VIRTUAL ASSEMBLY LINE INSIDE AN OPTISLANG SPM SYSTEM @BOSCH

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WOST 2019

dynardo | presented at the 16th Weimar Optimization and Stochastic Days 2019 |
Source: www.dynardo.de/en/library

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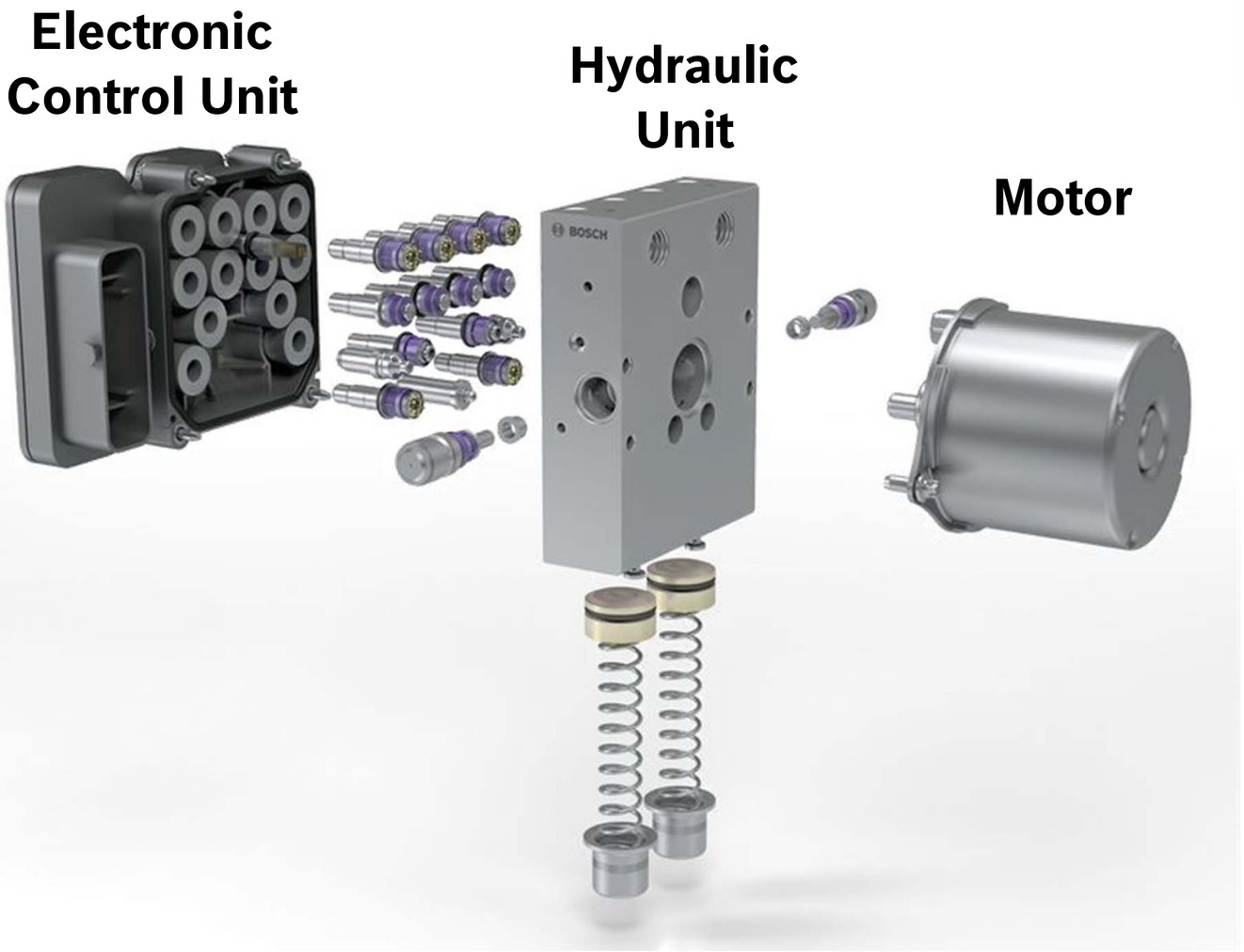
Introduction
Electronic Control Units like ESP



Efficient computational reliability assessment
Automated, fast and reproducible

climatic spectrum

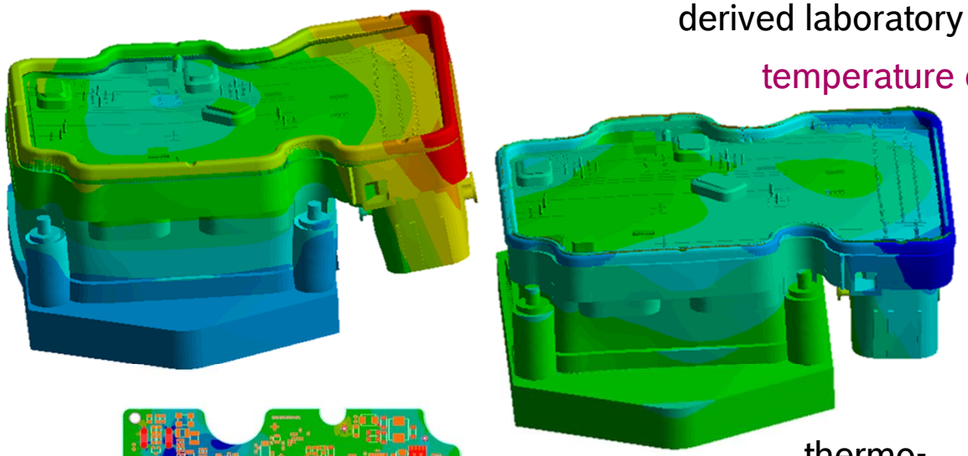
climatic load profile (region, climate)

