# Electrified Powertrains

## Challenges in the Automotive Industry and eMotor Technology

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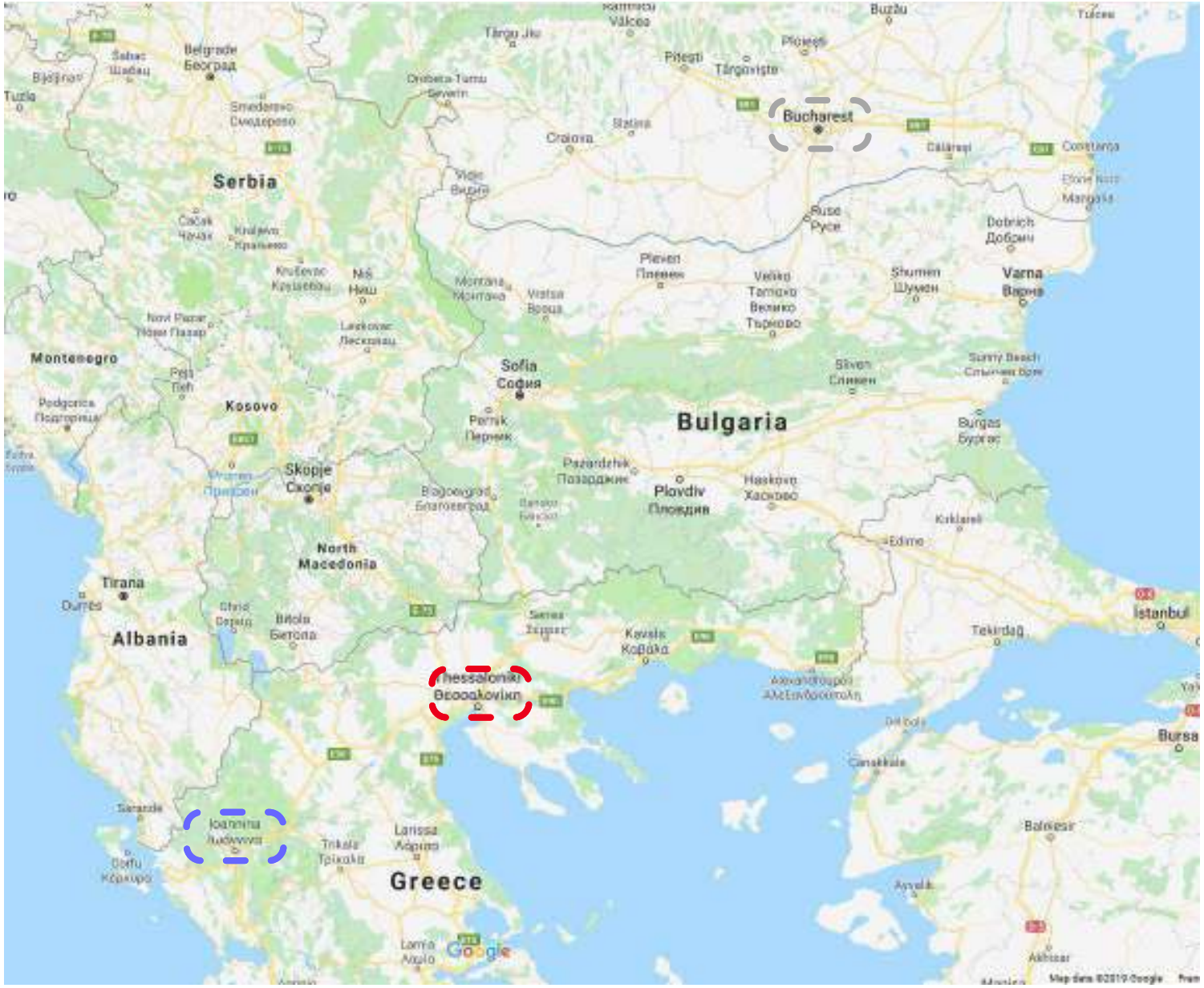
Inverter Software Leader and Validation Responsible

EV2019 Workshop PANDA – 03/10/2019

# Personal Statement

- Electrical and Computer Engineer | Specialization in Energy & Renewables
- Joined Renault in 2016

- DE-ME-S1 Team – “EV & HEV Software Development”
- ‘Inverter Software Leader and Validation Responsible’

