Cross-Cutting Approach to Integrate Functional and Material Design in a System Architectural Design – Example of an Electric Powertrain

Richard Messnarz, Damjan Ekert, ISCN GmbH, Anke Blume, Fabian Grunert, Uni Twente, Netherlands

EuroAsiaSPI 2019

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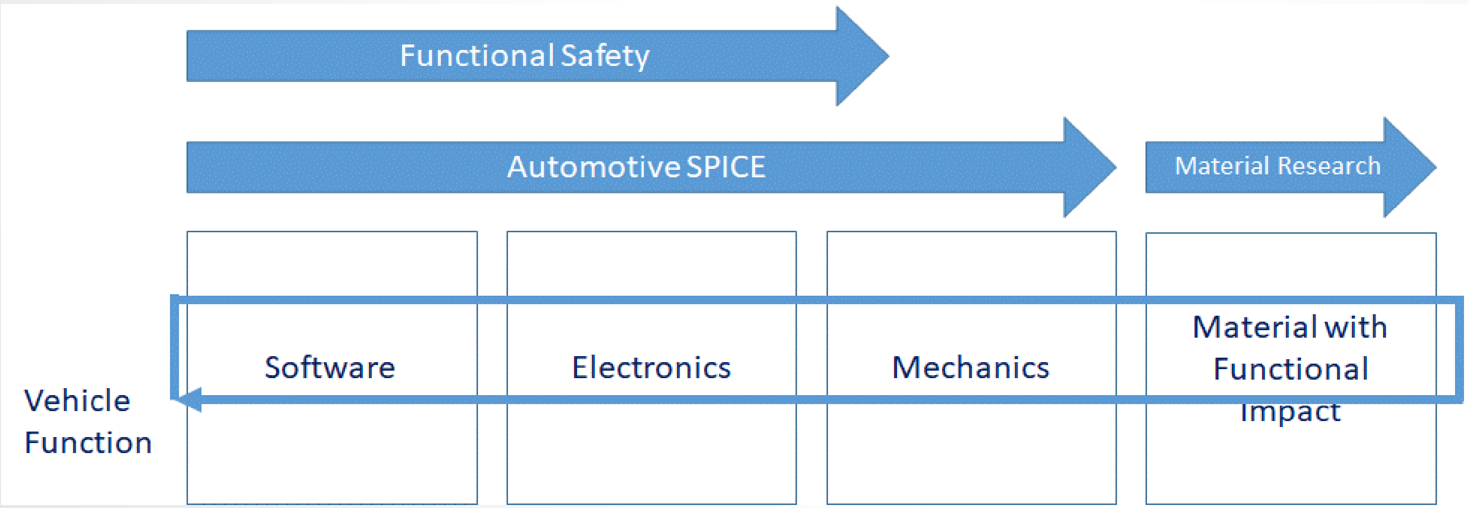
The whole is more than the sum of the items, Aistoteles

