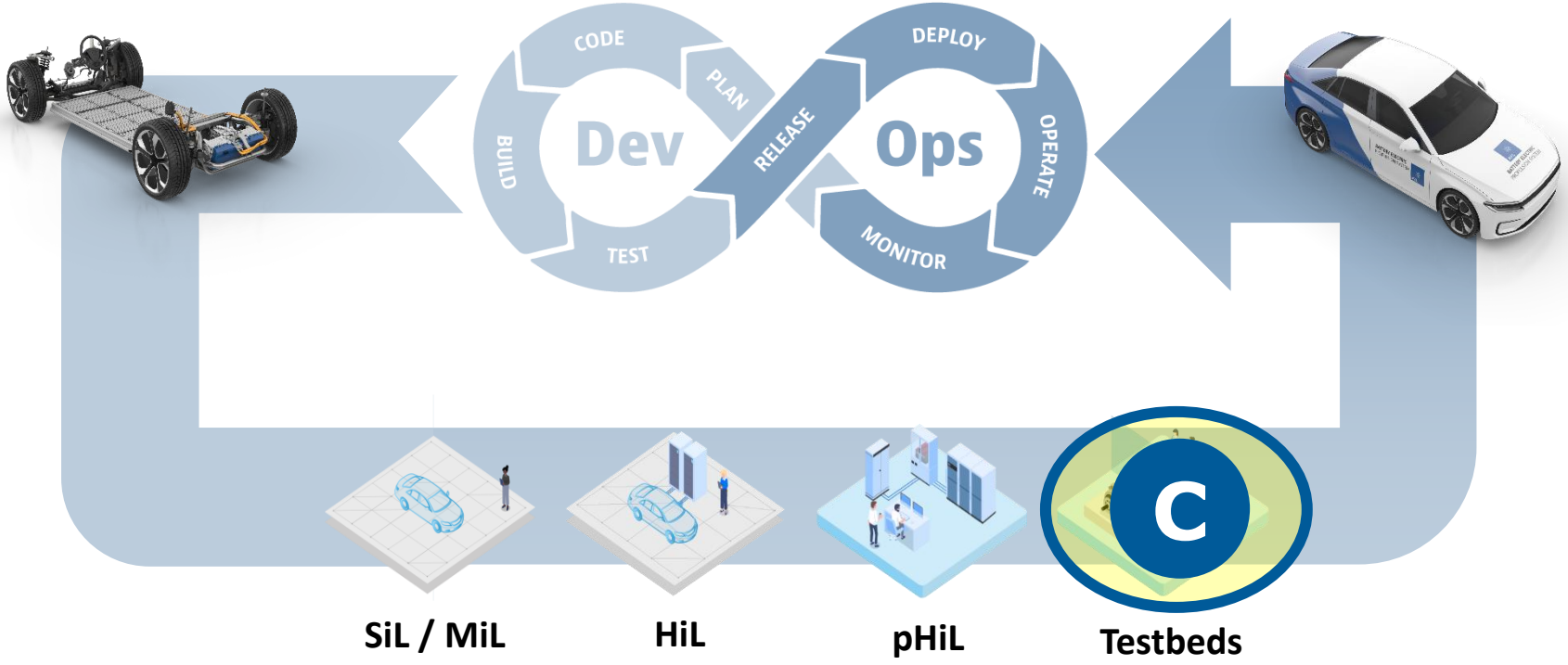
simulated vehicle

Key Benefits:

- 40% time-savings for preparation by automatic model integration
- Less modelling and integration work by re-using models across environments

1 Development time is too long and HW prototypes are cost drivers

C High pressure to optimize e-drive efficiency and calibrate maps in short time due to limited testbed time.

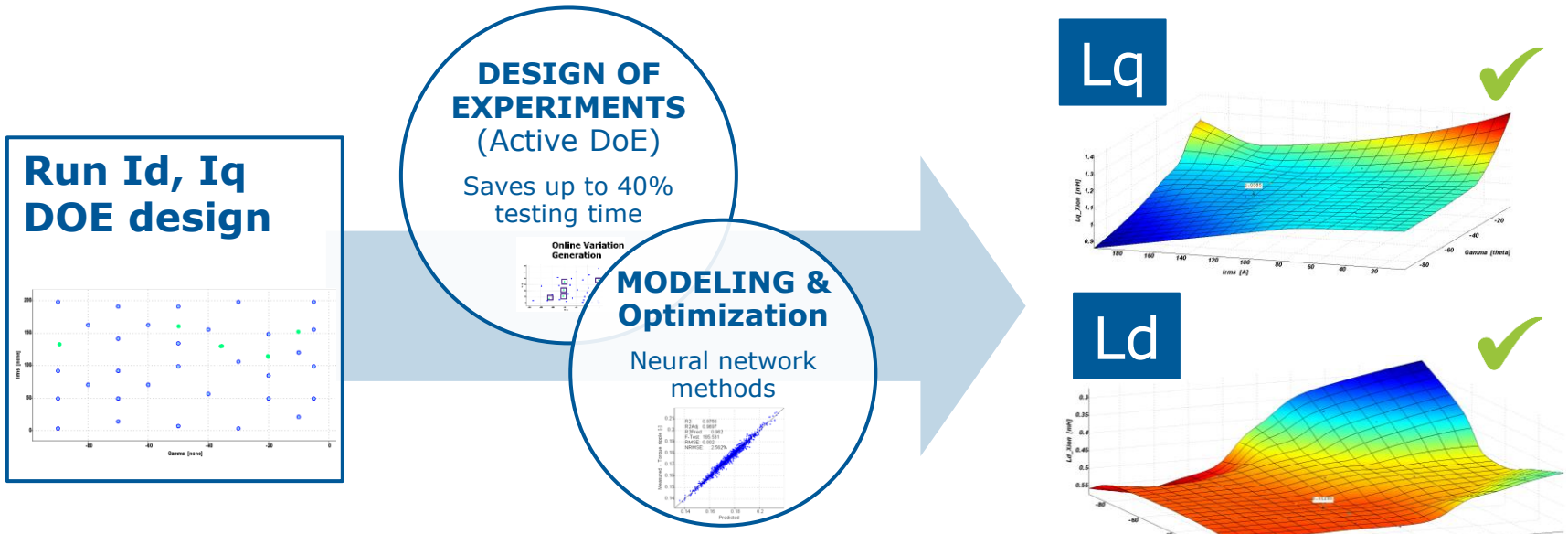


The Challenge:

Creating best E-drive efficiency and tuning of complete maps in a short time due to limited testbed resources and tight project milestones!

1 Development time is too long and HW prototypes are cost drivers

C High pressure to optimize e-drive efficiency and calibrate maps in short time due to limited testbed time.



Automatic map generation out of the online model

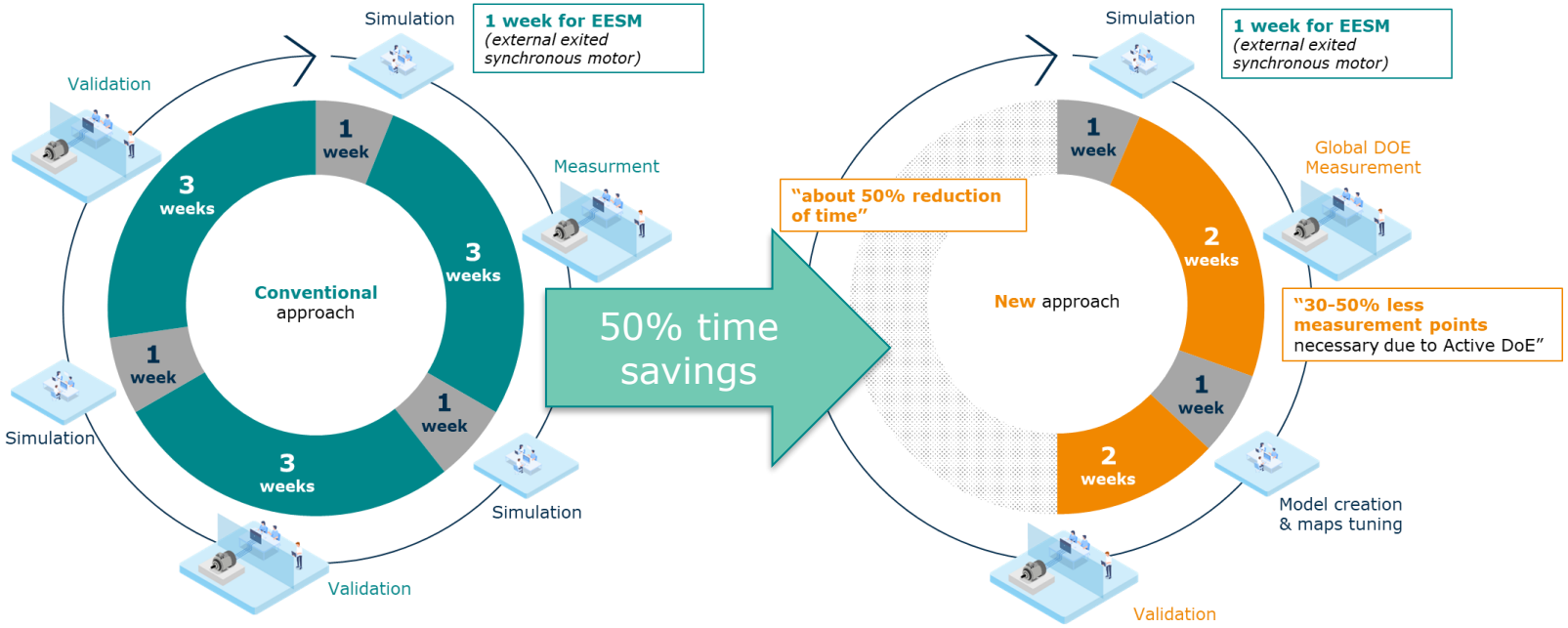
The Solution:

- A DoE test plan is executed as a start design
- It ensures efficient variation point distribution and has repetition points in noisy regions
- The measurements are used by CAMEO Active DoE to learn and execute extra test points in the noisy regions

1 Development time is too long and HW prototypes are cost drivers

High pressure to optimize e-drive efficiency and calibrate maps in short time due to limited testbed time.