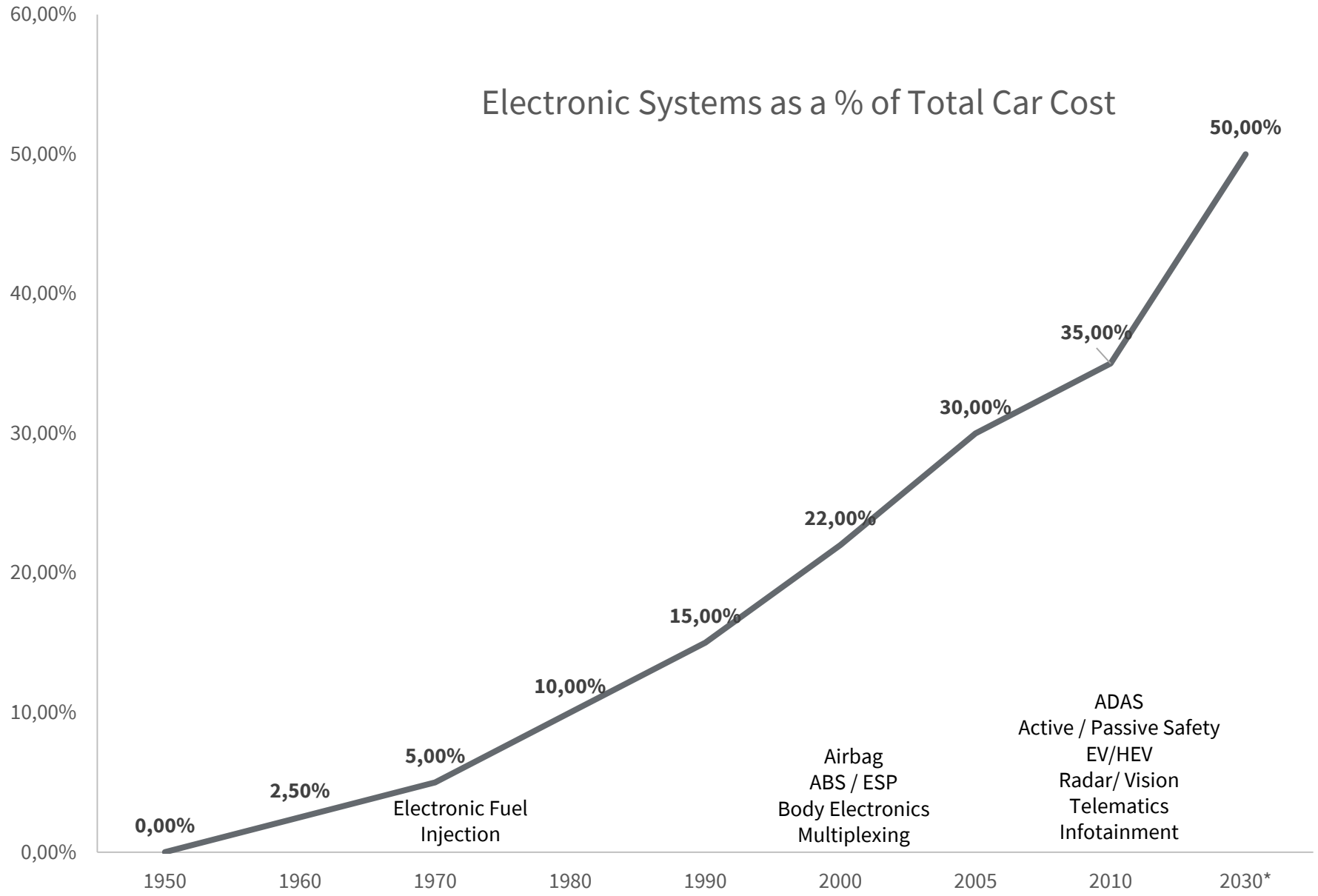


01

# Vehicle Electrification

Challenges in a Transforming Automotive Industry

# Evolution of Electronic Systems in Automotive




## Growth Drivers:

- Sophisticated Motor Control
- V2X
- Electrification of Powertrain
- ADAS
- Autonomous Driving
- Connected Services

## Quotes:

- To comply with ever changing regulations would be impossible without the usage of electronic systems
- A major part of current innovation (80%) is electronics