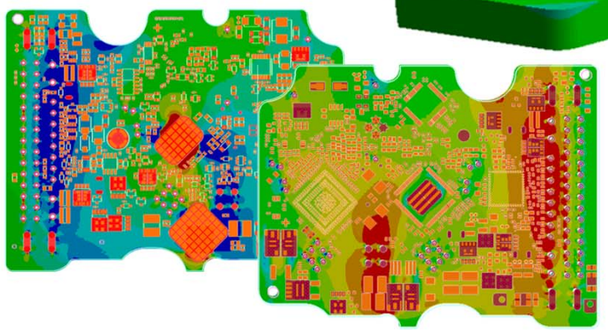
temperature changes

temperature chamber profile

derived laboratory load profile

temperature cycles



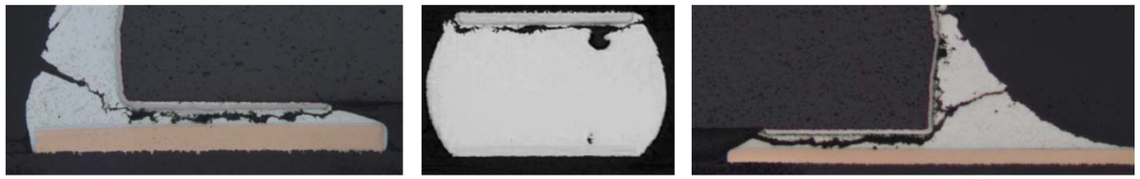


thermo-mechanical behaviour of the ECU assembly

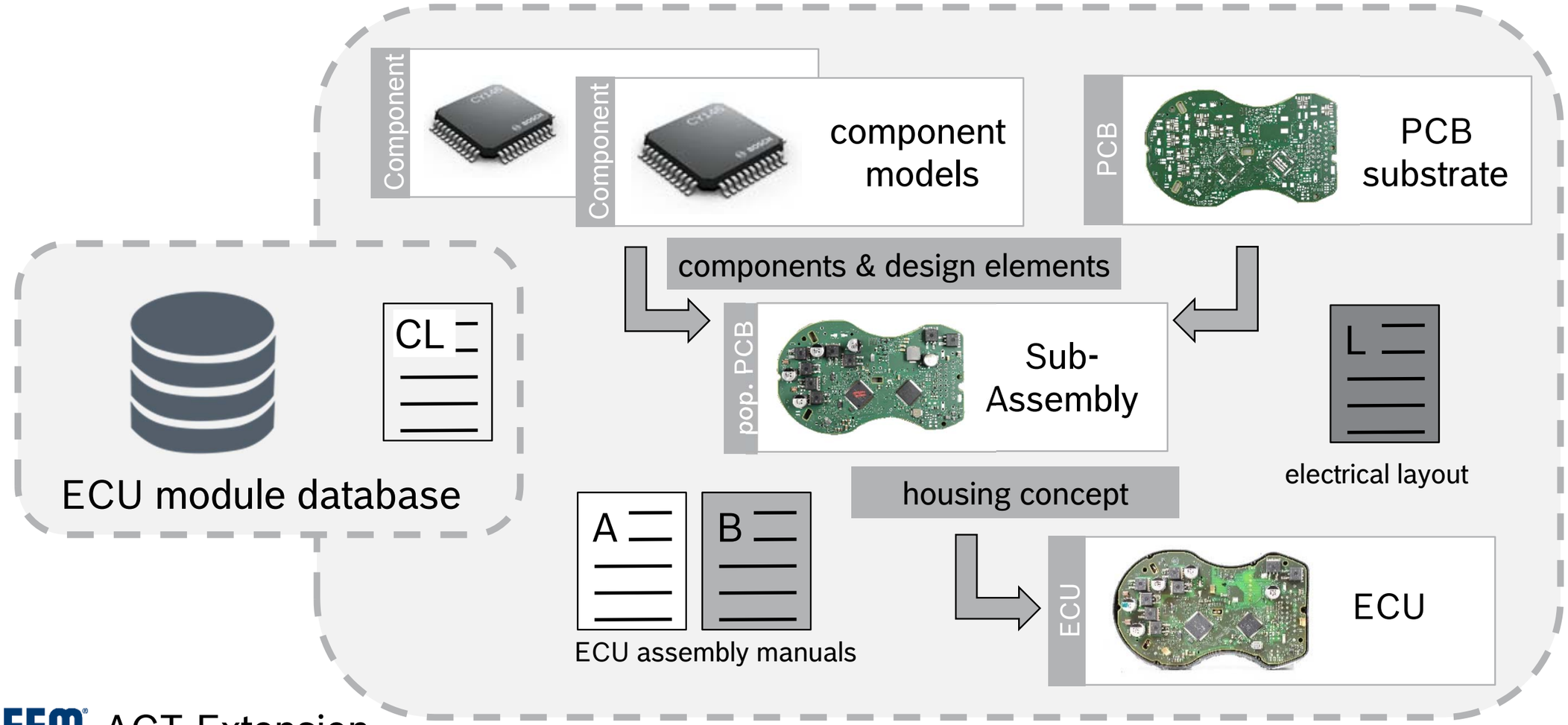
Solder joint reliability assessment to ensure functionality of electrical components

- **more than 600** components in an ESP layout!
- each component has **2 to 292** individual solder joints
- thousands of computational assessments of solder joint reliability w.r.t. creep fatigue