Example: Global efficiency and torque accuracy optimization for an EESM



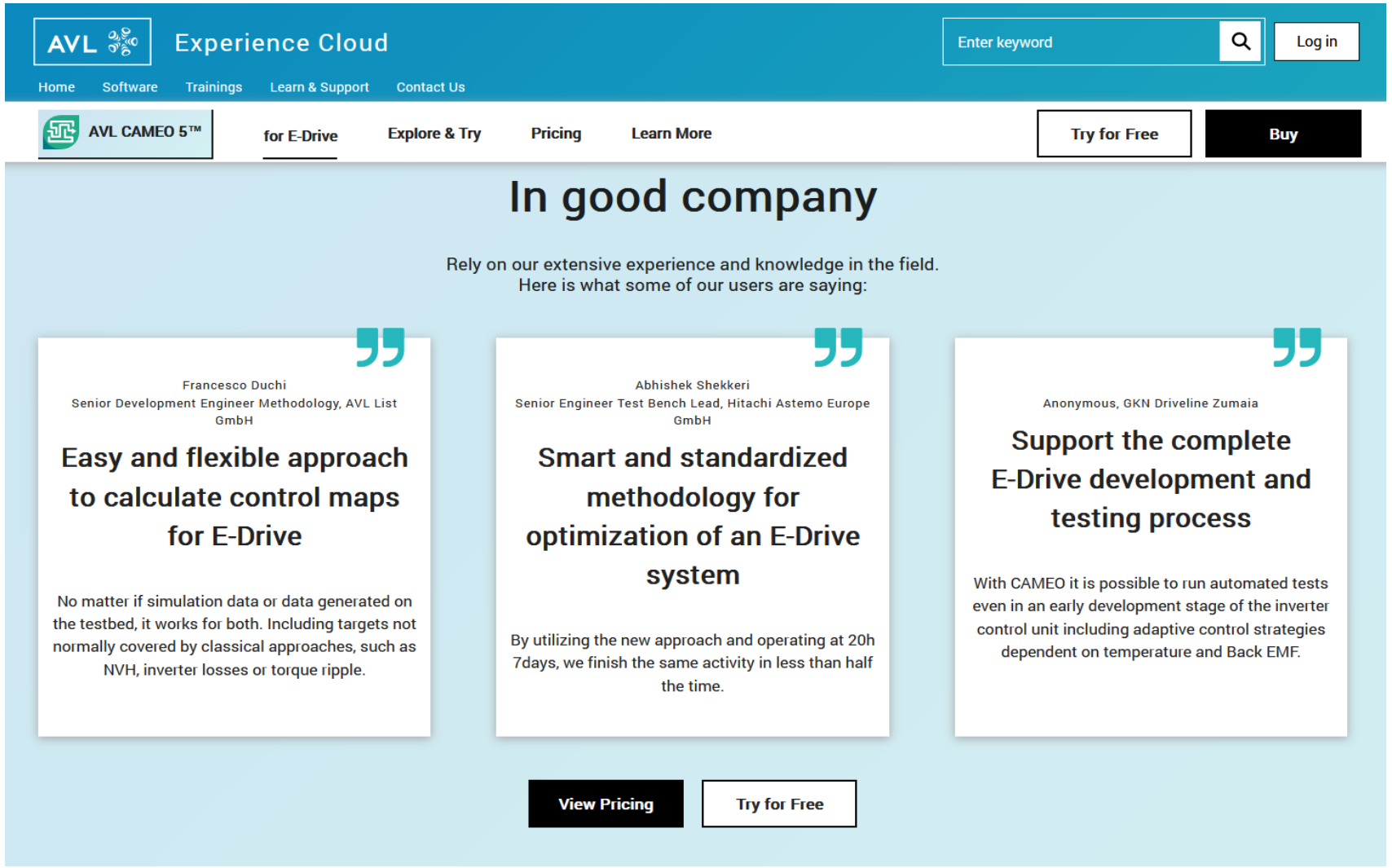
Key benefits:

- 50% time savings with AVL Active DoE
- Handle complex tuning of EESM with less effort
- Less manpower at testbed
- Reliable & reusable results

1 Development time is too long and HW prototypes are cost drivers

C

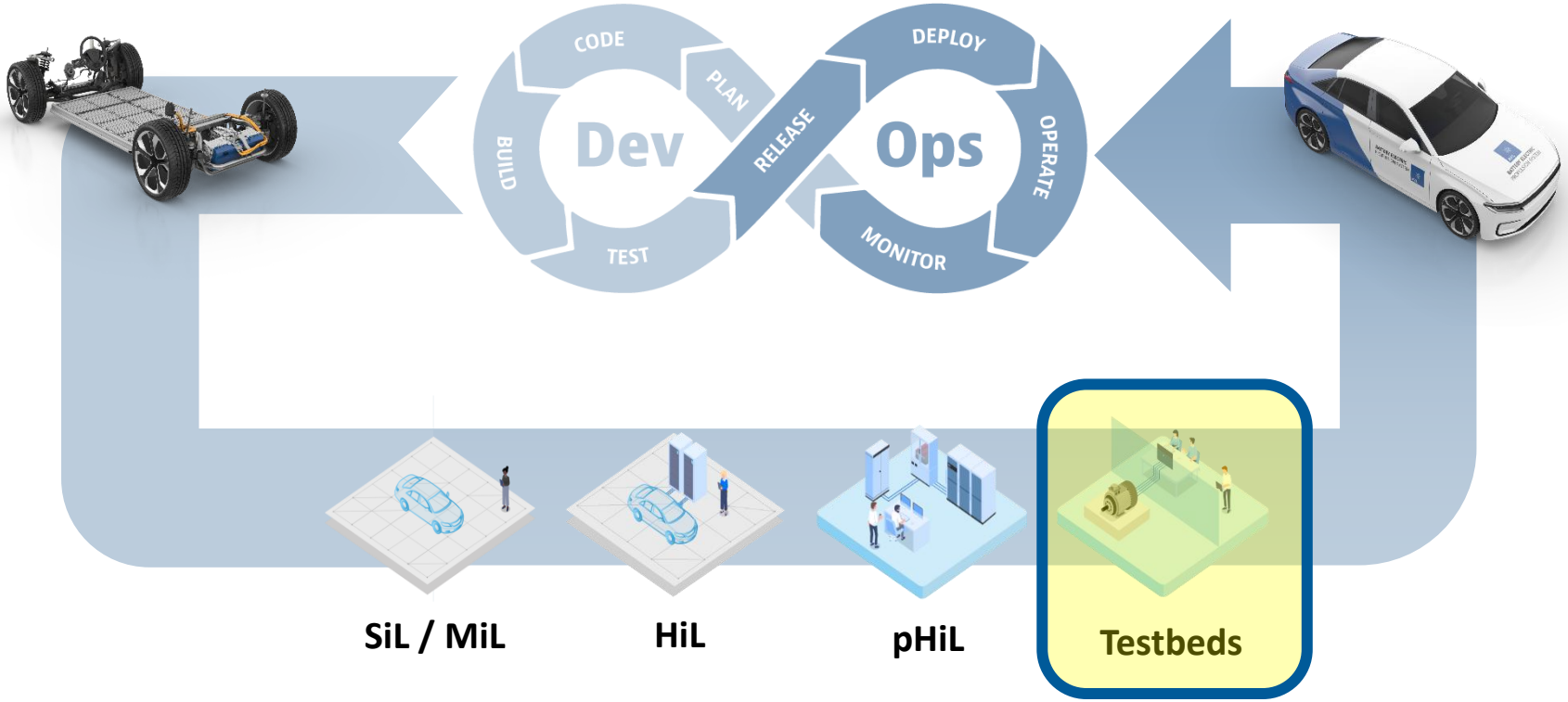
High pressure to optimize e-drive efficiency and calibrate maps in short time due to limited testbed time.



What others say ...