*source: Freescale*

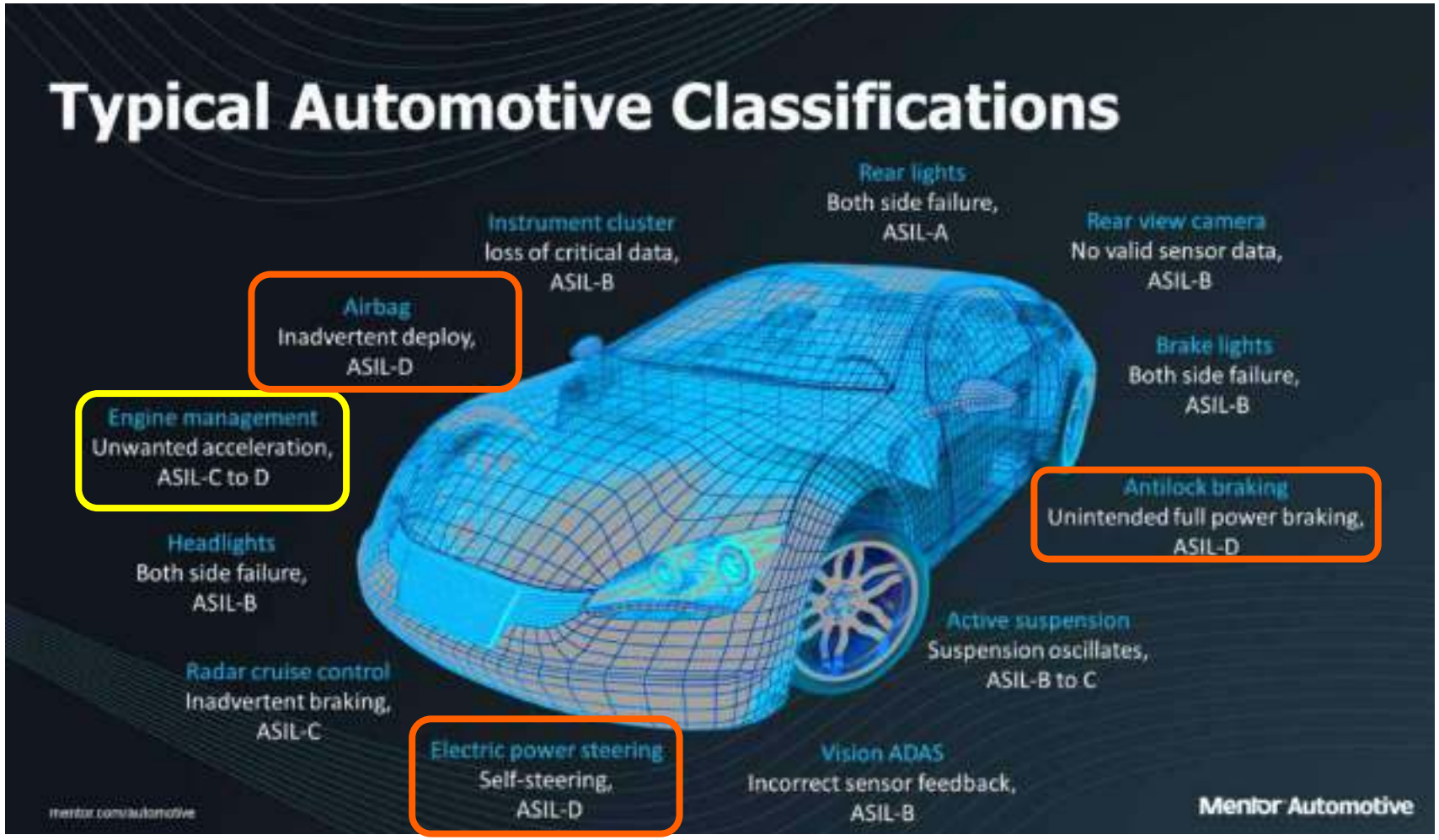
# Automotive Safety Metrics – ISO 26262

**Safety Metrics Driven by**

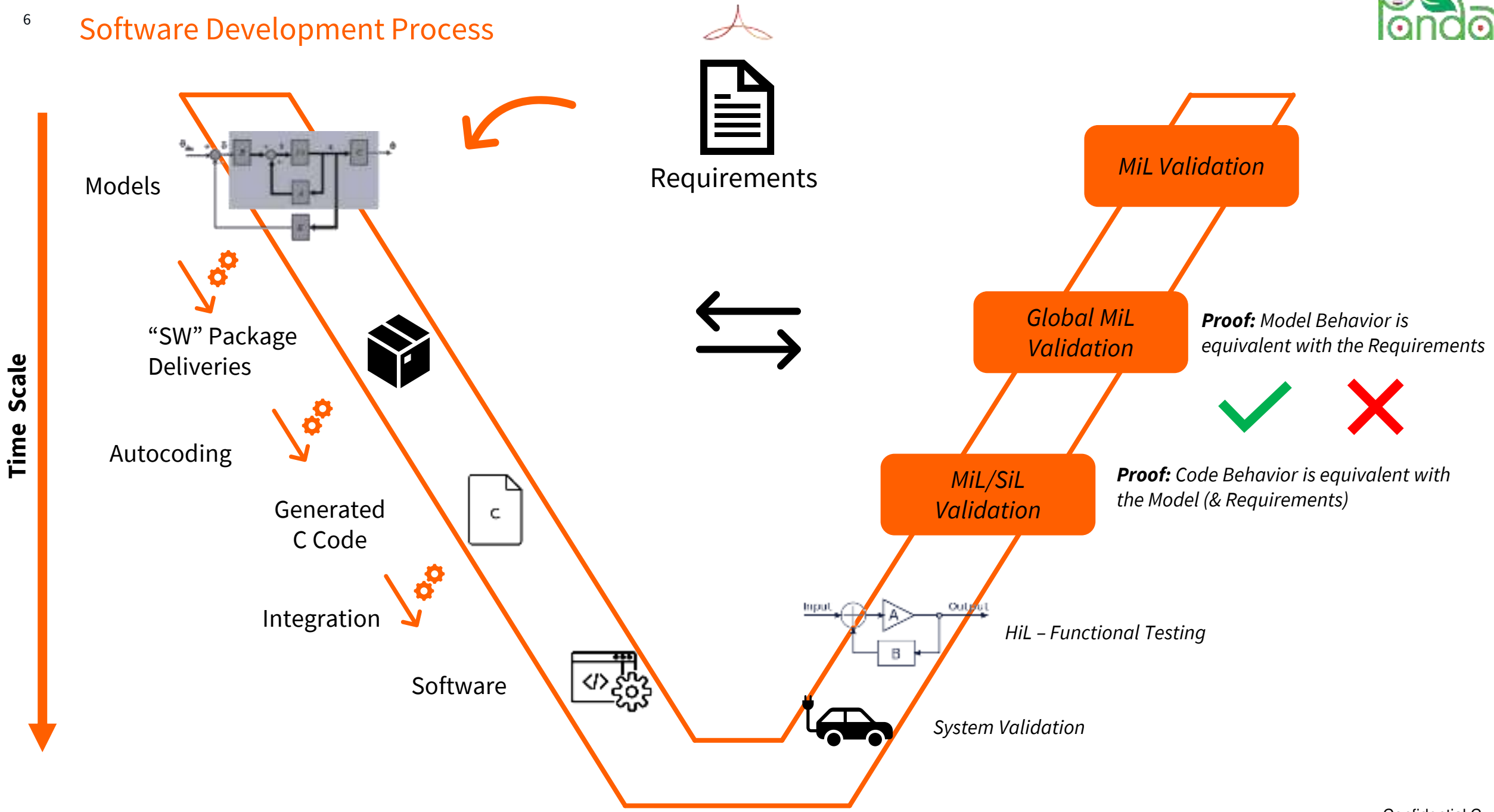
ISO 26262

**'Road Vehicles – Functional Safety'**

| ASIL Level | Severity Level | Severity Context |
|---|---|---|
| QM | 0 | NA |
| A | 1 | Marginal |
| B | 2 | Significant |
| C | 3 | Critical |
| D | 4 | Catastrophic |



# Software Development Process



# Regulation Challenges…

**«CAFE» : C**orporate **A**verage **F**uel **E**conomy
Wordwide Regulation, exists in the US, China, Brazil and Europe (affecting 31 Countries)

In effect from 1st of January 2020, severely impacting car manufacturers:

- **$CO_2$ target becomes 95gr/km vs 130gr today**
- **Penalty of 95€ for each gr/km & car sold over the target**

The new CAFE target will influence PWT line-ups deeply and will lead to the speed-up of Electrification.

| *Projection $CO_2$/km in 2021 | | | |
|---|---|---|---|
| | Forecast $CO_2$ 2021 | Objective* $CO_2$ 2021 | Penalties Forecast 2021 |
| Toyota | 87,1 | 95,1 | - |
| Renault / Nissan | 92,1 | 94,8 | - |
| PSA | 95,6 | 93 | 0,6B€ |
| FCA | 98,5 | 91,8 | 0,7B€ |
| Volkswagen | 101,5 | 97,7 | 1,4B€ |

«CAFE» Calculation:
For every Manufacturer is calculated:
- Average $CO_2$ Emissions
- For all the registrations during a calendar year

$$Objective = 95 + 3{,}3 \times \frac{Car\ Mass - 1380}{100}$$

*source: PA Consulting*

# …and Impact
# Electrification Roadmap

2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | … | … | 2040

**2019**

- Target of 500k Sales of EVs

**2020**

- Production of 1m EVs | Range 1000km

**2021**

- 40% of global models electrified

**2022**

- 20% of Production BEV | 8 New BEV Launches / 12 electrified PWTs

**2025**

- 50% sales fully electric | 1 million electrified cars on the road

**2026**

- At least 10 BEV launches

**2027**

- Forbiddance of ICE sales

**2029**

- At least one electrified version for all 300 models

**2030**

- Announced ban of ICE, action plan in place, **no** Set Date

**…**

- Ban of Thermal Engine Vehicle sales

**2040**

- Forbiddance of ICE sales

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- EV or pHEV options for all new launches
- More than 10 BEV launches
- All models to have some kind of electrification
- 26 new electrified PWTs
- mHEV | pHEV | BEV for the entire range
- All car lines with EV or pHEV PWT
- 15-25% of total sales EVs
- 15-25% of cars to be electrified mHEV | pHEV | BEV
- 1m BEV sales, 5,5m Electrified vehicles
- 2/3 of available models to be electrified