Computational assessment has to be fast and reproducible:
→ **automation!**



Virtual Assembly of ECUs
ACT solution



CADFEM ACT Extension

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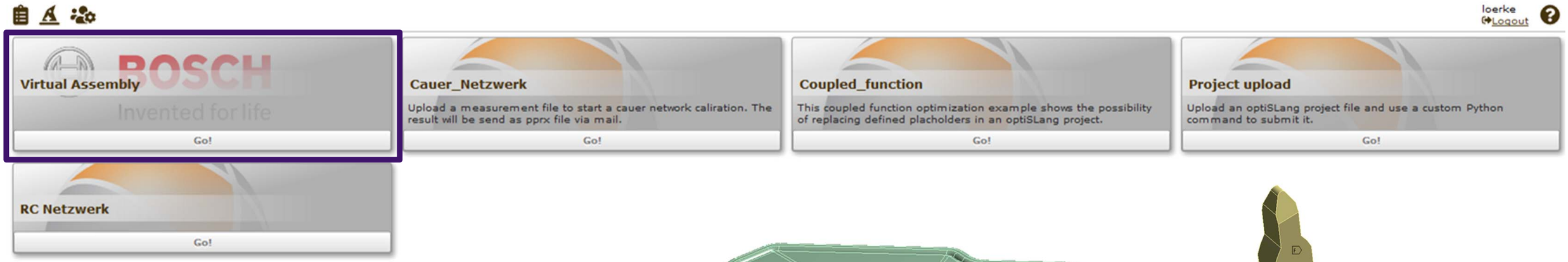
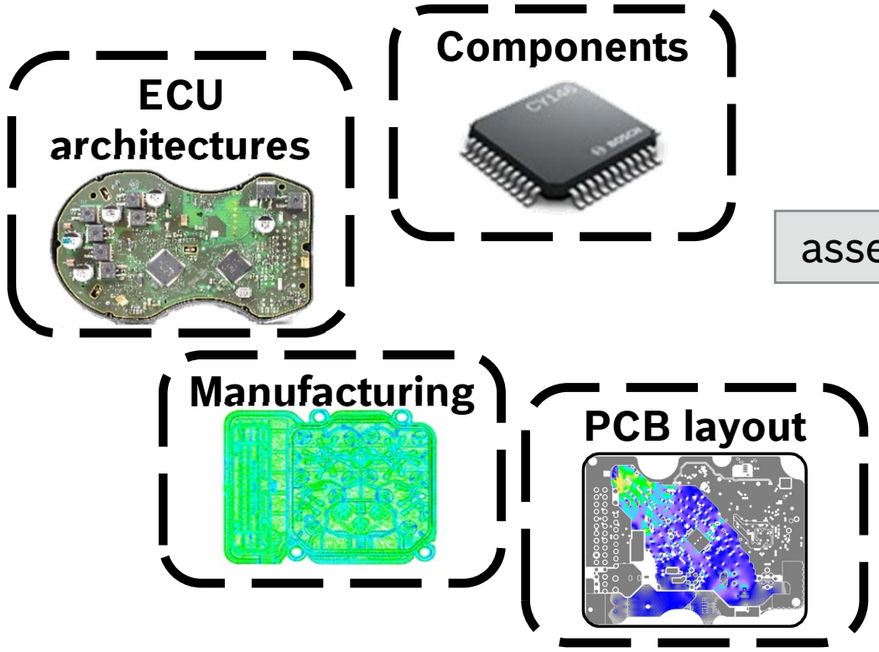
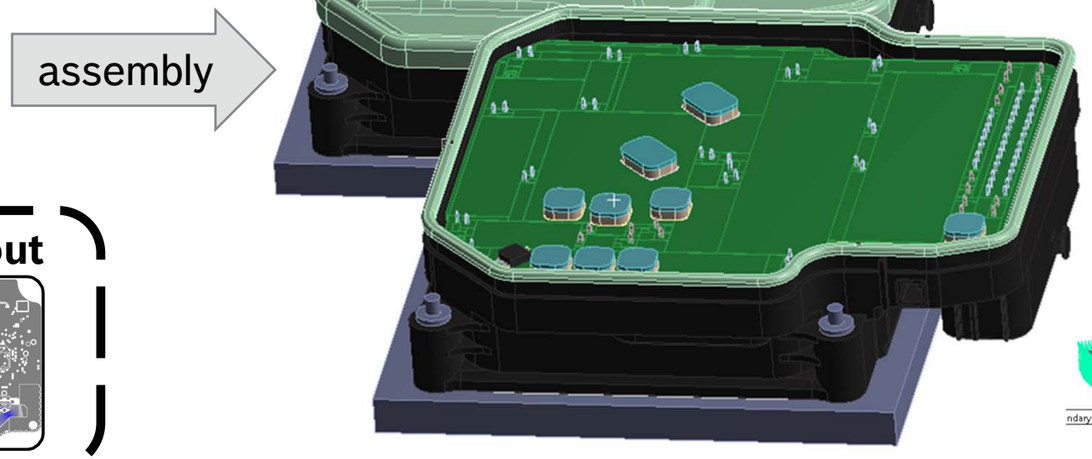
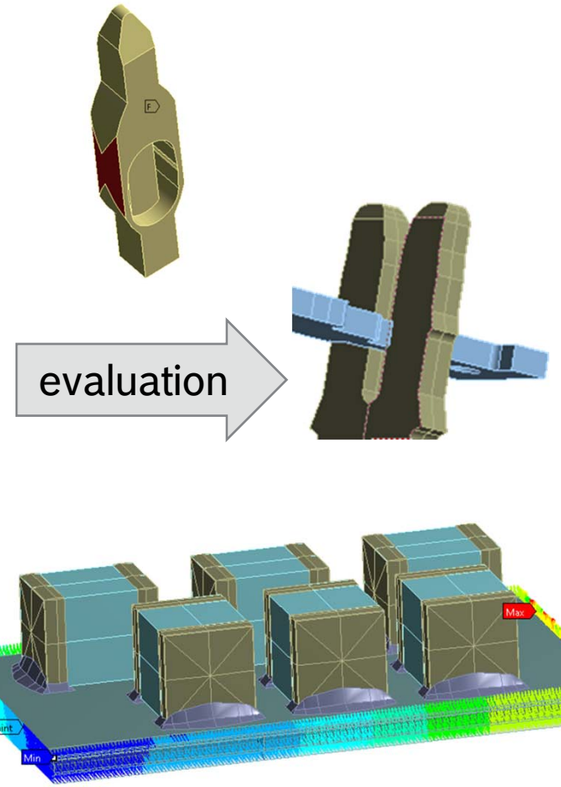
Virtual Assembly of ECUs
Web application









Virtual Assembly of ECUs
XML-based set-up

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<?xml version="1.0" encoding="utf-8" ?>
<pcbClass>
    <pcb refDes="PCB" path="wbdata/03_pcb/pcb/ESP_Gen9_3_46pol_16SH1221H00000008.wbpz" pcbThickness="1.678" componentContactReference="contact_PCB" housingContactReference="contact_ECU">
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        <rotation xy="0.0" yz="0.0" zx="0.0" unit="degree" />
        <transformationPopPcb x="0.0" y="0.0" z="0.0" unit="mm" />
        <rotationPopPcb xy="0.0" yz="0.0" zx="0.0" unit="degree" />
    </pcb>
    <filters>
        <filter name="Physics" value="Thermal" />
        <filter name="Stackup" value="16SH1221H00000008" />
        <filter name="Product" value="ESP_Gen9_3" />
        <filter name="Connector" value="46pol" />
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</pcbClass>
```

```xml
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        <transformation x="0" y="0" z="-0.8" unit="mm" />

    </ecad>
    <ecadGeometry stringID="PCB(PCB)" />
    <ecadSettings advancedModeling="black/white" tracematConductive="ECAD_Cu" tracematDielectric="ECAD_FR4" platingThickness="0.025" unit="mm" platingMaterial="ECAD_Cu"
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```