1 Development time is too long and HW prototypes are cost drivers

D Low test equipment utilization

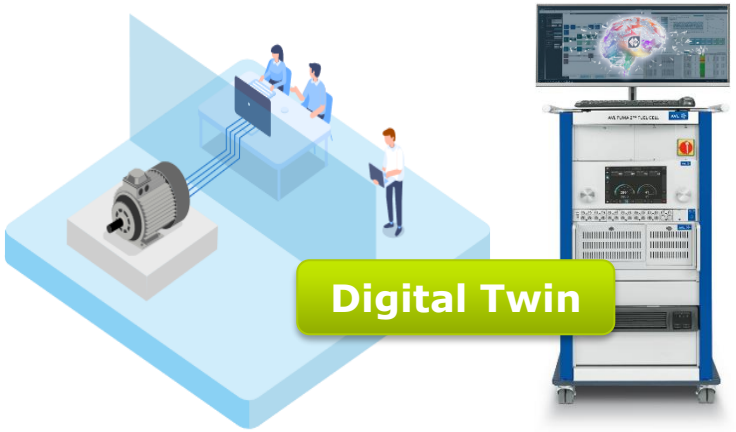


The Challenge:

- High operational cost and project delays because test runs need to be repeated
- Damages on UUT and testbed are detected too late

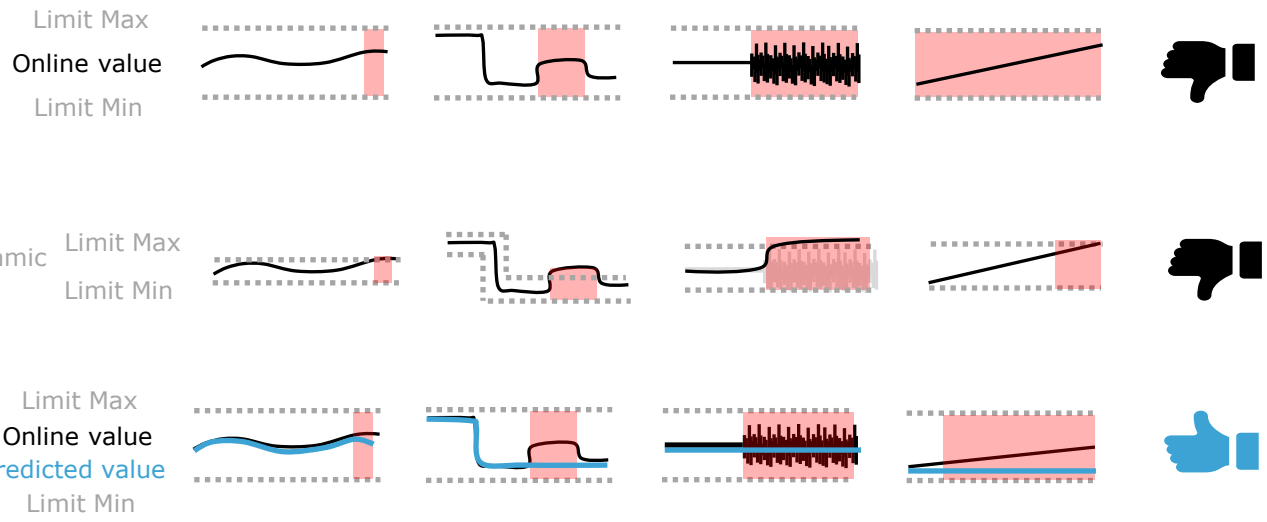
1 Development time is too long and HW prototypes are cost drivers

D Low test equipment utilization



PUMA2 Machine Learning detects non-plausible measurements

- Auto generate models from measurements
- Execute on testbeds for predictions
- No domain experts or complex configurations required

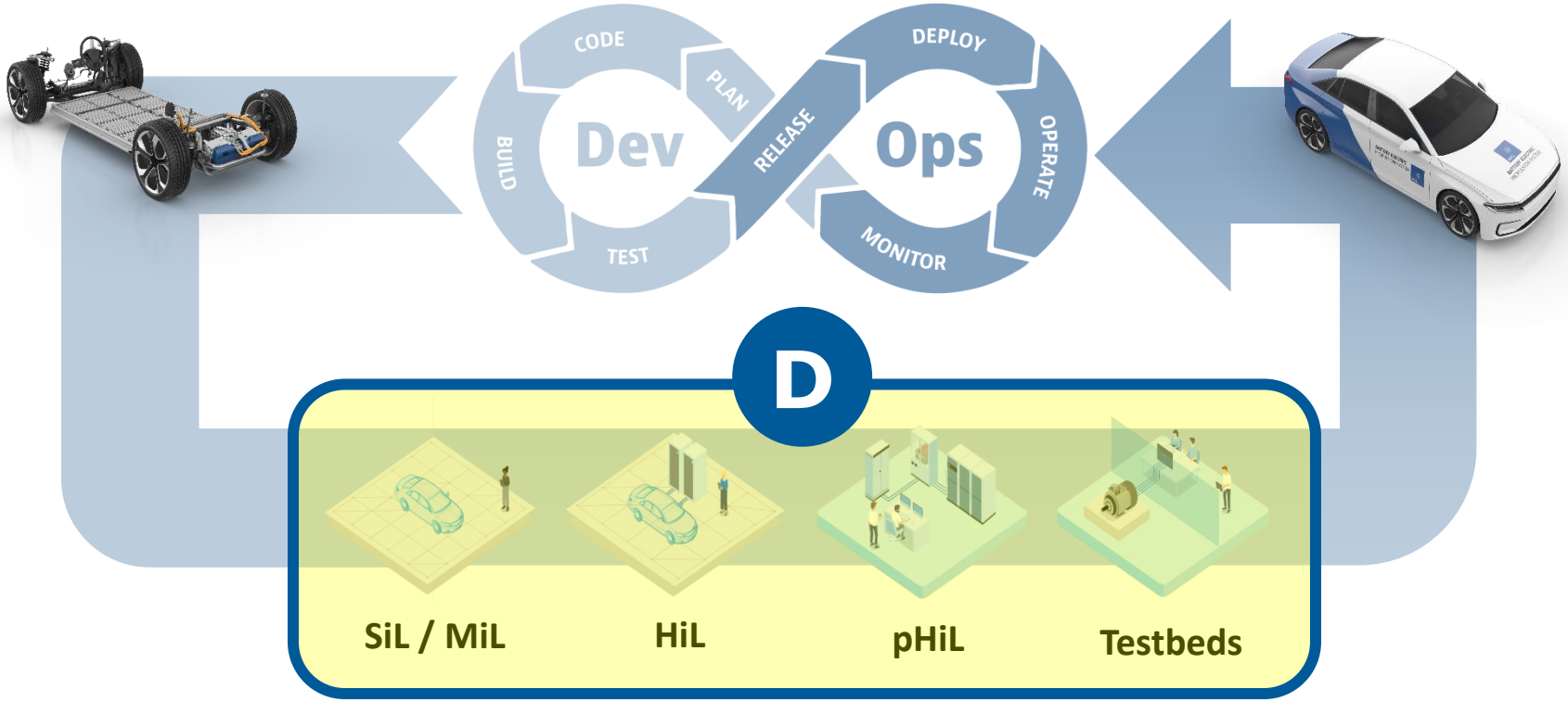


The Benefits:

- Detection of non-plausible behavior already during runtime
- Reduce testbed downtime:
  Stop invalid tests
- Save expert resources:
  Models are created automatically

1 Development time is too long and HW prototypes are cost drivers

D Low test equipment utilization

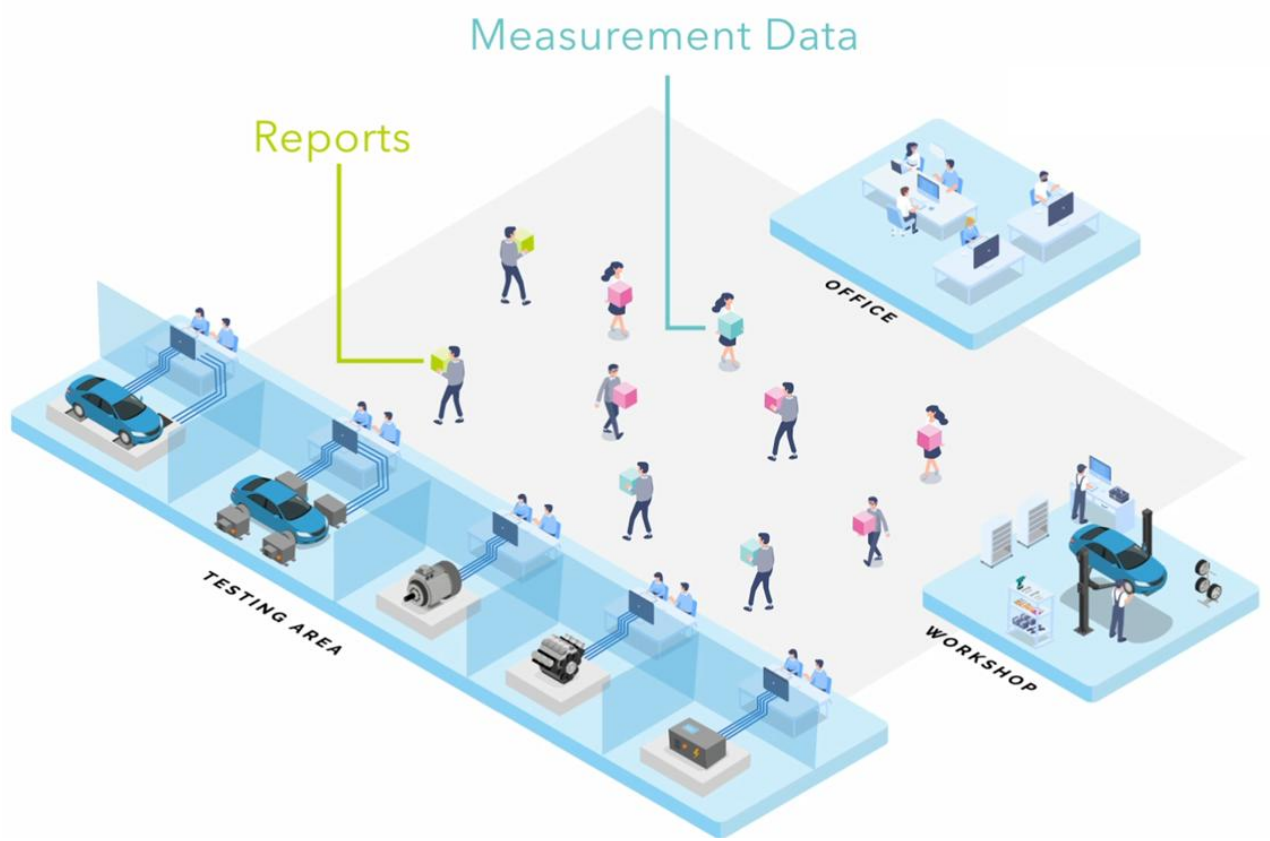


How to master the lab operations complexity?