*source: Automakers, Wikipedia, BBC*

02

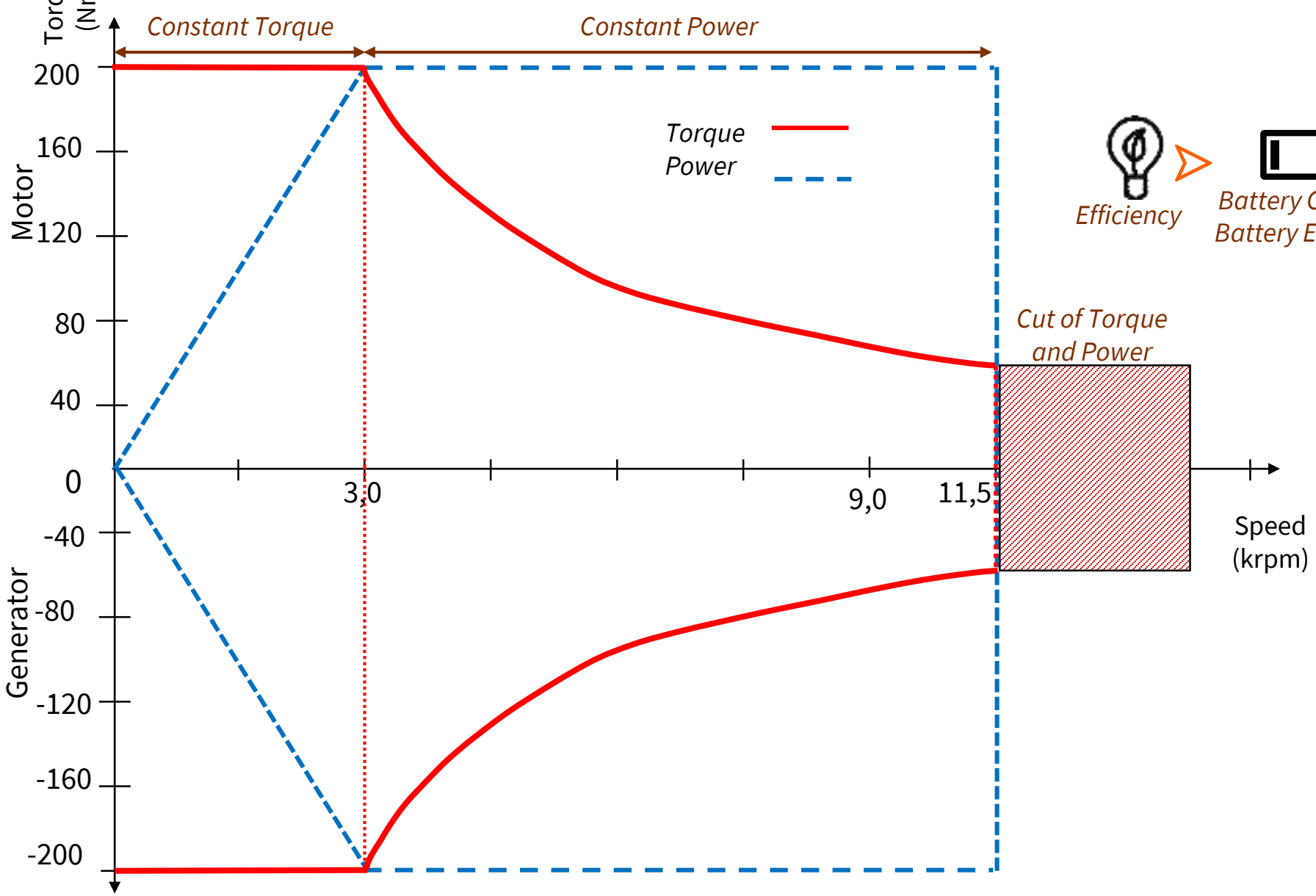
# eMotors in EVs / HEVs

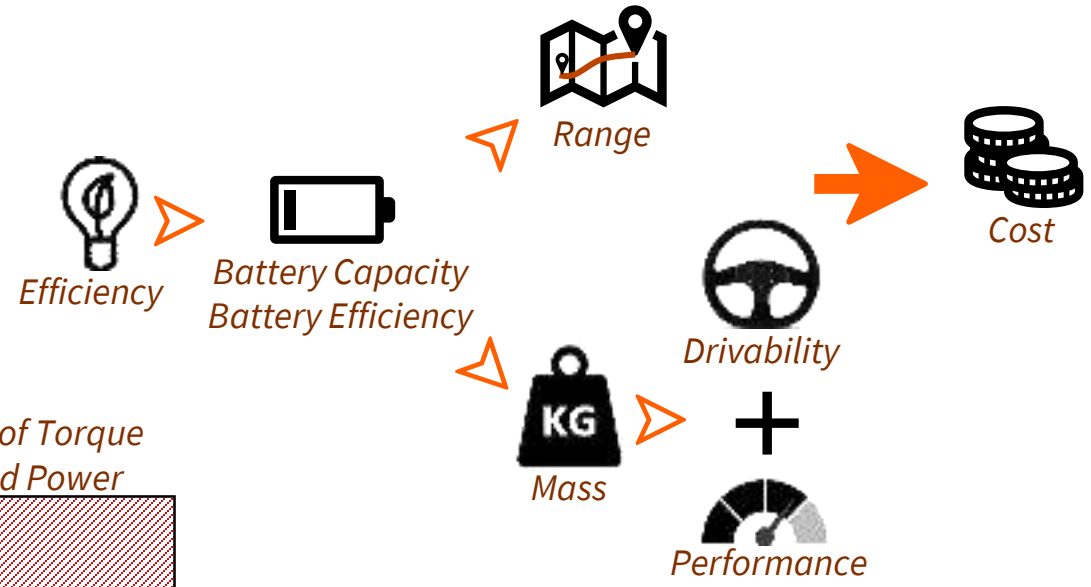
Comparison, Challenges, Requirements

# eMotors AutoMotive vs Industrial

| | EV/HEV eMotors | Traditional Industrial eMotors |
|---|---|---|
| **Ambient Temperature** | −40~140 °C | 20~40 °C |
| **Operation Environment** | Adverse | Indoor |
| **Coolant Temperature** | 75~150 °C | <40 °C |
| **Winding Temperature** | 160~200 °C | 75~130 °C |
| **Speed Range** | 0~15,000 rpm | <3000 rpm |
| **Noise Level** | Very low | Low |
| **Speed Demand** | Frequent Changes | (Usually) Kept Uniform |
| **Installation Space** | Very Limited | Loose |
| **System Voltage** | Variable | Static Grid |
| **Efficiency** | As High as Possible | Determined by application |

# eMotors for EVs / HEVs




i. High Torque & and Power Density
ii. Very wide speed range
iii. Extended area of high efficiency
iv. Large torque output at low Speed
v. Strong overload capability
vi. Reliability
vii. Motor noise and torque ripple should be suppressed
viii. Reasonable Cost

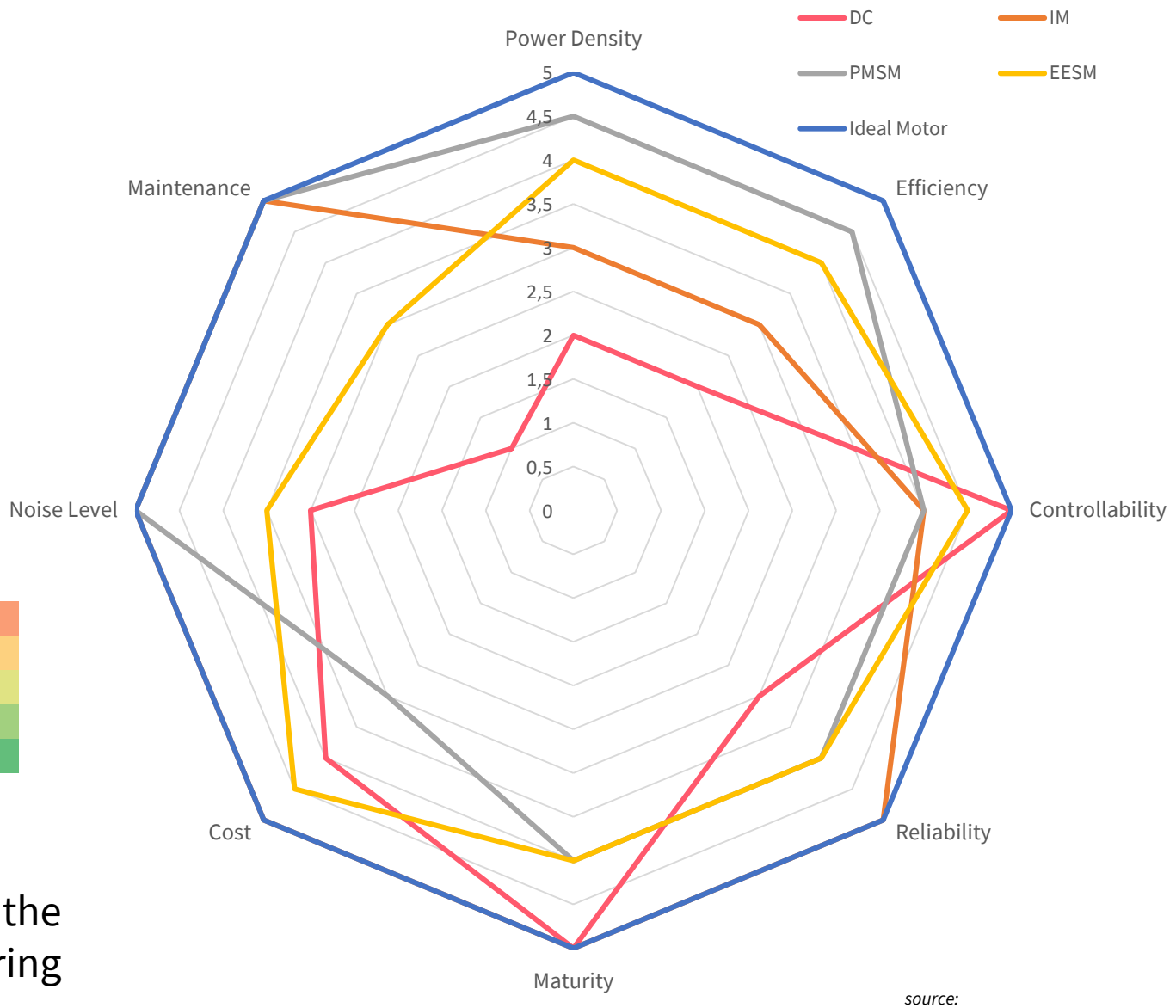
# eMotors used in EVs and HEVs - Comparison