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```

XMLs

- Example: PCB
- Predefinition of possible configurations

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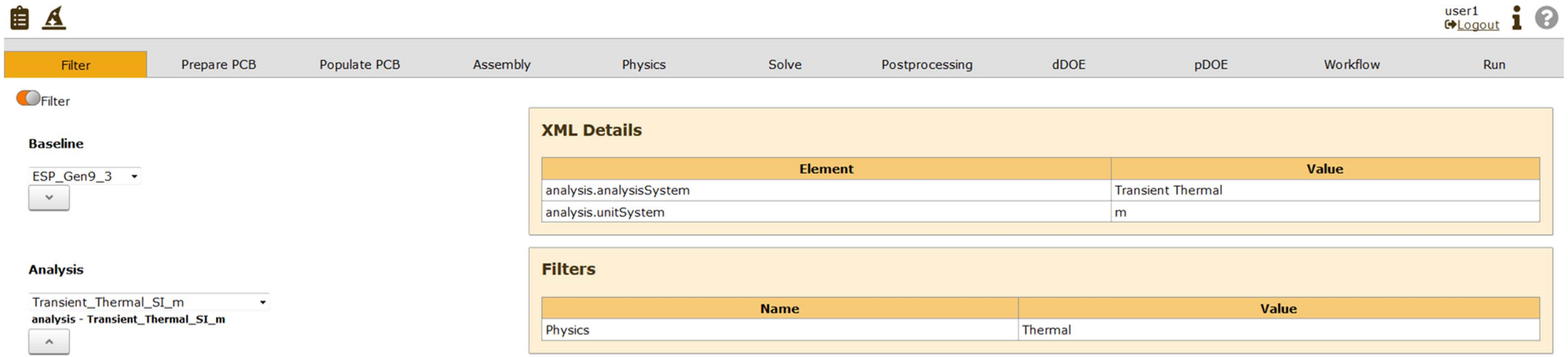
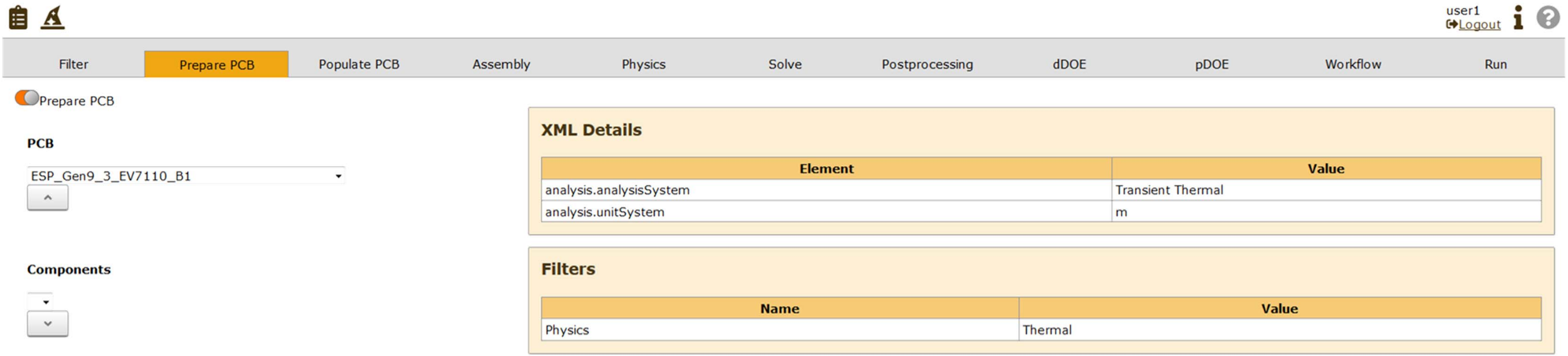
Virtual Assembly of ECUs
Domain based filtering



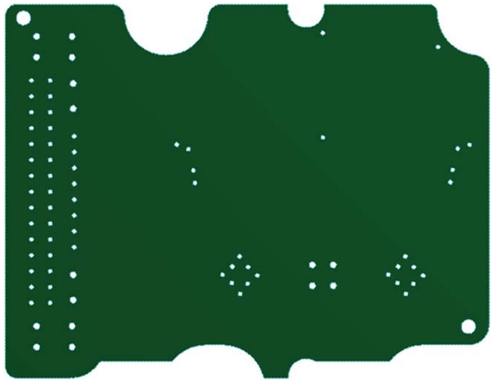
Filtering

- filtering of product classes and physical domains
- users are only provided with options valid for their product class

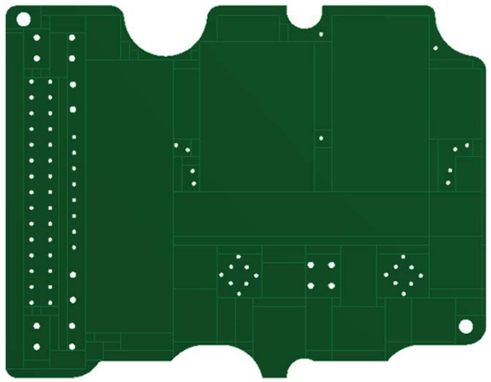
Virtual Assembly of ECUs
PCB preparation