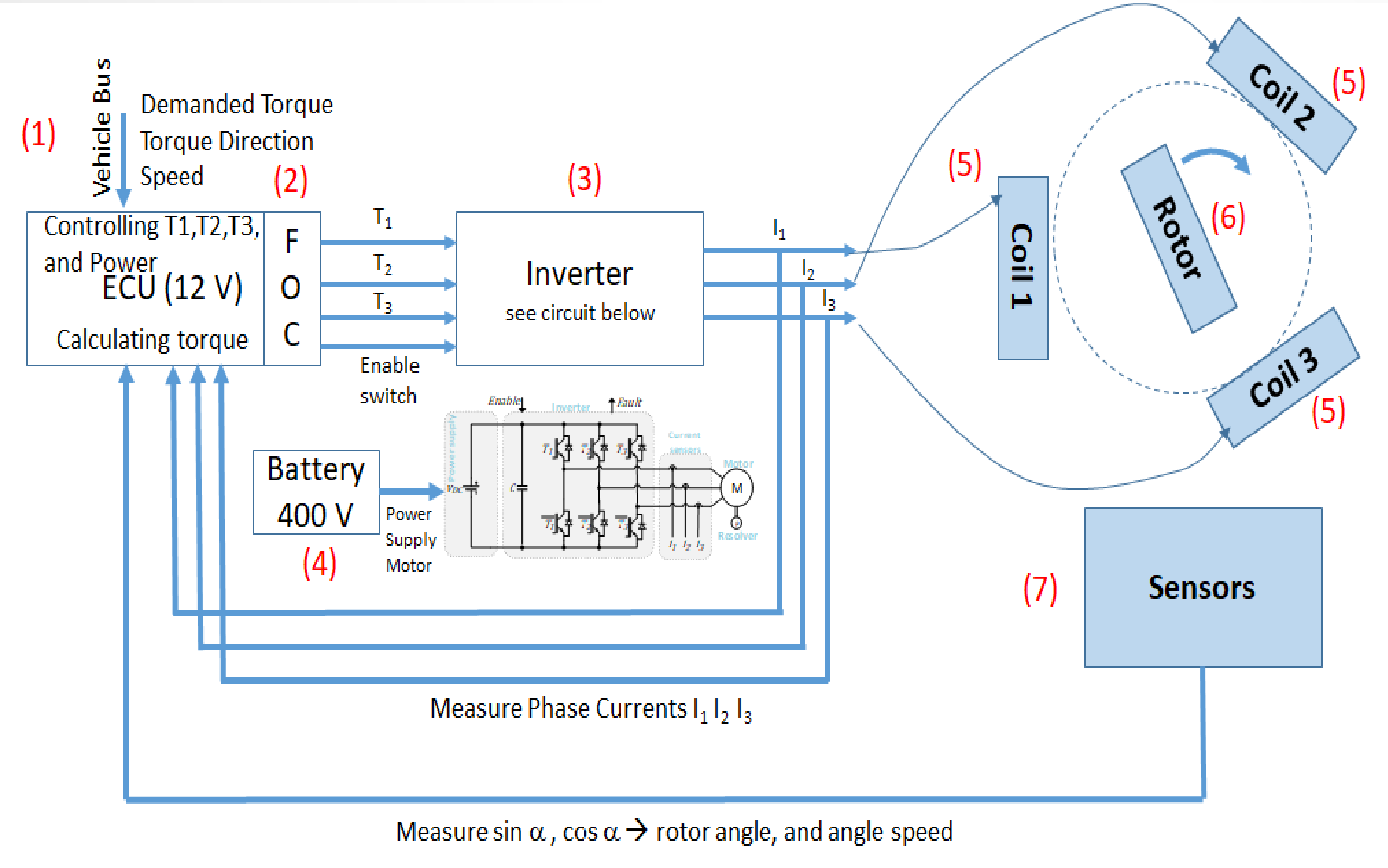
Modern Design Paradigms

Systemic View

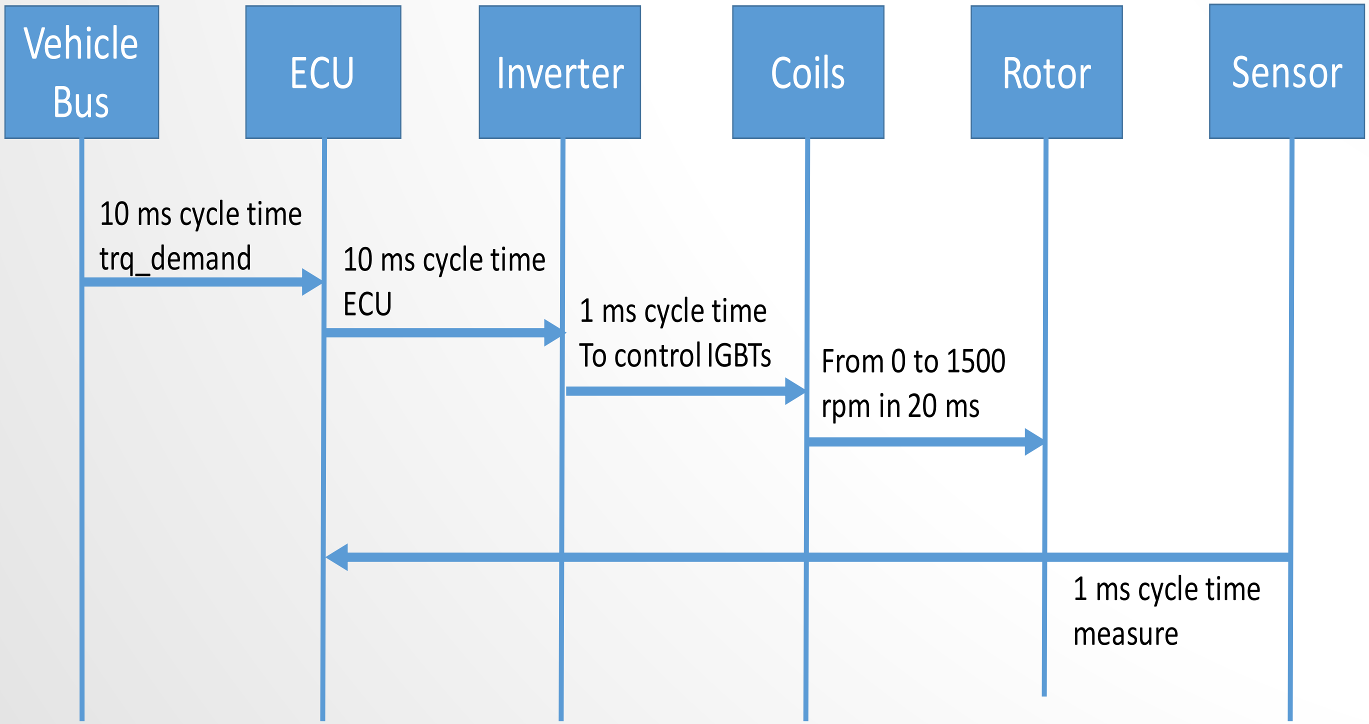


- Automotive SPICE assesses software, electronics, mechanics
- Making an electric car drive long distances requires more than mechatronics design
- A vehicle function also includes material design assumptions, material with a functional impact.