| | DC | IM | PMSM | EESM | "Ideal" Motor |
|---|---|---|---|---|---|
| **Power Density** | 2 | 3 | 4,5 | 4 | 5 |
| **Efficiency** | 2 | 3 | 4,5 | 4 | 5 |
| **Controllability** | 5 | 4 | 4 | 4,5 | 5 |
| **Reliability** | 3 | 5 | 4 | 4 | 5 |
| **Maturity** | 5 | 5 | 4 | 4 | 5 |
| **Cost** | 4 | 5 | 3 | 4,5 | 5 |
| **Noise Level** | 3 | 5 | 5 | 3,5 | 5 |
| **Maintenance** | 1 | 5 | 5 | 3 | 5 |
| **Total:** | 25 | 35 | 34 | 31,5 | 40 |

**DC = Direct Current*
**IM = Induction Asynchronous*
**PMSM = Permanent Magnets Synchronous Motor*
**EESM = Externally Excited Synchronous Motor*

**Rating**

| | |
|---|---|
| Worst | 1 |
| | 2 |
| Average | 3 |
| | 4 |
| Best | 5 |

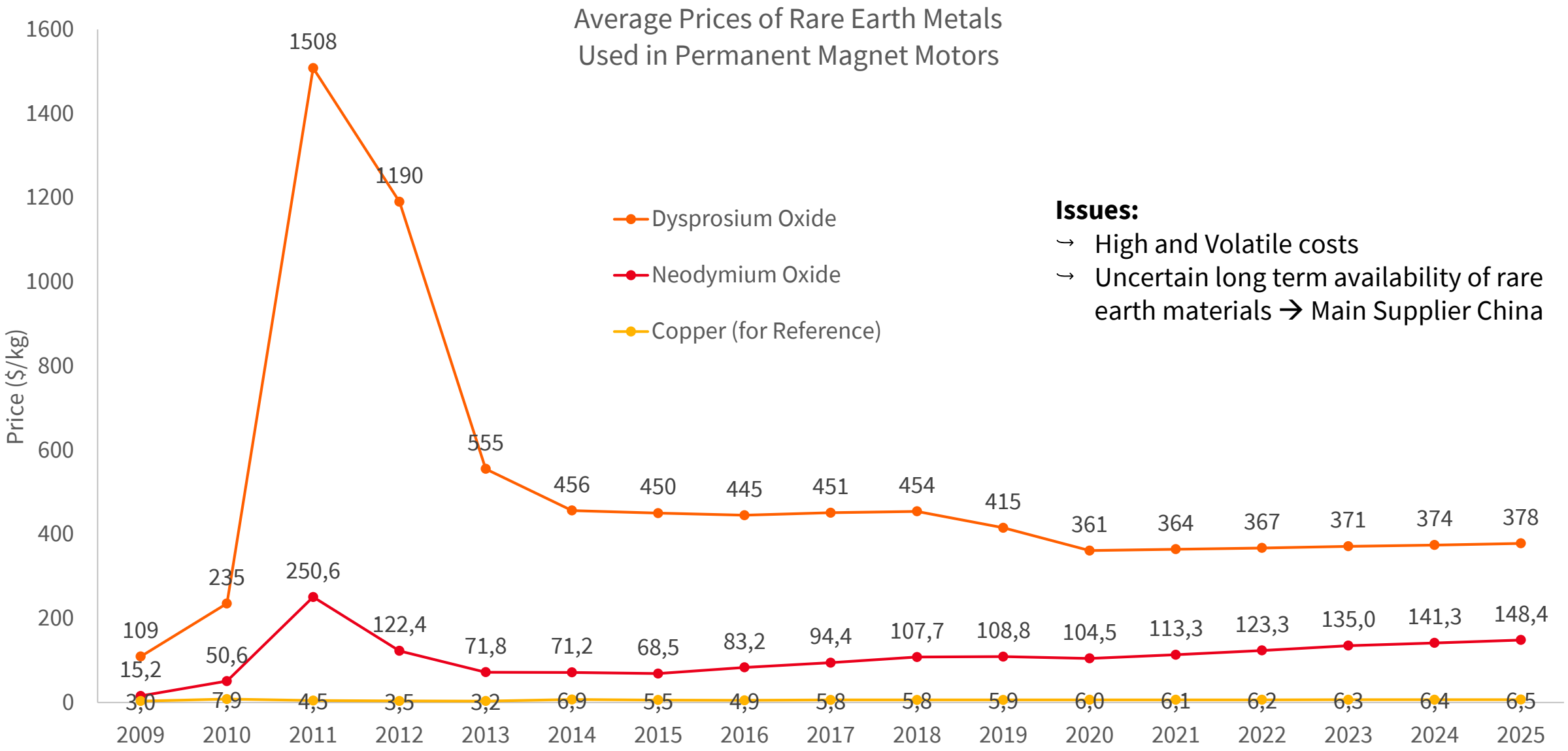



## Observation:

- Every application has different requirements for the eMotor that have to be taken into consideration during the design phase

*source:*
*Paper 1: "Comparison of Electric Motors used for Electric Vehicle Propulsion"*
*Paper 2: Overview of electric machines for electric and hybrid vehicles*

# Permanent Magnet SM Challenges




**Issues:**

- High and Volatile costs
- Uncertain long term availability of rare earth materials → Main Supplier China