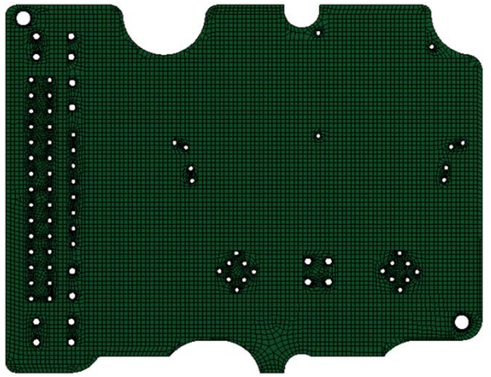
CAD import



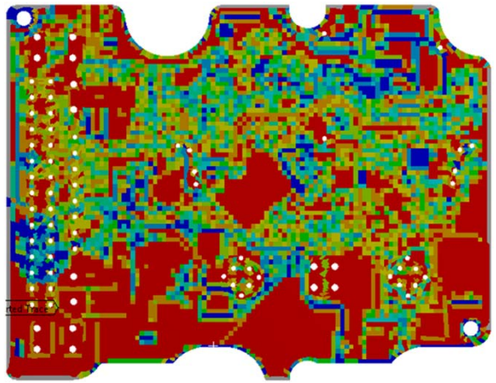
Slicing



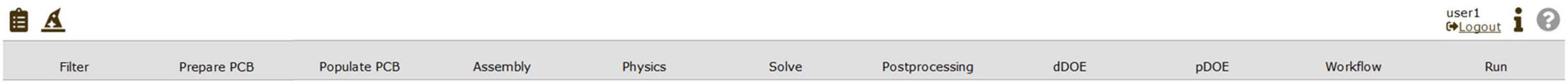
Meshing

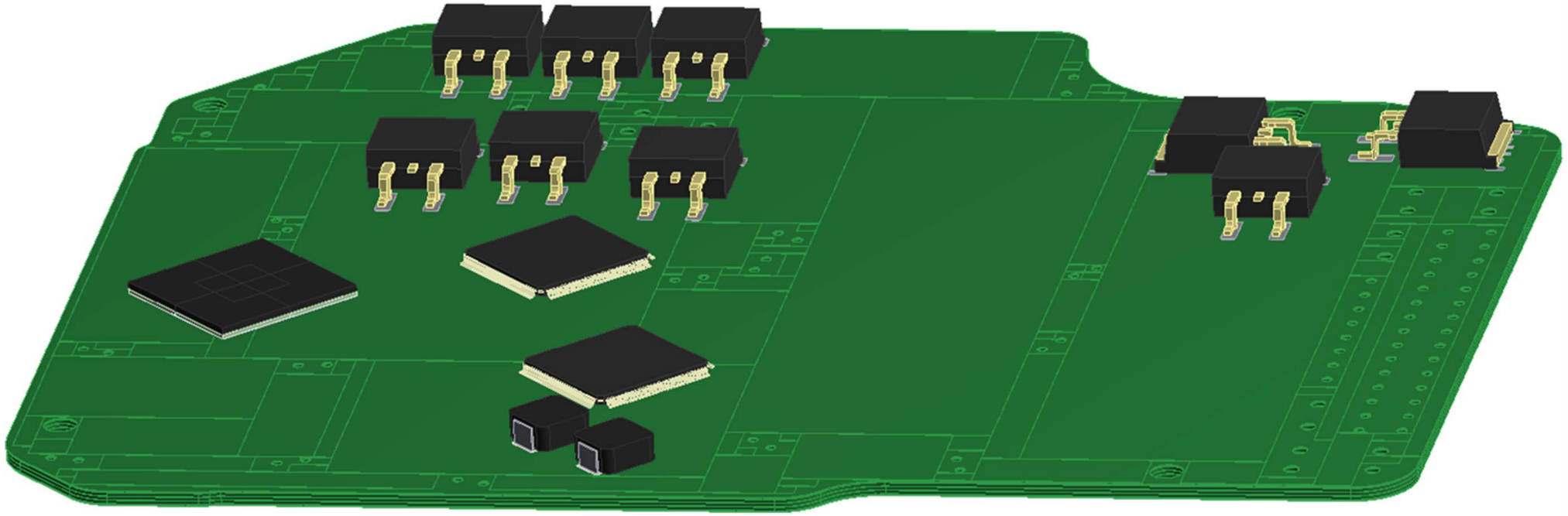


Circuit layout mapping



Virtual Assembly of ECUs
PCB population



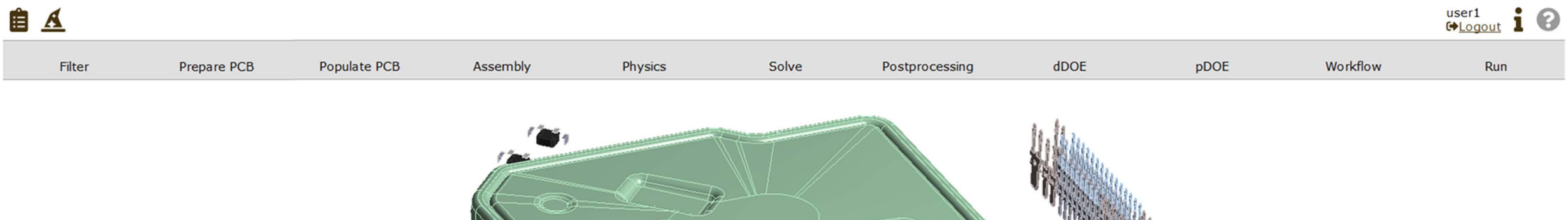


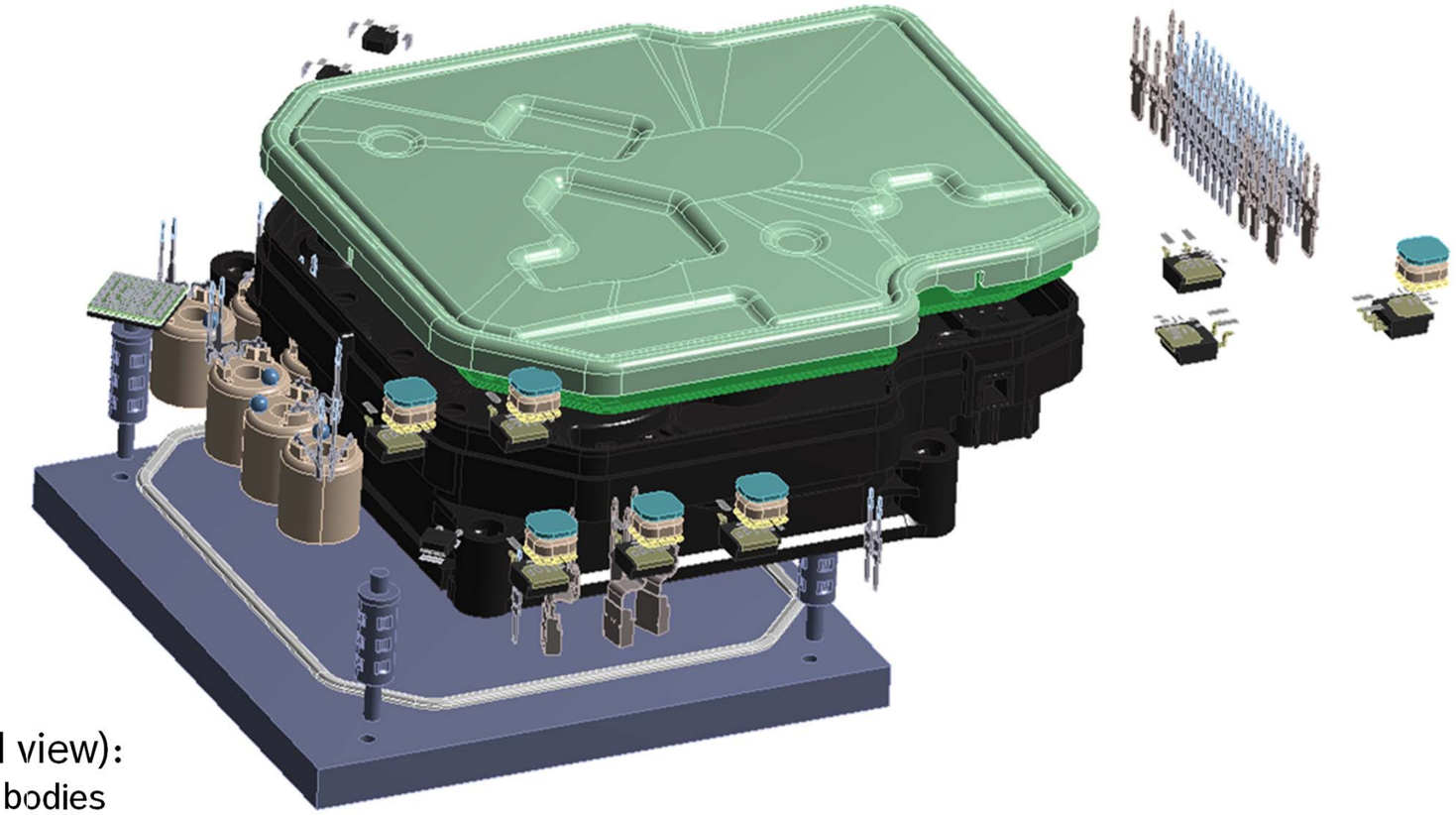
PCB population

- Matching of domain-relevant components with electric layout
- Automated component placement