1 Development time is too long and HW prototypes are cost drivers

D Low test equipment utilization

Inefficient Lab Operations



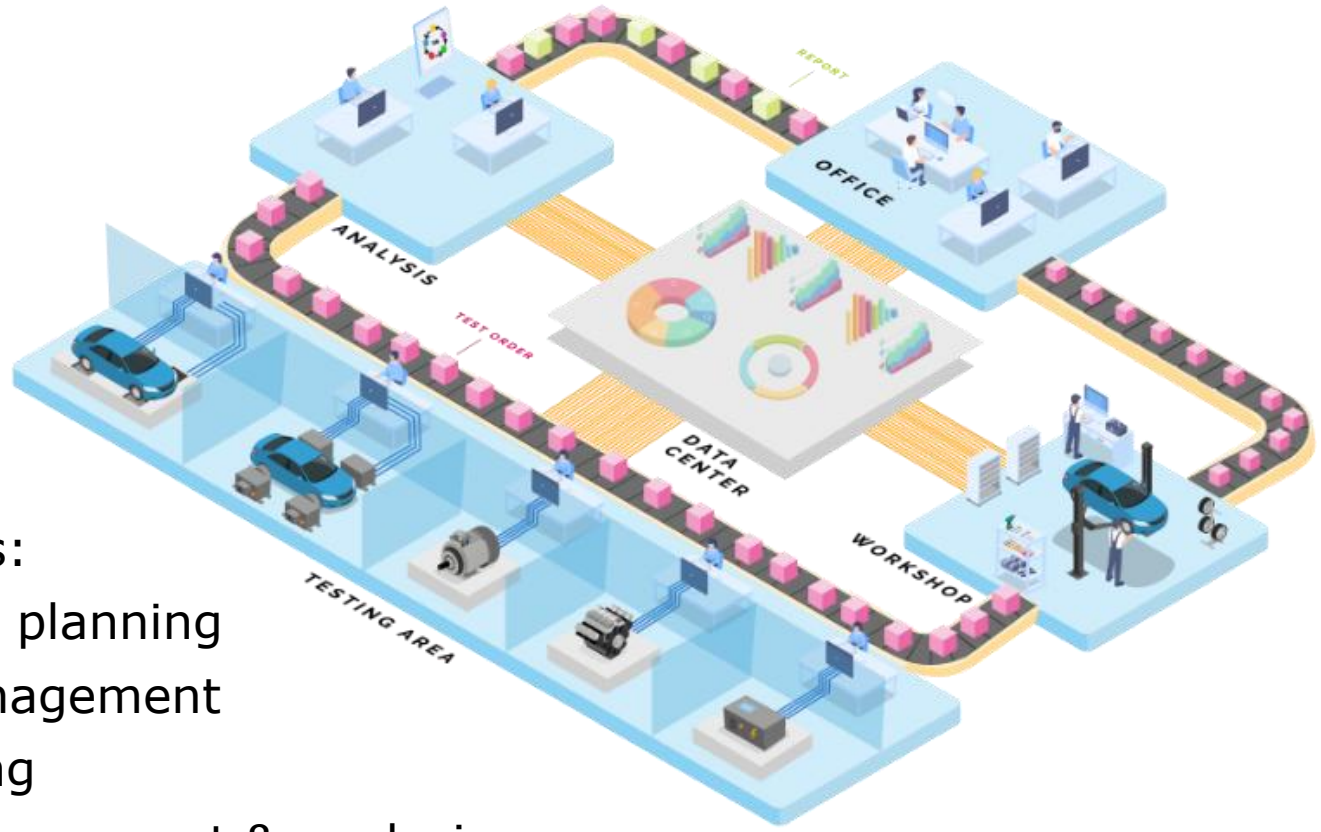
The Challenge:

- Increasing regulatory requirements
- Complex certification processes
- Disconnected, individual software solutions
- Lack of traceability
- High administrative overhead

1 Development time is too long and HW prototypes are cost drivers

D Low test equipment utilization

Optimized Lab Operations



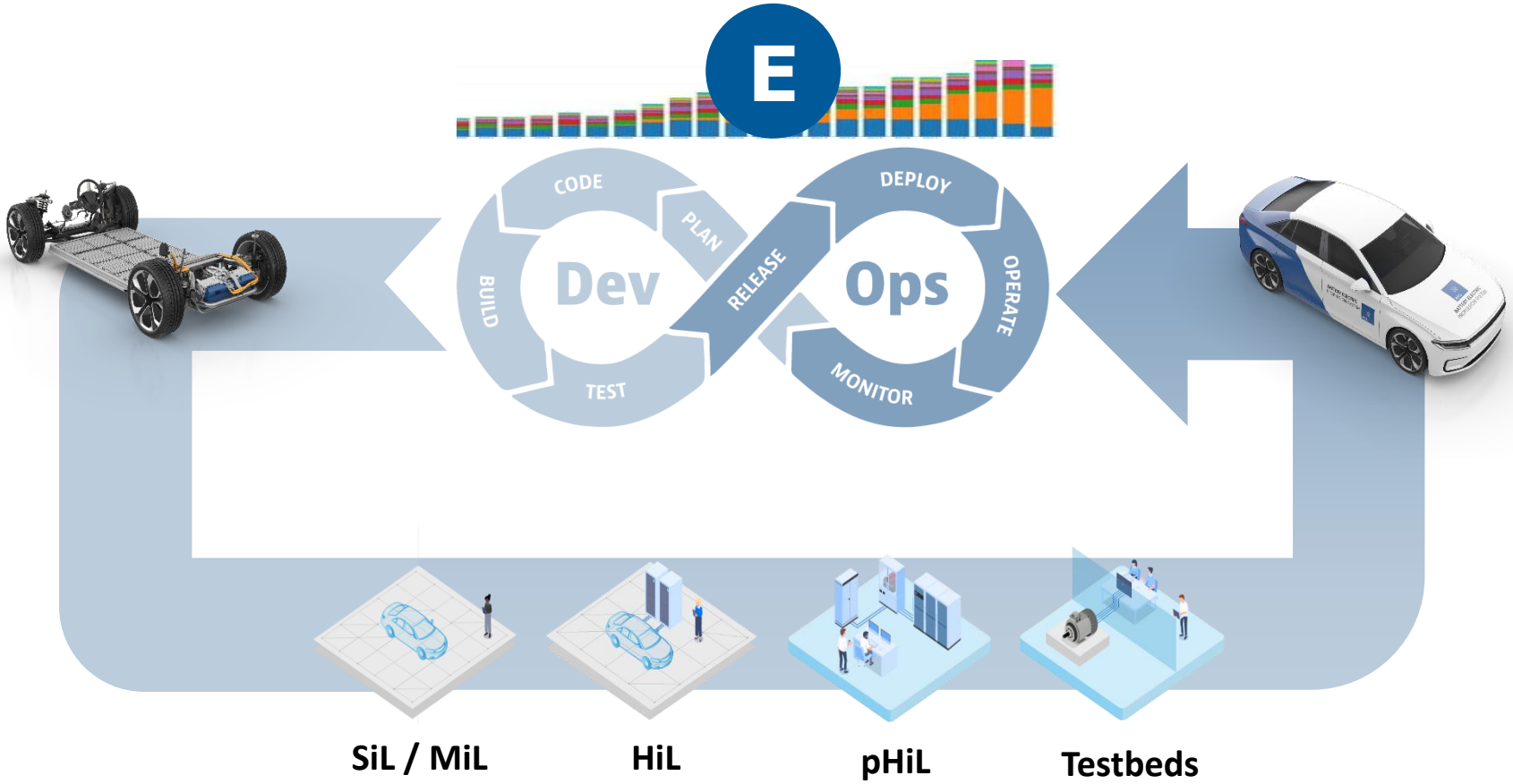
Key aspects:

- Resource planning
- Task management
- Monitoring
- Data management & analysis

The Solution:

- Template processes
- Seamless toolchain
- Automated resource scheduling
- Chain of custody
- 35% increased testbed utilization

1 Development time is too long and HW prototypes are cost drivers

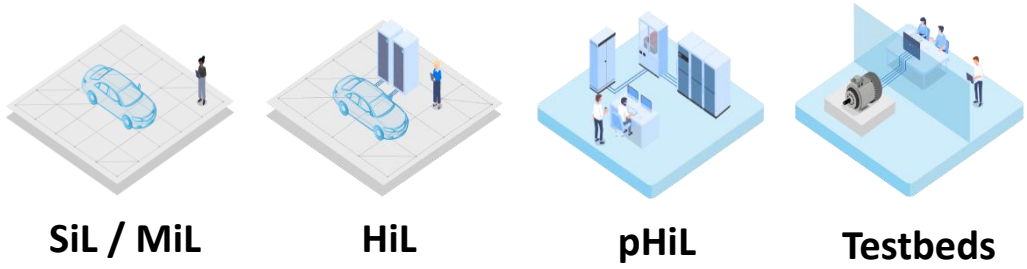


E Lack of product maturity progress tracking across the development process.