# Renault Concept Cars – Alliance Vision

**EZ GO**
**Geneva 2018**
Transmission: RWD
4Control Steering
Autonomous Driving: Level 4
Shared Robo Vehicle
Connected: Grid and Services

**Zoe e-Sports**
**Geneva 2017**
Motor: 2 x PMSM (as in Formula-e)
Power in kW/hp: 340 kW/460 hp
Max. torque: 640Nm
Range: Four different driving modes and 2x40kWh batteries
Transmission: AWD (F + R Inverter & eMotor)

**Symbioz**
**Frankfurt 2017**
Power in kW/hp: 360 kW/480 hp
Max. torque: 550Nm
Range: 500km / 72kWh battery pack
Transmission: RWD (2 x Inverter & eMotors driving independently each wheel)
Autonomous Driving: Level 4
Connected: GPS, 4G, WiFi

Connected

Autonomous

Electric

Shared Mobility Services

**Dezir**
**Paris 2010**
Motor: EESM
Power in kW/hp: 110 kW/150 hp
Max. torque: 225 Nm
Range: 160 km
Transmission: RWD
KERS → from Formula 1

Level 4: "Mind off" (Hands off + Eyes off)
Level 5: Steering Wheel Optional

**TreZor**
**Paris 2016**
Power in kW/hp: 260 kW/350 hp
Max. torque: 380Nm
Range: 2 x battery packs with individual cooling, one in the front one in the rear(for optimal weight distribution)
Transmission: RWD
Connected with the Grid
BERS → from Formula-e

# Portfolio of Alliance EVs

| **Kangoo Z.E.** | **2011** |
|---|---|
| Motor | EESM/12.000rpm |
| Power | 44 kW |
| Torque | 226Nm |
| Max Speed | 130 km/h |
| Range | 170 km / 24kWh |

| **Fluence Z.E.** | **2011** |
|---|---|
| Motor | EESM/12.000rpm |
| Power | 70 kW |
| Torque | 226Nm |
| Max Speed | 135 km/h |
| Range | 185km / 22kWh |

| **Twizy** | **2012** |
|---|---|
| Motor | Induction/10.000rpm |
| Power | 13 kW |
| Torque | 57Nm |
| Max Speed | 80 km/h |
| Range | 100 km / 5,5kWh |

| **Leaf II** | **2017** |
|---|---|
| Motor | PMSM/10.000rpm |
| Power | 110 kW |
| Torque | 320Nm |
| Max Speed | 160 km/h |
| Range | 270 km / 40kWh |

| **Smart** | **2017** |
|---|---|
| Motor | EESM/12.000rpm |
| Power | 60 kW |
| Torque | 160Nm |
| Max Speed | 130 km/h |
| Range | 160 km / 18kWh |

| **Zoe – R110** | **2018** |
|---|---|
| Motor | EESM/12.000rpm |
| Power | 80 kW |
| Torque | 225Nm |
| Max Speed | 135 km/h |
| Range | 400 km / 40kWh |