Virtual Assembly of ECUs

ECU assembly

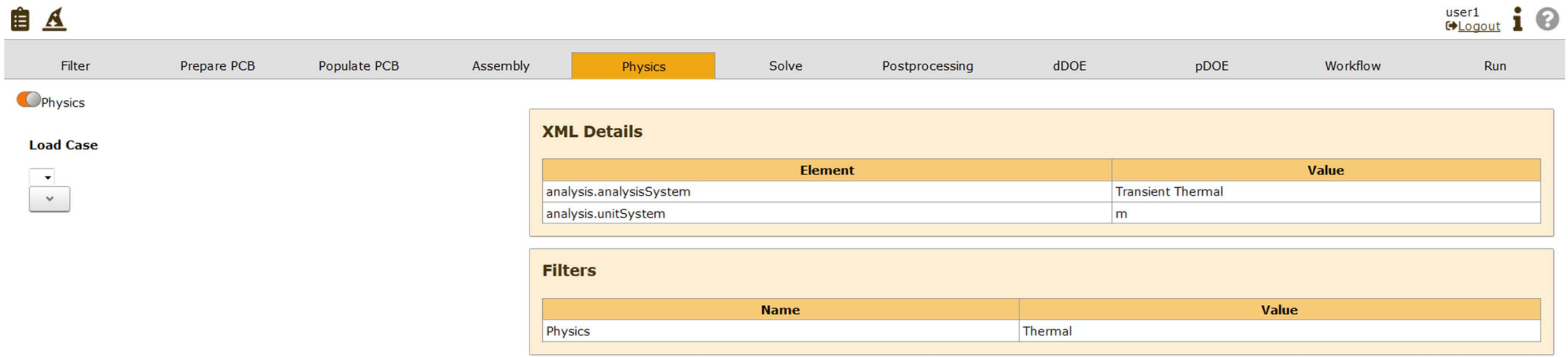




ECU assembly

- Example (exploded view):
  - Assembly of 3000 bodies
  - Contact generation between components, PCB and housing parts

Virtual Assembly of ECUs
Load cases



Load Cases

- Prepared load cases can be chosen by user
- Load cases:
  - Thermal sources
  - Mechanical loads
  - Preloads
  - ...

Virtual Assembly of ECUs
DOE with discrete configurations

user1
Logout

Filter | Prepare PCB | Populate PCB | Assembly | Physics | Solve | Postprocessing | dDOE | pDOE | Workflow | Run

Parameter selection

- [x] PCB
- [ ] Components
- [ ] ECU Mechanics
- [ ] Load Case

Sampling

Name	PCB	Components	ECU Mechanics	Load Case	Active
Design_1	ESP_Gen9_3_EV7110_B1				☑
Design_2	ESP_Gen9_3_EV7110_B1_refined2_cadfem				☑
Design_3	ESP_Gen9_3_EV7110_B1_refined_cadfem				☑
Design_4	ESP_Gen9_3_EV7110_B1_transformed_cadfem				☑
Design_5	ESP_Gen9_3_EV7140_C2				☑
Design_6	ESP_Gen9_3_EV7145_C1				☑

Discrete DOE

- Discrete configurations can be simulated and later compared
- Configurations:
  - Cover variants
  - PCB technology variations
  - Different component packages
  - Load variations
  - ...

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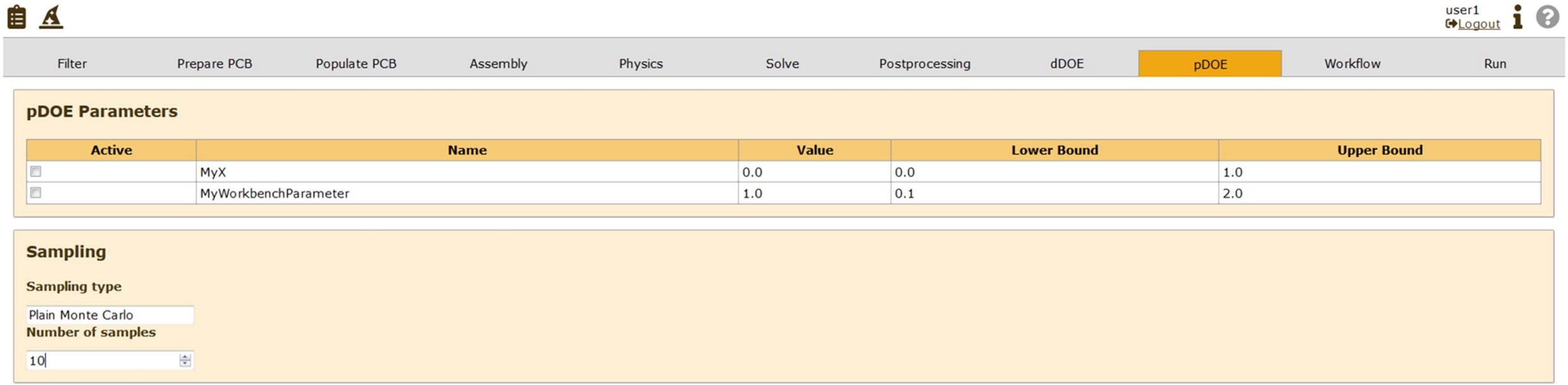
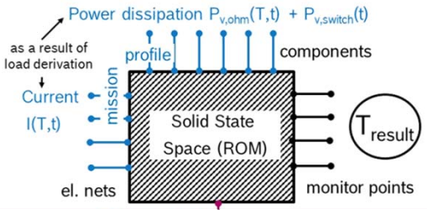
Virtual Assembly of ECUs
DOE with continuous parameters



Parameter DOE

- Offers the parameters of the underlying Workbench projects
- Parameters:
  - CTE
  - Stiffness
  - Heat conductivity
  - ...