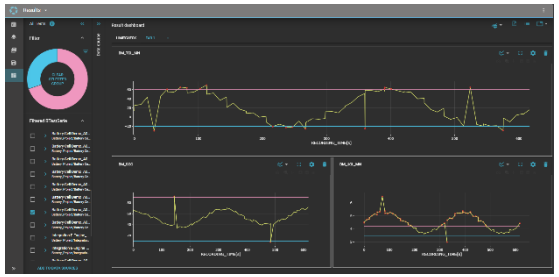
The Challenge:

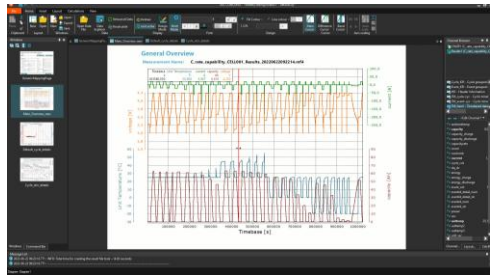
- No single point of truth for test data
- Unreliable manual data collection
- Traceability and regulatory compliance not given
- Manual, error-prone data analysis with fragmented tool-chain

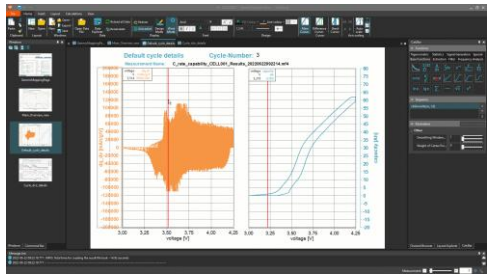
1 Development time is too long and HW prototypes are cost drivers



Result data







E Lack of product maturity progress tracking across the development process.

The Solution:

- Automated data ingest, harmonization and evaluation
- Full data traceability
- Less manual work and no data loss
- Automated KPI tracking along the dev. process

We will show …

How to save 50% of test time and 40% of time for model integration

1

Development time is too long and HW prototypes are cost drivers

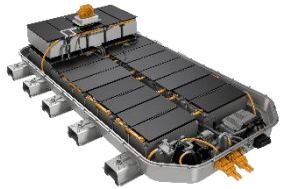
How to move battery validation to the lab and improve health prediction with AI

2

Battery performance must improve along with reduced time-to-market

2 Battery performance must improve along with reduced time-to-market

Cell Development & Qualification | **Pack Integration and Validation** | **In-Use Phase**



A

B

C

A SOH determination takes a lot of cell-testing time

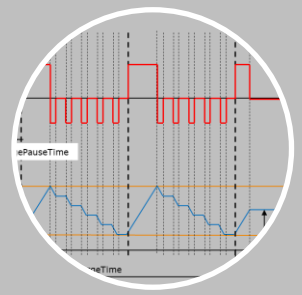
B Late battery validation with physical vehicle prototypes may lead to SOP delay or degraded performance

C EV battery health status is unreliable

2 Battery performance must improve along with reduced time-to-market

A SOH determination takes a lot of cell-testing time

Influencing factors on cell aging…



Charge, Discharge

Temperature

Resting

Mechanical Stress

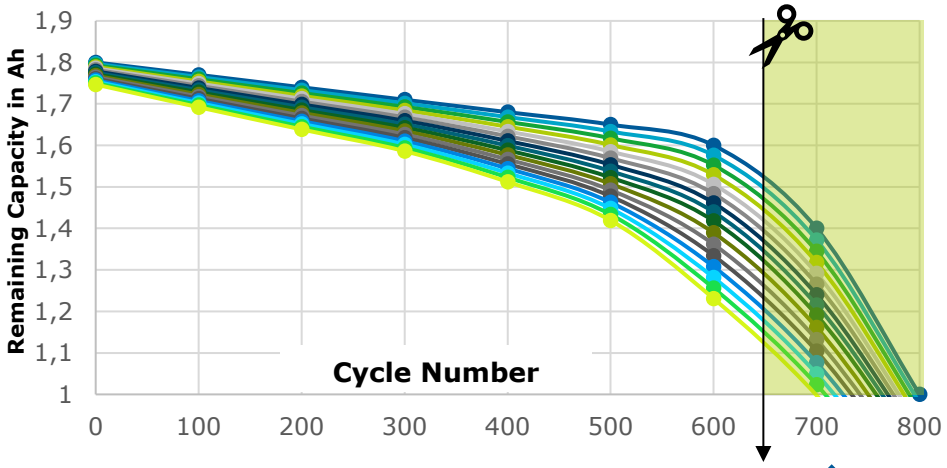
And each parameter variation takes months to measure!

The Challenge:

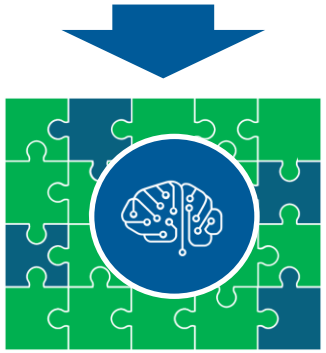
- Many influencing factors
- Each parameter variation takes months of test time
- Total aging test time takes more than a year

2 Battery performance must improve along with reduced time-to-market

Cell cycling until SOH=80%



Measurement data



AI based method:

Train a model on test data correlating fast- and slow-aging cells to predict slow cells' EOL

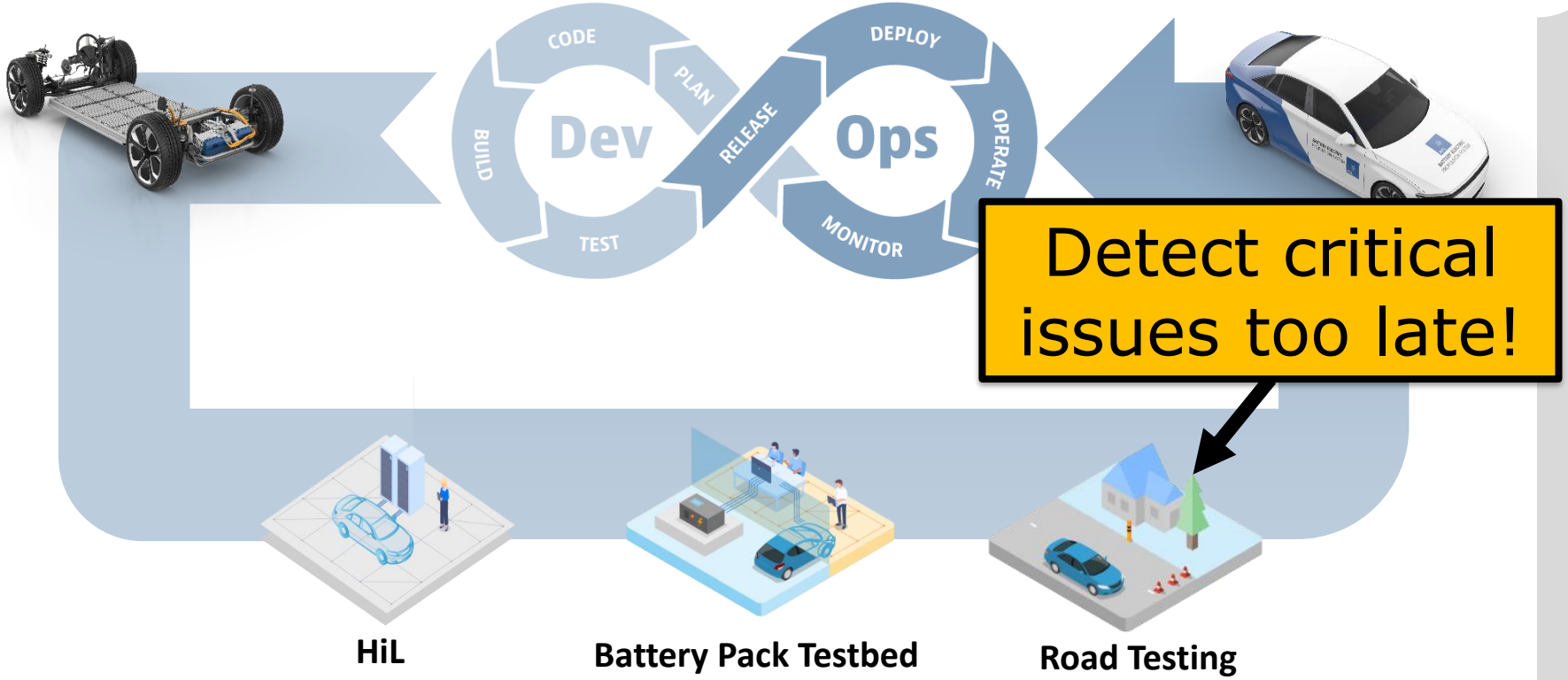
20% - 40% reduction of test time

A SOH determination takes a lot of cell-testing time

The Solution:

- Train a model to learn the relationship between fast aging and slower aging cells
- Once model precision is good enough predict the remaining cycles using the model