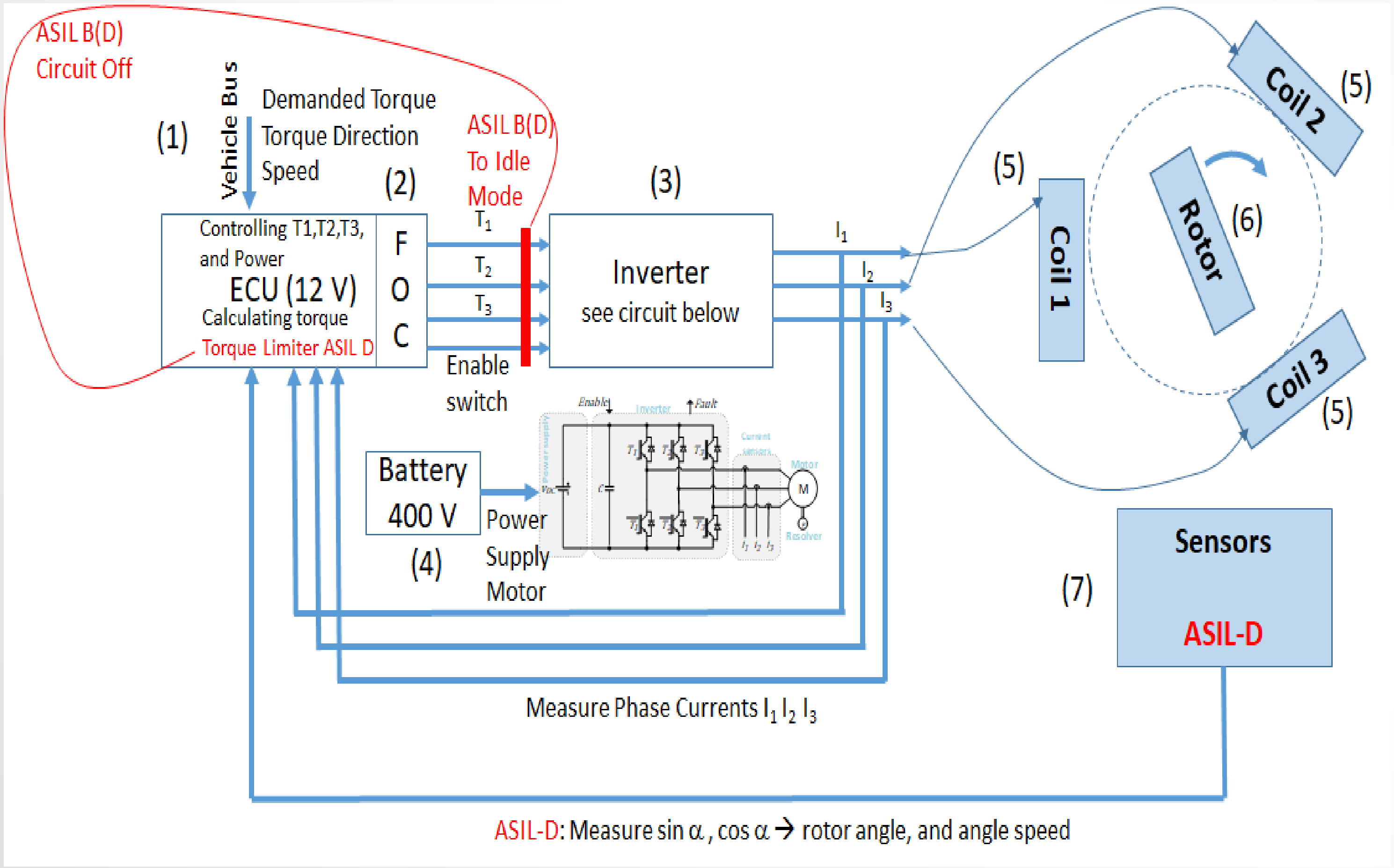
ELECTRIC POWERTRAIN EXAMPLE (ASPICE – FUNCTIONAL VIEW)



ELECTRIC POWERTRAIN EXAMPLE (ASPICE DYNAMIC VIEW)



ELECTRIC POWERTRAIN EXAMPLE (SAFETY VIEW)



ELECTRIC POWERTRAIN EXAMPLE (CONNECTED MATERIAL FUNCTION VIEW)

- Why is the first E-Golf driving less distance than …la
- **What consumes the power of the battery**?
- Rolling Resistance
  - Formula (i):
    - **Rolling Resistance Coefficient**
      CR = Rolling Resistance / max. load capacity of tire
    - In case of a Continental tire 185/60 R14, for instance, the rolling resistance has been reduced to 7,6 due to recent research, and the (Lastindex) max. load capacity index of the tire is 82, which represents a max. weight of 475 kg
    - **CR =** 7,6/475 = **0,016** (rolling resistance coefficient)
  - Formula (ii):
    - **FR – rolling resistance force** for a specific vehicle, with a specific weight, in kWh
    - The typical estimation formula for a given car is **FR = CR * FN**
      - **CR Rolling Resistance Coefficient**
      - **FN Newton power on the wheel depending on the weight of the car**
      - **Conversion: 1 kg = 9,81 N , and 1 kWh = 3,6 MJ (Mega Joule)**