Virtual Assembly of ECUs
Postprocessing



Reduced Order Model matrices

1D model

ANSYS

1D-model (ROM)

Load data

Load specification

Electro-Thermal Load

Python

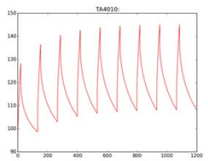
Report Sent by Email

MATLAB

generate report

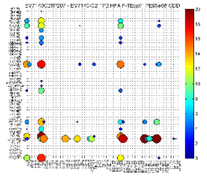
Data Send

results

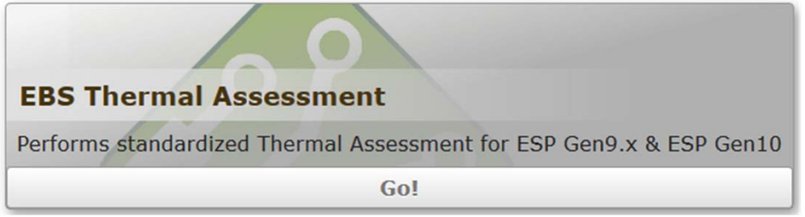


temperature courses

assessment



Thermal Assessment



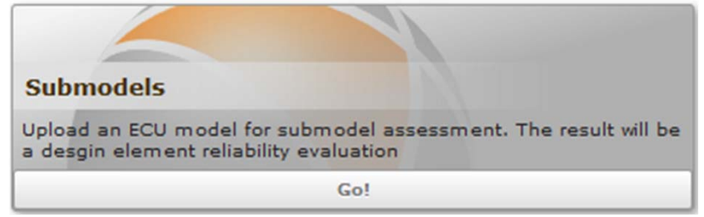
Setup of optiSLang project

- Simple optiSLang setup for the MATLAB-based calculation of temperature courses (and assessments) based on ANSYS-provided Reduced Order Model (ROM) matrices (MORinsideANSYS)
- Python-node to auto-generate Microsoft PowerPoint report
- Data Send node to send PowerPoint results + result zip-files by Email

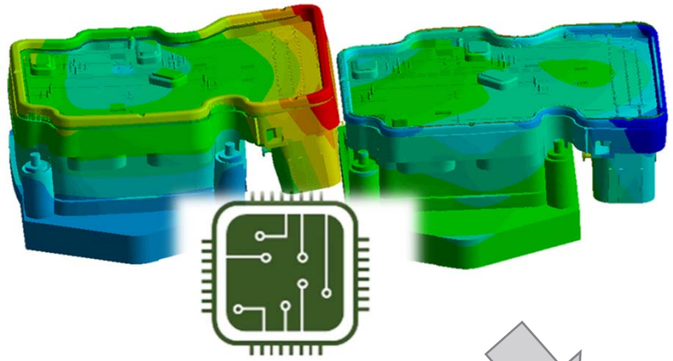
Placeholders and Registered files

- Definition of placeholders to be provided by user interface

Virtual Assembly of ECUs
Submodels



FE calculation of thermo-mechanical ECU deformation

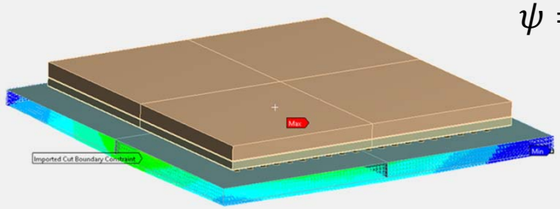


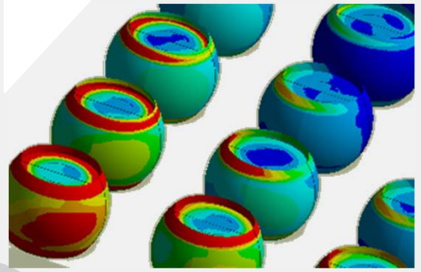
2nd level: calculation of damage inducing quantity on solder joint level:
rate-dependent non-linear kinematic hardening

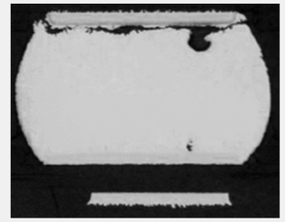
$$\psi = \psi(\boldsymbol{\varepsilon}^e, \boldsymbol{\varepsilon}^i, T, \dots)$$

+ continuum damage mechanics

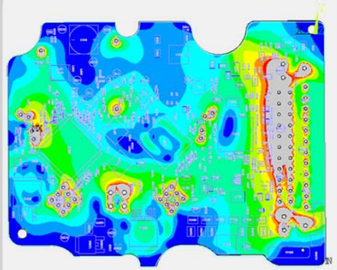
$$\psi = \psi(\boldsymbol{\varepsilon}^e, \boldsymbol{\varepsilon}^i, T, \dots, D)$$

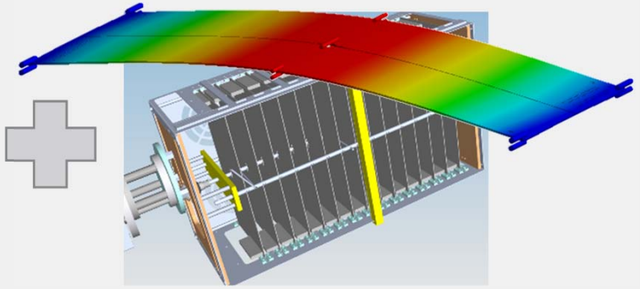


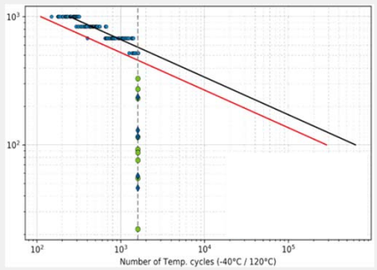


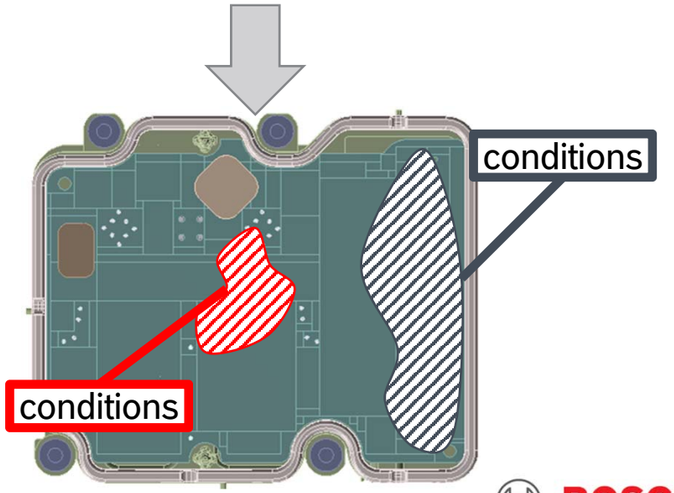


1st level: calculation of component specific damage inducing quantity on PCB level
+ evaluation with **experimentally obtained S-N curves**