03

# RTR ePWT Activity

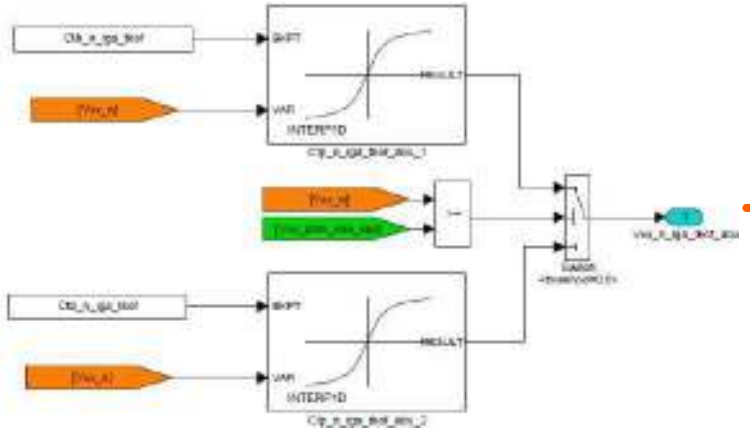
Software, Hardware & More…

# Electric and Hybrid Powertrain Department

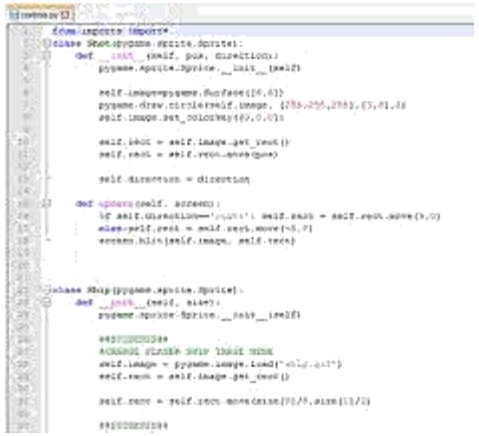
Renault Technologie Roumanie

## Mission → Development of Electric and Hybrid Powertrains

### Software development

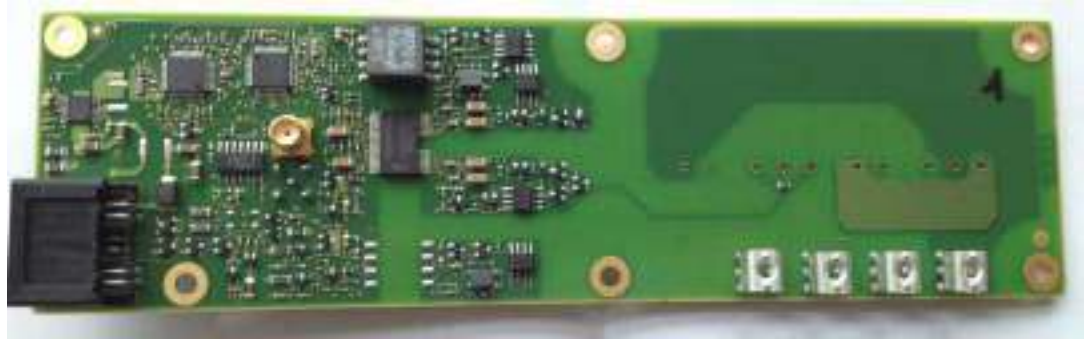


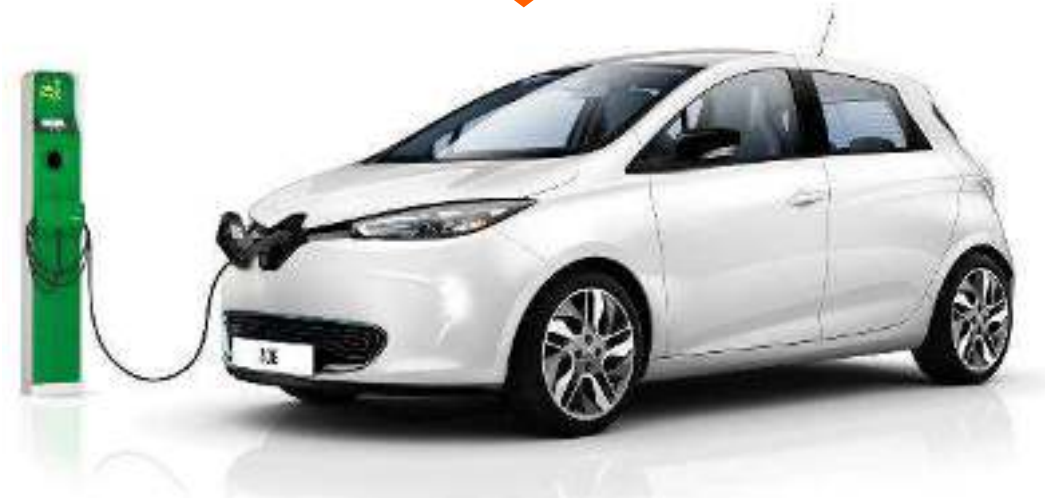
### Code



### Electric/HEV Powertrain

### Hardware development

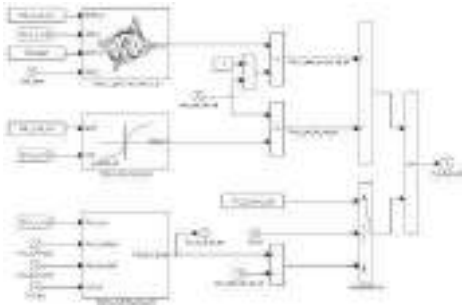




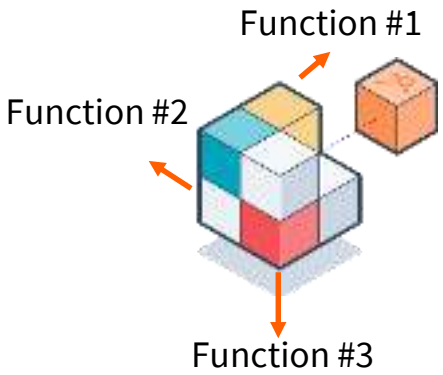
# Software Activity

Software

## Software Project Management



Algorithm Design for Powertrain Control Strategies in Simulink





*HiL – dSpace Bench*

Perimeters for designers in 2019:

- EV Supervisor
- Inverter
- Charger

Function leaders in 2019 @ RTR :

- Energetic Optimization
- High Voltage
- Torque Management
- Diagnostics
- Safety

Software Leaders in 2019 @ RTR:

- BMS (**B**attery **M**anagement **S**ystem)
- Charger
- Inverter
- EVC (**E**lectric **V**ehicle **C**ontroller)
- HEVC (**H**ybrid and **E**lectric **V**ehicle **C**ontroller)

*System Validation*

# System Validation

## Mission: Manage System Validation activity for Software

- Realize EV system validation using Vehicles
- System Validation → EV Functionalities:
  - HV Network
  - Electric Drive
  - Electrotechnical System Management
  - Charging System

- Charging Stations: AC and DC Stations
- Fleet Rolling → Failure analysis and follow-up
  Current Fleet (2019):



Test Tracks

AC Charging


System Validation


DC Charging

Software

System

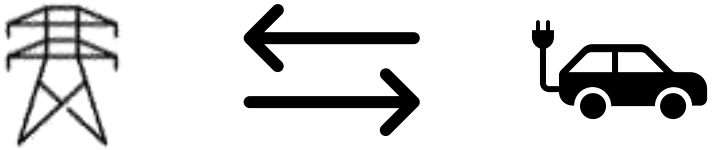
# Network Bench

System

Network Bench:

- Used for Infrastructure Validation
- Simulation of the Network Grid

**Regulation:** EMC Perturbation on the network / Harmonics Injections into the network



**Tests Performed:**

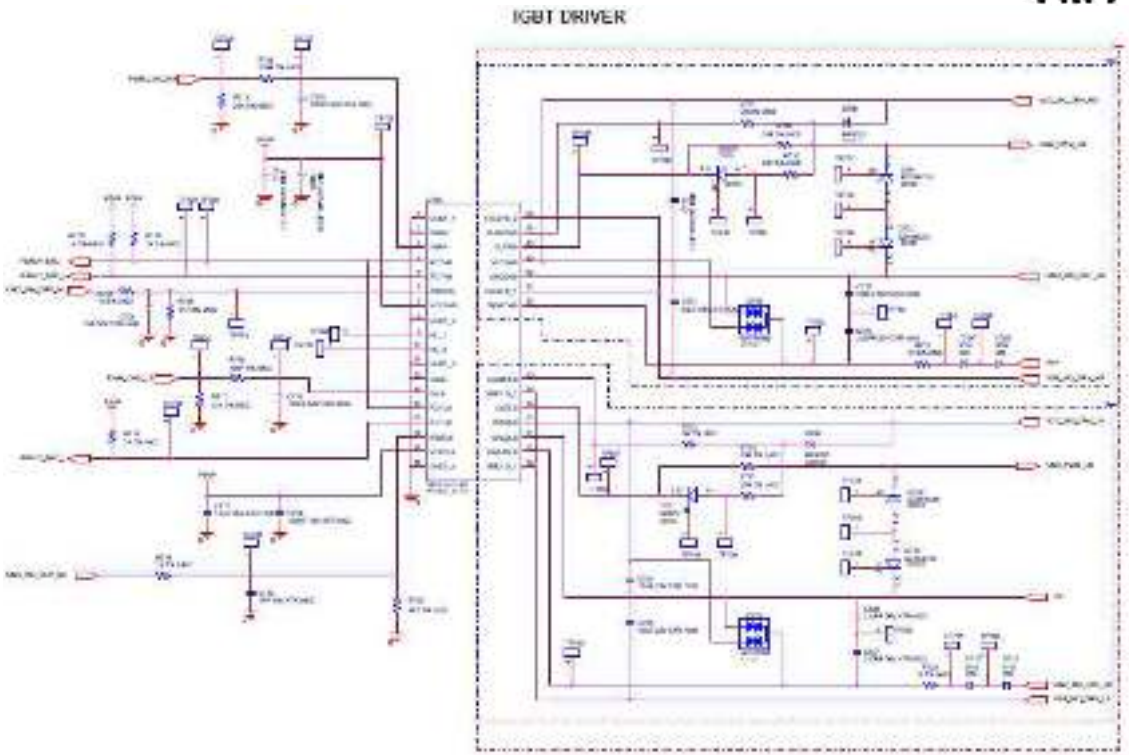
- “Bad” network does not affect charging of the EV (Voltage, Frequency, Waveform)
- The Vehicle is immune to Low Quality Power and charging is performed
- The vehicle is not polluting the network

# Hardware Activity - 1

Hardware

## Build to Print (B2P) Hardware Development:

- Design of electronic boards
  - Functions justification
  - Prototyping of critical functions
  - Electrical, thermal, EMC simulations
  - Layout specifications
- Validation of electronic boards
- Production support to the plant




## Tools Used:

Electronic Simulation and Software development tools:

- LTSPICE
- ORCAD

# Hardware Activity - 2

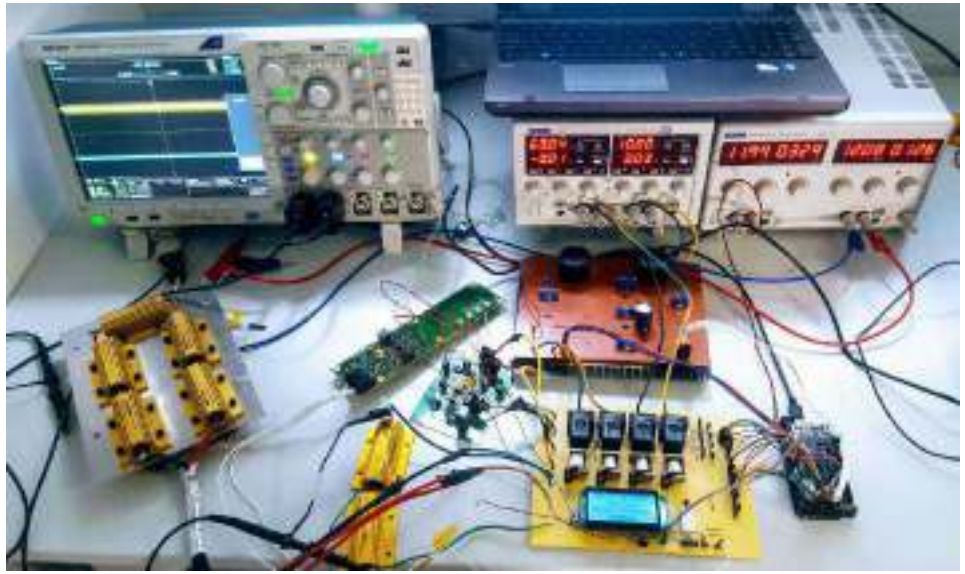
Hardware

## Hardware Development

### Tools:

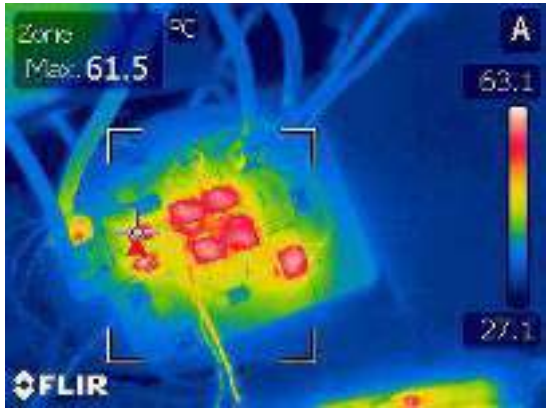
- Low and High Voltage Validation Tools
- Thermic Validation

Low voltage Validation
(Up to $60V_{dc}$)



High Voltage Validation &
Destructive Tests
($0..400V_{dc}$ | $3x400V_{ac}$) | P = 70kW)

Thermal Chamber
Reliability Tests
(-40..150°C)



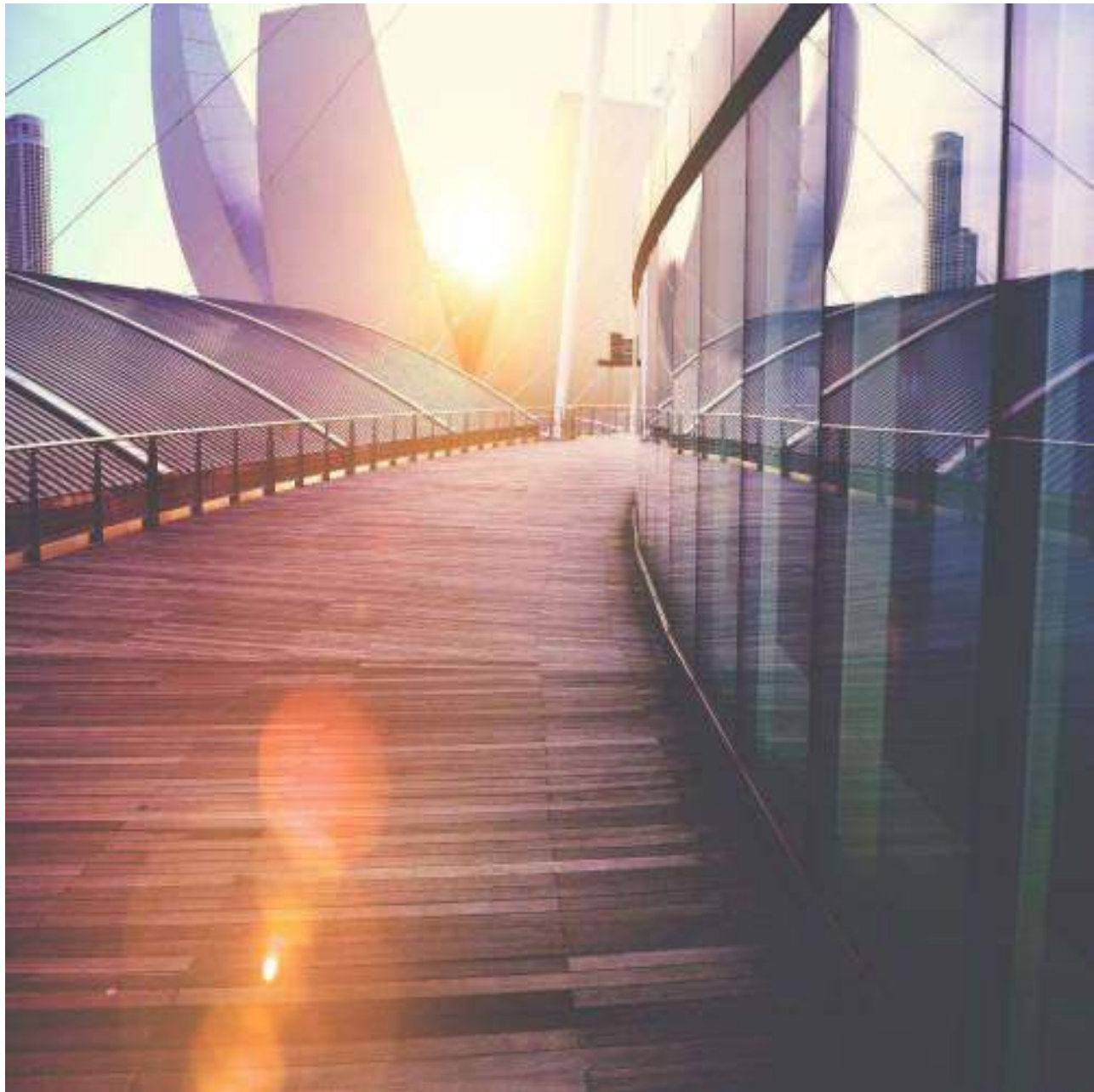

# Electromagnetic Compatibility (EMC)

Hardware

EMC chamber (2020 Investment)

EMC Testing Bench


# Questions?



# Thank You!

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