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  - **Example**
    - **Vehicle with 2020 kg, with a Continental 185/60 R14 tire the CR = 0.016, the resistance force will be approx. 2020 * 9,81 * 0.016 = 317 N.**
    - **This produces per 100 km 317 N · 100 000 m = 31,7 MJ = 8,80 kWh power consumption just caused by tires resistance and weight of the car**

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    - Drives 179 km
    - Battery power 35,8 KWh
    - **Consumption by weight and resistance force** by wheels 179/100*8,8 = 15,75 KWh
  - **Forces not calculated**
    - **Wind resistance (also contribute to a large amount)**
  - **Functions need to include the material impact? - yes**

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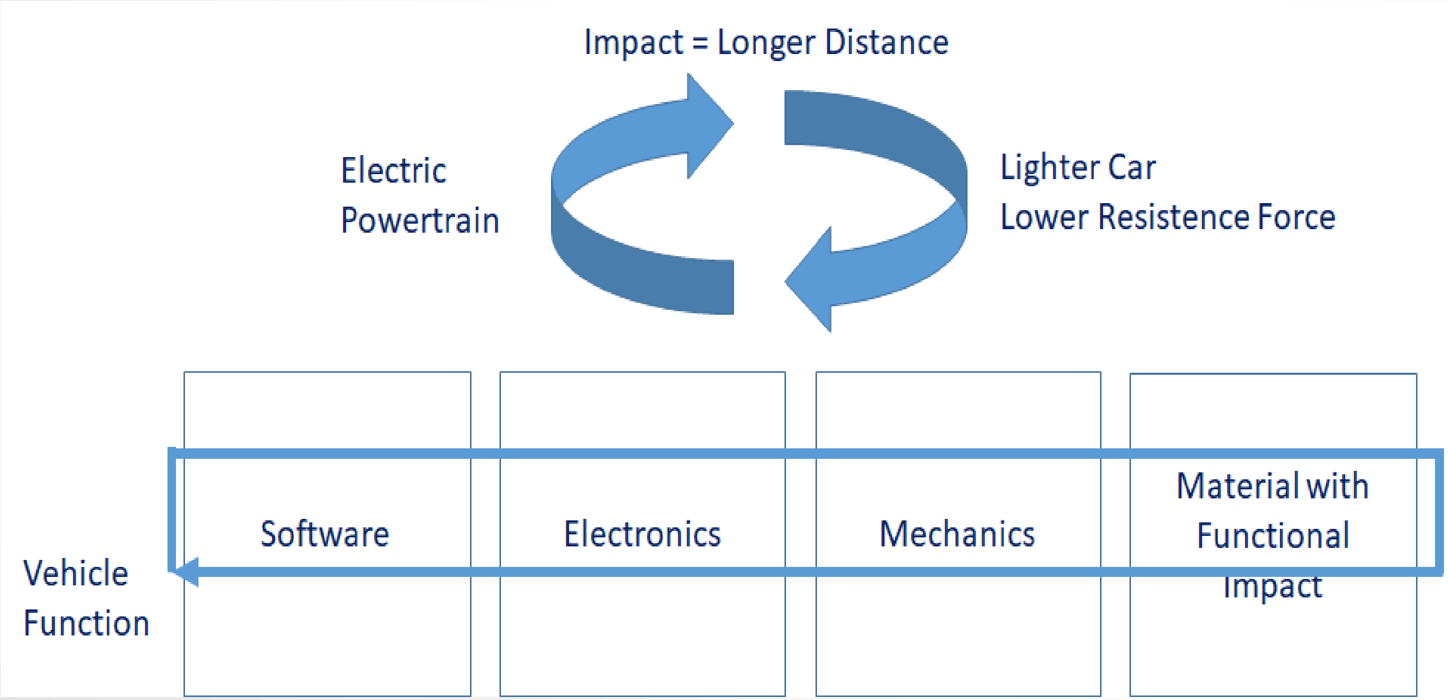

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“Everything should be made as simple as possible, but not simpler.” –Albert Einstein

“If you feel no resistance you have not done real research.” –Richard Messnarz