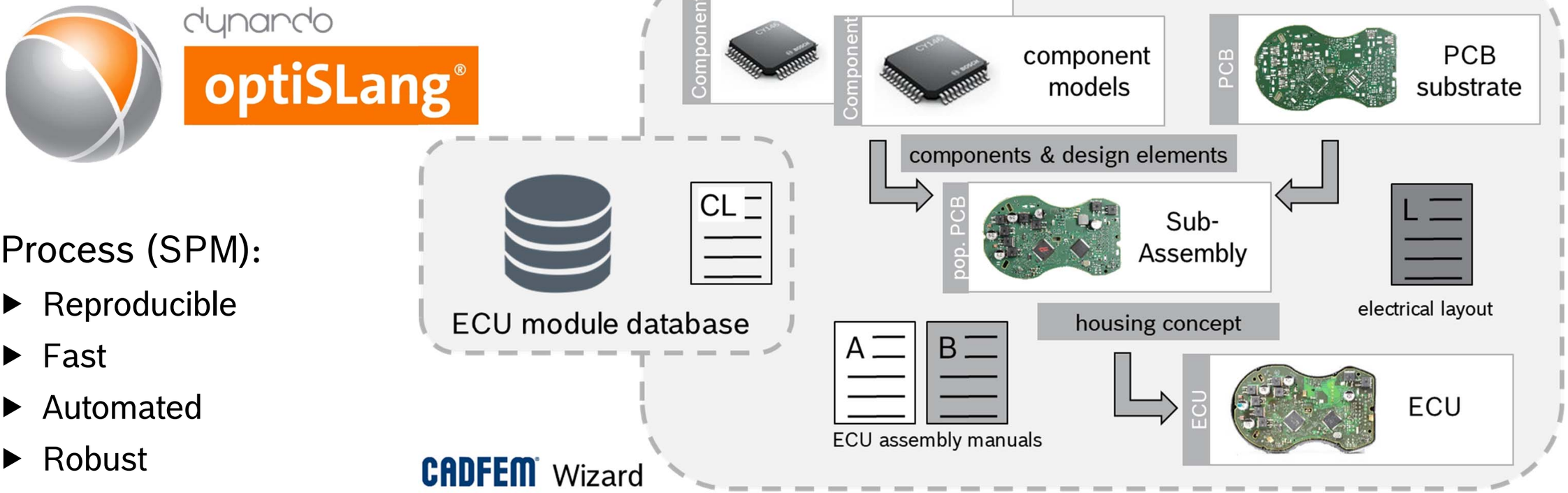








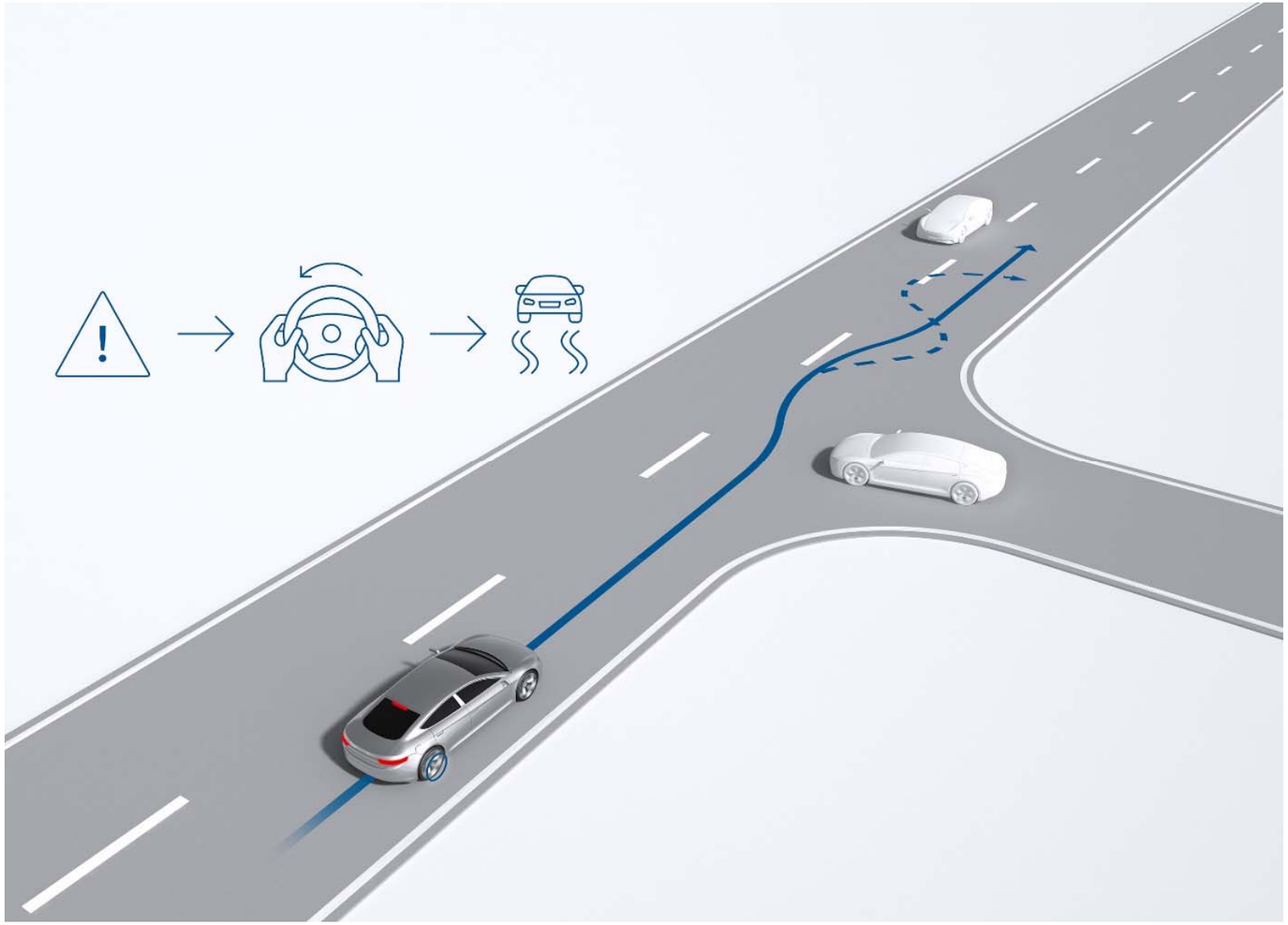
Virtual Assembly of ECUs and more
This is only the beginning ...



- Process (SPM):
  - Reproducible
  - Fast
  - Automated
  - Robust
- Resources:
  - Process owners for process definition and maintenance
  - Large computational resources
  - Efficient use of available licenses and resources

- Future:
  - Meta-Models of scalable ECU architectures
  - Sensitivity studies and Robust Design Optimization

Virtual Assembly of ECUs and more
Final remarks



Automated and efficient computational design assessment enables **design for reliability**

Vastly decreasing development times necessitate virtual design strategies and capacities

Future proof **simulation process (and data) management** concepts are implemented @BOSCH