2 Battery performance must improve along with reduced time-to-market



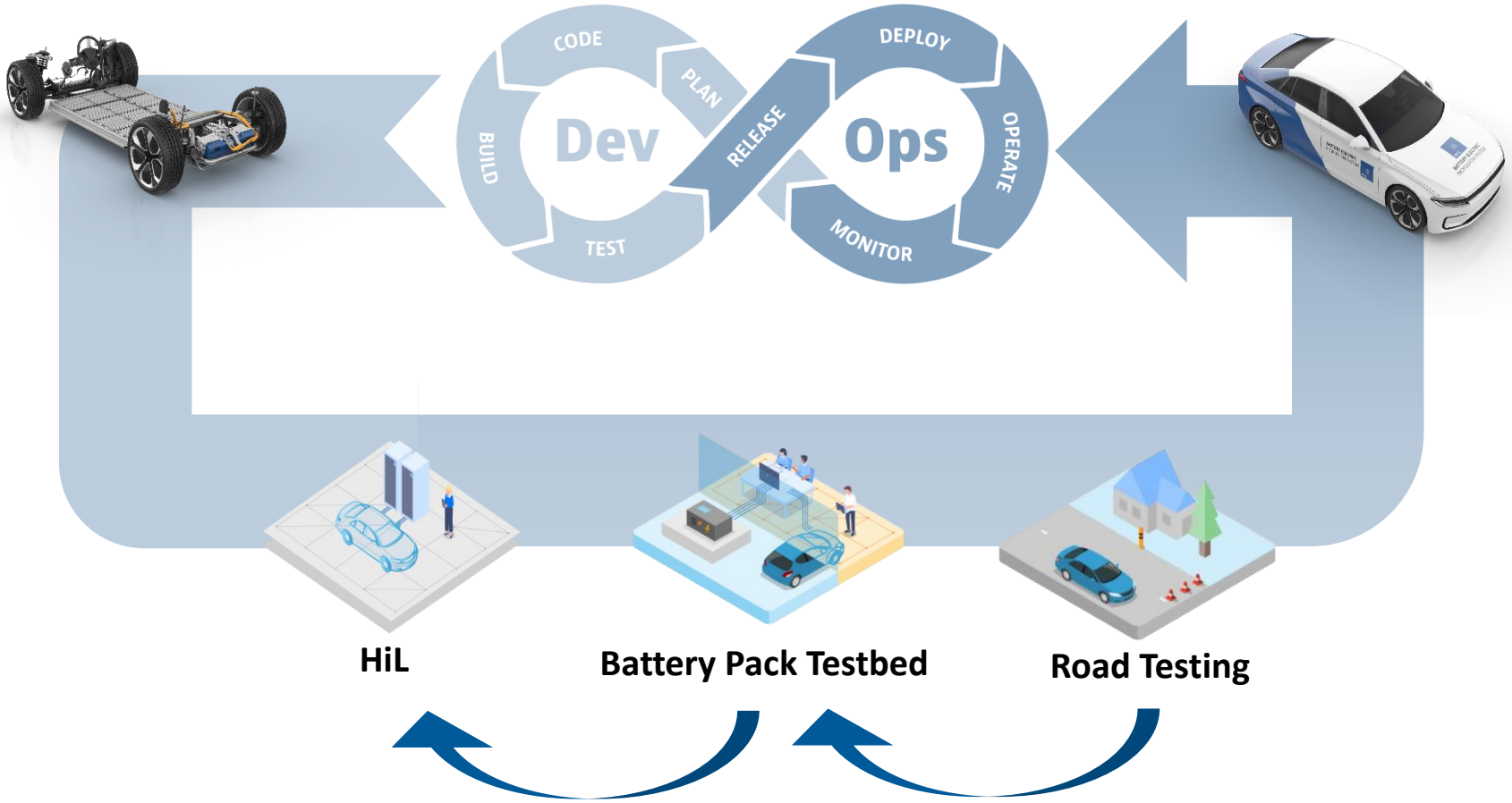
B

Late battery validation with physical vehicle prototypes may lead to SOP delay or degraded performance

The Challenge:

- Physical battery pack validation in the vehicle gives realistic results …
- But it’s too late
- High risk for SOP delay and huge cost

2 Battery performance must improve along with reduced time-to-market



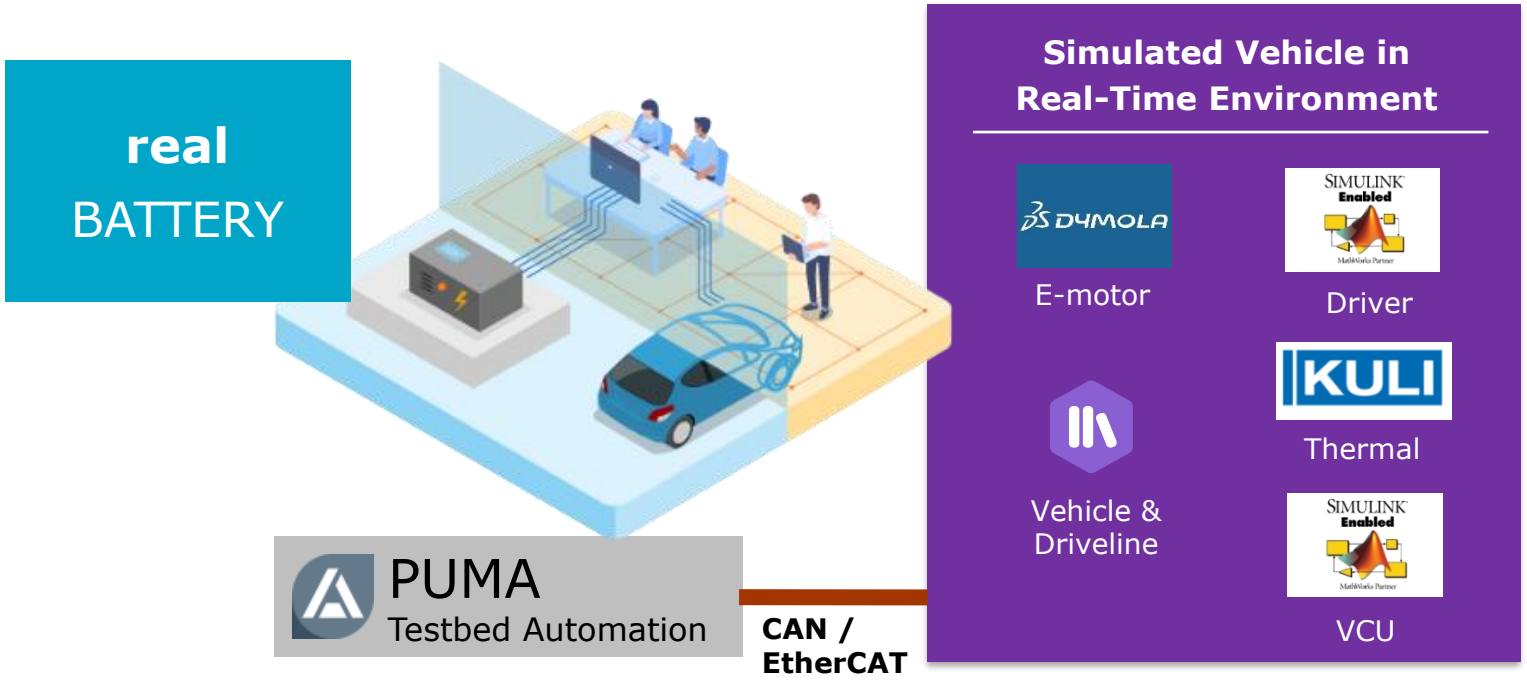
B Late battery validation with physical vehicle prototypes may lead to SOP delay or degraded performance

The Solution:

- Shift left battery pack validation to the battery testbed
- Integrate realistic vehicle simulation incl. driver and thermal system
- Perform BMS development on the HIL with vehicle simulation

2 Battery performance must improve along with reduced time-to-market

Battery in-the-loop setup



B Late battery validation with physical vehicle prototypes may lead to SOP delay or degraded performance

The Benefits:

- Predict aging behavior with realistic vehicle and thermal loads
- Early SOx validation and pack testing with vehicle behavior
- Vehicle range validation
- Consider various thermal strategies
- Performance testing on vehicle level

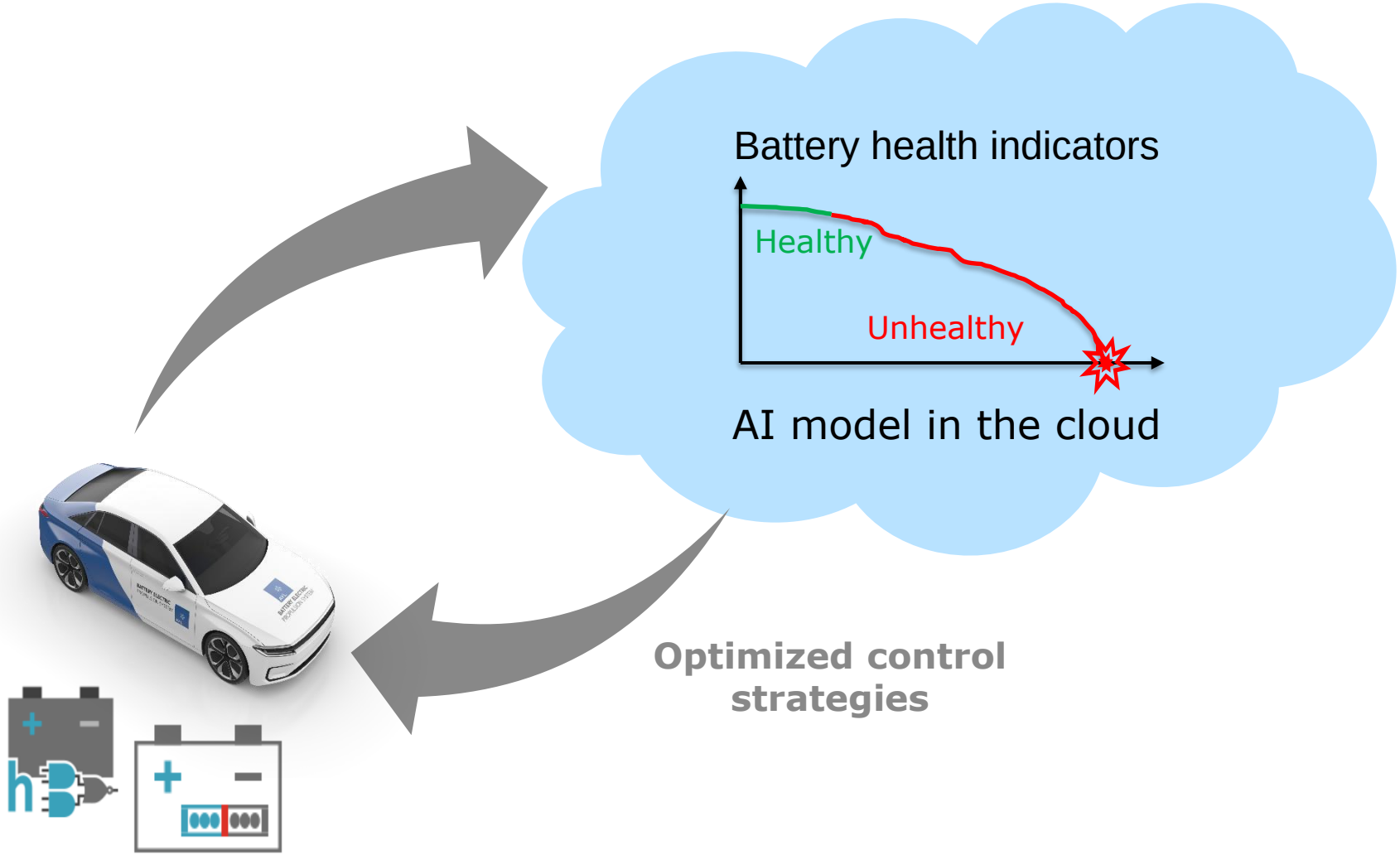
2 Battery performance must improve along with reduced time-to-market

C EV battery health status is unreliable

The Challenge:

- SOx prediction inconsistent
- BMS needs to detect warranty events
- Calculate maintenance planning

2 Battery performance must improve along with reduced time-to-market

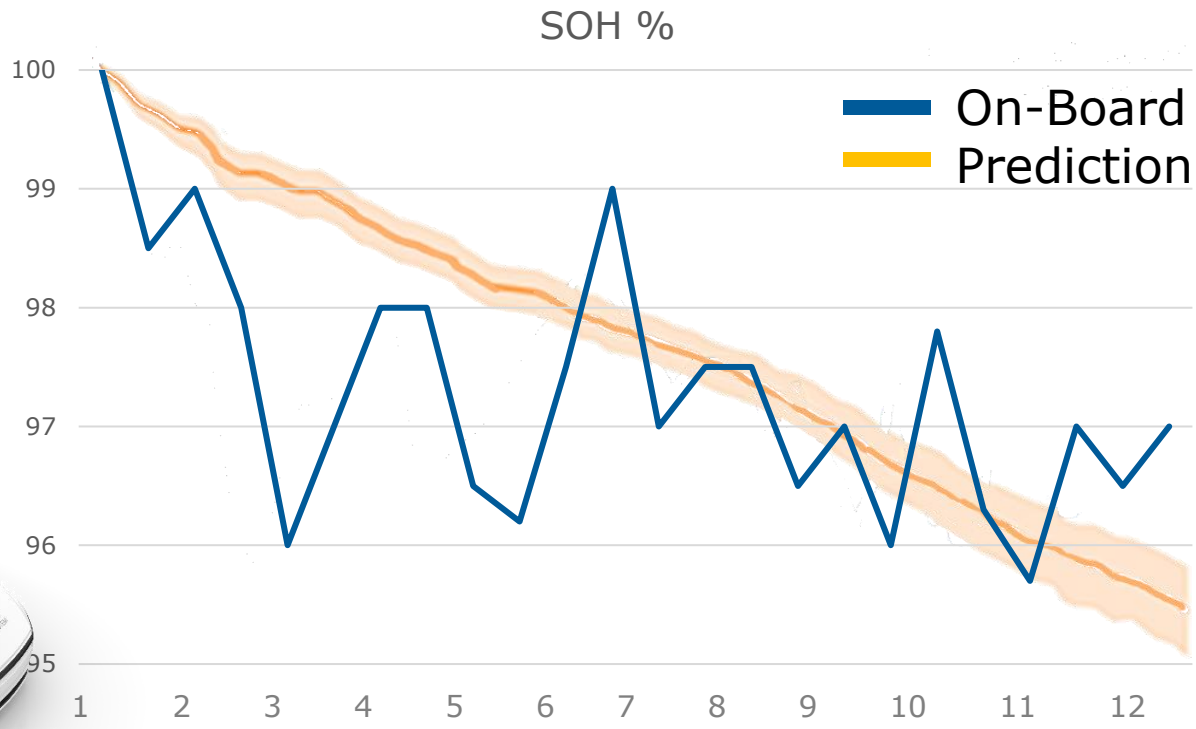


C EV battery health status is unreliable

The Solution:

- SOH prediction model in the cloud
- Update BMS with optimized control strategies

2 Battery performance must improve along with reduced time-to-market



C EV battery health status is unreliable

The Benefits:

- Exact SOx status
- Anomaly detection
- Consistent lifetime prediction

We will show …

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Development time is too long and HW prototypes are cost drivers

How to move battery validation to the lab and improve health prediction with AI

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Battery performance must improve along with reduced time-to-market

How to save hundreds of millions of $ in repair costs for OEMs using AI

3

OEMs are facing high warranty cost due to many product re-calls

3 OEMs are facing high warranty cost due to many product re-calls

Automotive OEMs spent about 45 B$ for warranty claims in 2022

Largest BEV recalls due to risk of fire in the US

2018
200.000 vehicles

2019
100.000 vehicles

2021
75.000 vehicles
→ 800 M$ repair cost

Warranty claims in the automotive industry have a huge potential for cost savings

A Quality issues in the fleet are unpredictable during operation

The Challenge:

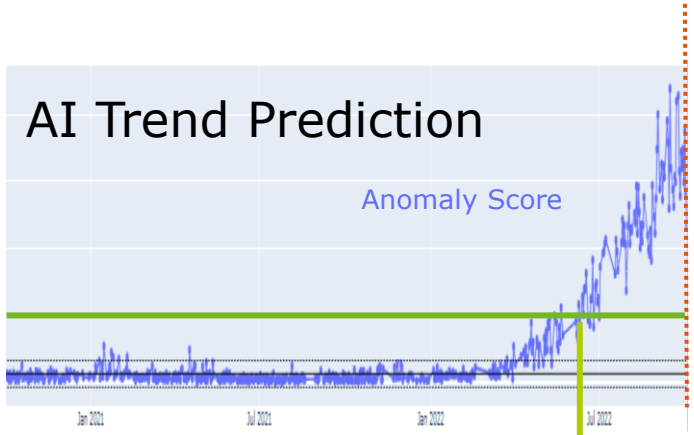
- A single vehicle recall action can lead to costs of up to $1.8 billion.
- The damage to brand reputation is hard to recover.

https://research.alpha-sense.com/?docid=WEB-EX-SGX-2aec62a47b78093cfcaf571d6a770683&k=automotive%20OEM%20warranty%20expenses&stmt=fse75531&page=22%2C22&slop=15&scope=ANYWHERE&hl=fse75531

https://interestingengineering.com/lists/biggest-ev-recalls

3 OEMs are facing high warranty cost due to many product re-calls

Battery failure



Potential identification 3 months before failure

Recalls

Recalls avoided

VIN / Vehicle*)	Risk
1FAFP45X83F403461	87,6%
1C4NJPBA1CD661292	82,7%
1G8ZF5287XZ363384	79,3%
WMWRC33474TC49530	74,1%
WP0CA29924S650563	68,9%
WV2YB0257EH008533	64,1%
5TEWN72N63Z275910	60,7%
1GCFG25F6V1059733	54,1%
2G1WH55K5Y9322458	52,7%
SAJWA2GEXBMV00832	46,0%
5XYKT3A69DG353356	43,6%
2B3ED56F5RH142129	43,4%
4V4N99EH3CN554692	42,5%
1G4HP54KX24151104	42,2%
1FMCU14T6JU400773	36,2%
JHMSZ542XDC028494	30,8%
1GCHK23244F199207	28,1%
JH4DA9340LS003571	26,5%
1FAFP58S11A177991	23,5%
JM3TB2MA5A0235007	19,2%
JH4DC2380RS000036	16,2%
WBACB4324RFL14401	11,0%

*) Listed VINs are not real ones

97% of issues are identified one month ahead
38% of issues are identified one year ahead

Joint publication with Jaguar Land Rover at the 10th International Symposium on Development Methodology, Nov. 2023

A Quality issues in the fleet are unpredictable during operation

Key Benefits:

- 92% less product recalls
- Hundreds of million $ saved in repair cost
- Safeguard brand reputation

We will show …

How to save 50% of test time and 40% of time for model integration

1

Development time is too long and HW prototypes are cost drivers

How to move battery validation to the lab and improve health prediction with AI

2

Battery performance must improve along with reduced time-to-market

How to save hundreds of millions of $ in repair costs for OEMs using AI

3

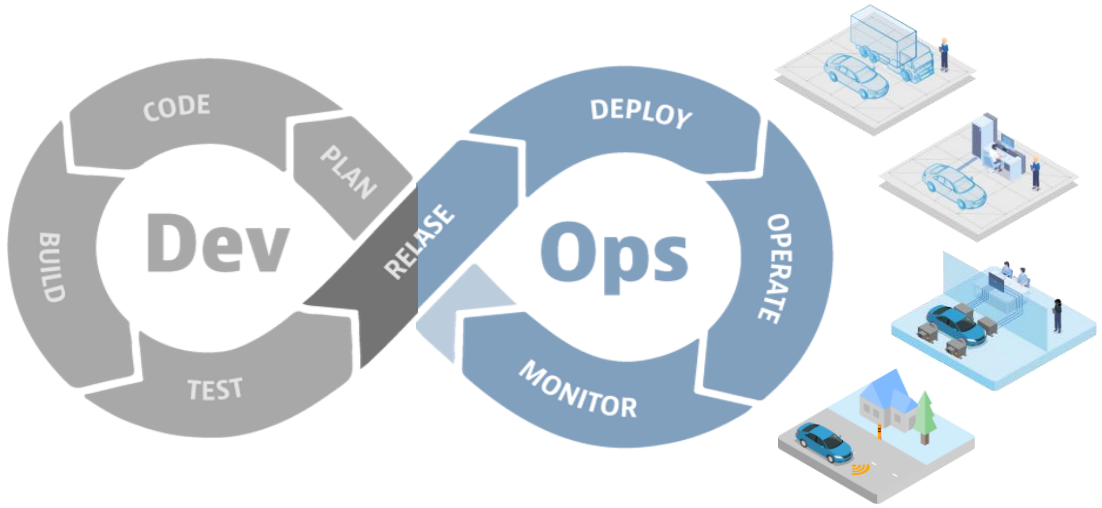
OEMs are facing high warranty cost due to many product re-calls

How to manage and shorten the SW update release cycle from months to days

4

Many OEMs are challenged with complex and slow software releases

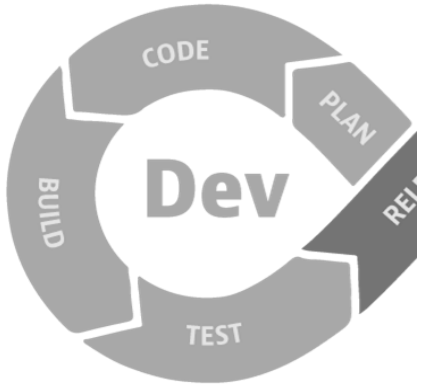
4 Many OEMs are challenged with complex and slow software releases

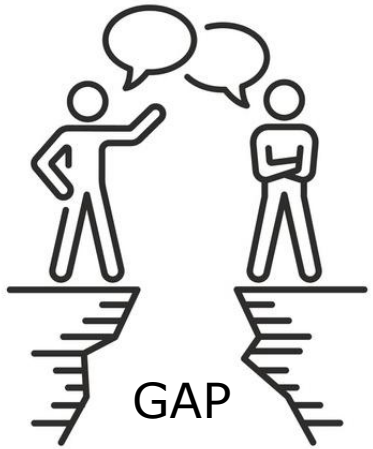


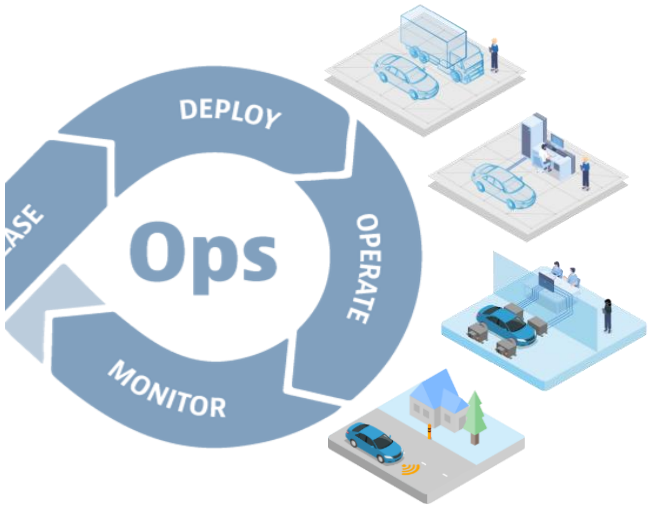
Software experts

Test-/calibration experts

4 Many OEMs are challenged with complex and slow software releases







Software experts

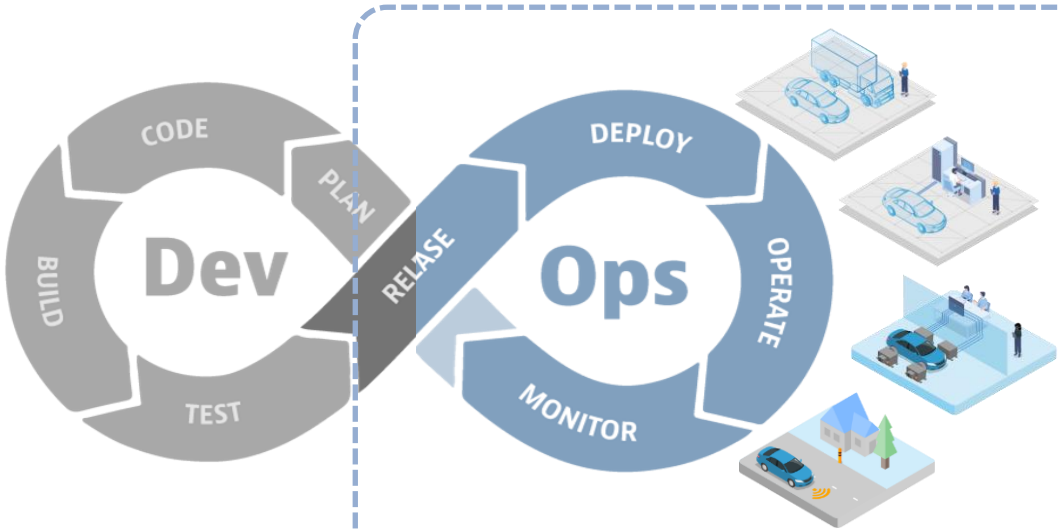
Test-/calibration experts

A Modern software development pushes the current sequential methodology to its limits.

B This requires tighter integration of software development, calibration, and testing.

C Despite faster release cycles, compliance aspects like UN ECE R156 SUMS must be fulfilled.

4 Many OEMs are challenged with complex and slow software releases



Software experts

Test-/calibration experts

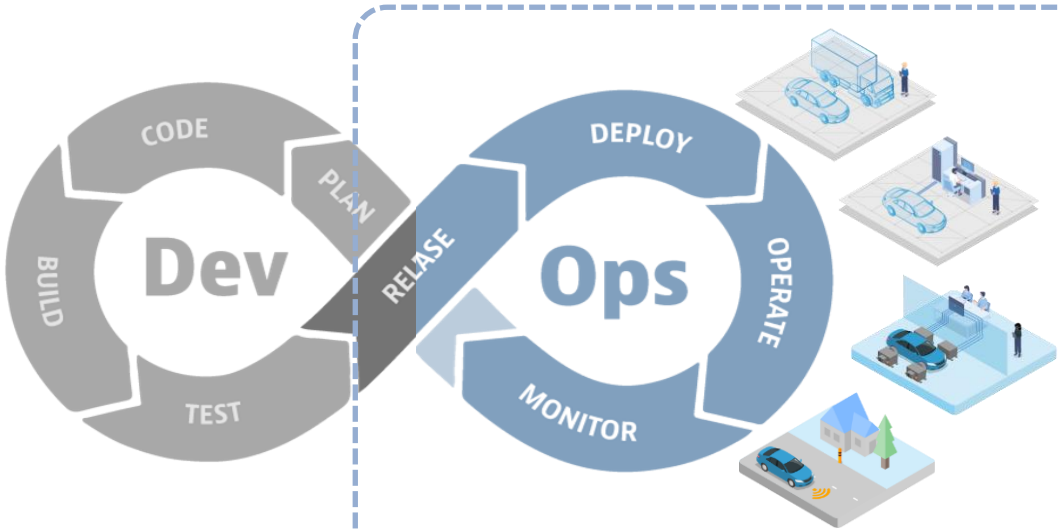
AVL CRETA™ PLATFORM
Calibration Life Cycle Management

Increase in automation and integration within the software lifecycle for control units

The Solution:

- Automation of software release integration
- API for process integration
- Guided Review-process, SUMS support
- Support for automotive cyber security
- Management of variants and responsibilities

4 Many OEMs are challenged with complex and slow software releases



Software experts

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AVL CRETA™ PLATFORM
Calibration Life Cycle Management

Increase in automation and integration within the software lifecycle for control units

Key Benefits:

- Master daily software updates
- Facilitate collaboration of calibration and software teams
- Maximize software re-use through efficient variant management
- Achieve compliance with UNECE R156

SUMMARY

What We Showed Today …

How to save 50% of test time and 40% of time for model integration	Deep Dive Webinar available from 30th June
How to move battery validation to the lab and improve health prediction with AI	Deep Dive Webinar available from 06th November
How to save hundreds of millions of $ in repair costs for OEMs using AI	Deep Dive Webinar available from 18th September
How to manage and shorten the SW update release cycle from months to days	Deep Dive Webinar available from 08th May

Contact

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Thank you

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