STAMP/STPA case study

Range Extender System for Electric Vehicles

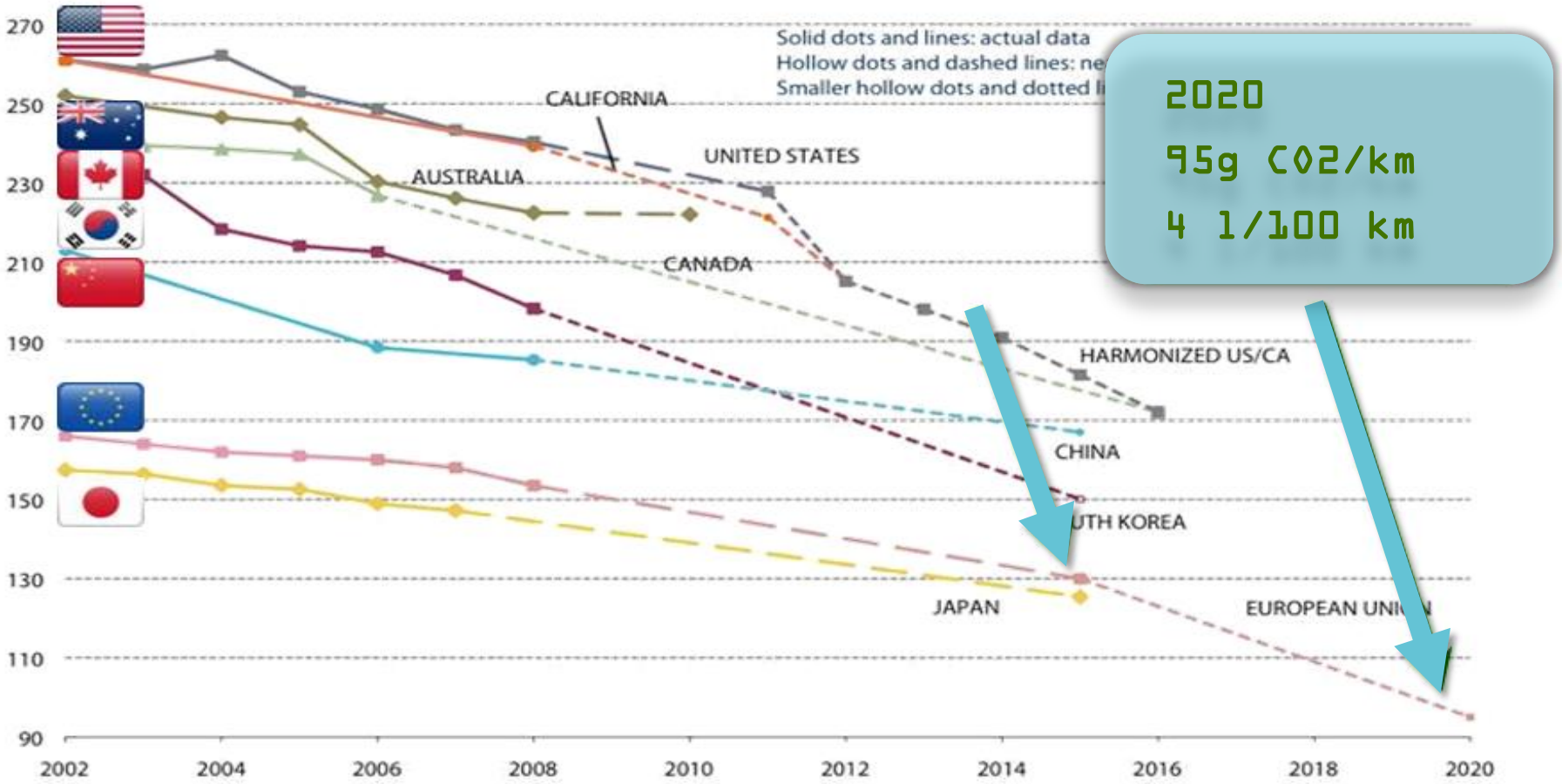
Hossam Yahia &
Esmaiel Fawzy

VIAS - Egypt

Agenda

- Introduction to electric and hybrid vehicles
- Range extender system
- High level safety control structure
- STPA application
- Comparison with results from FTA/CPA
- Conclusion
- Q&A

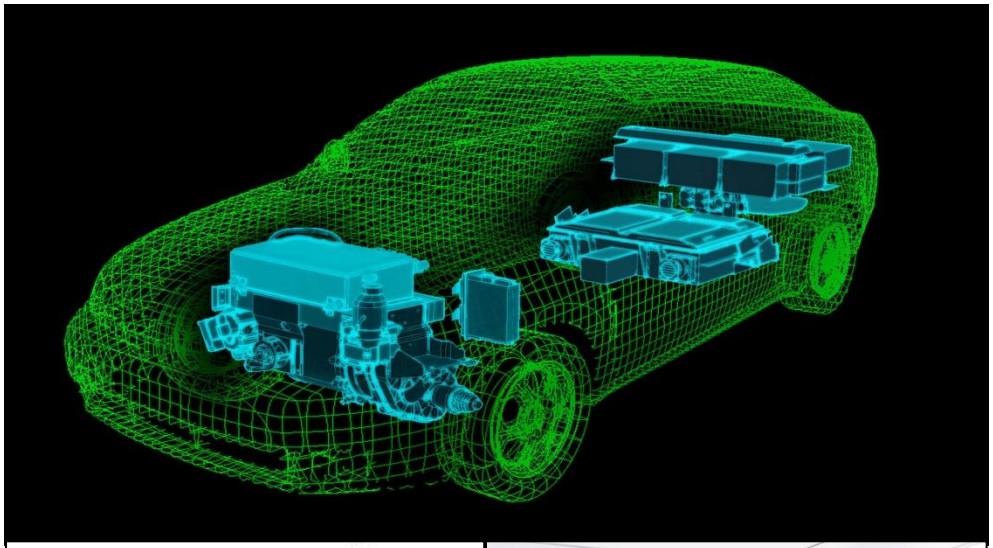
CO2 Standards



Introduction to electric and hybrid vehicles

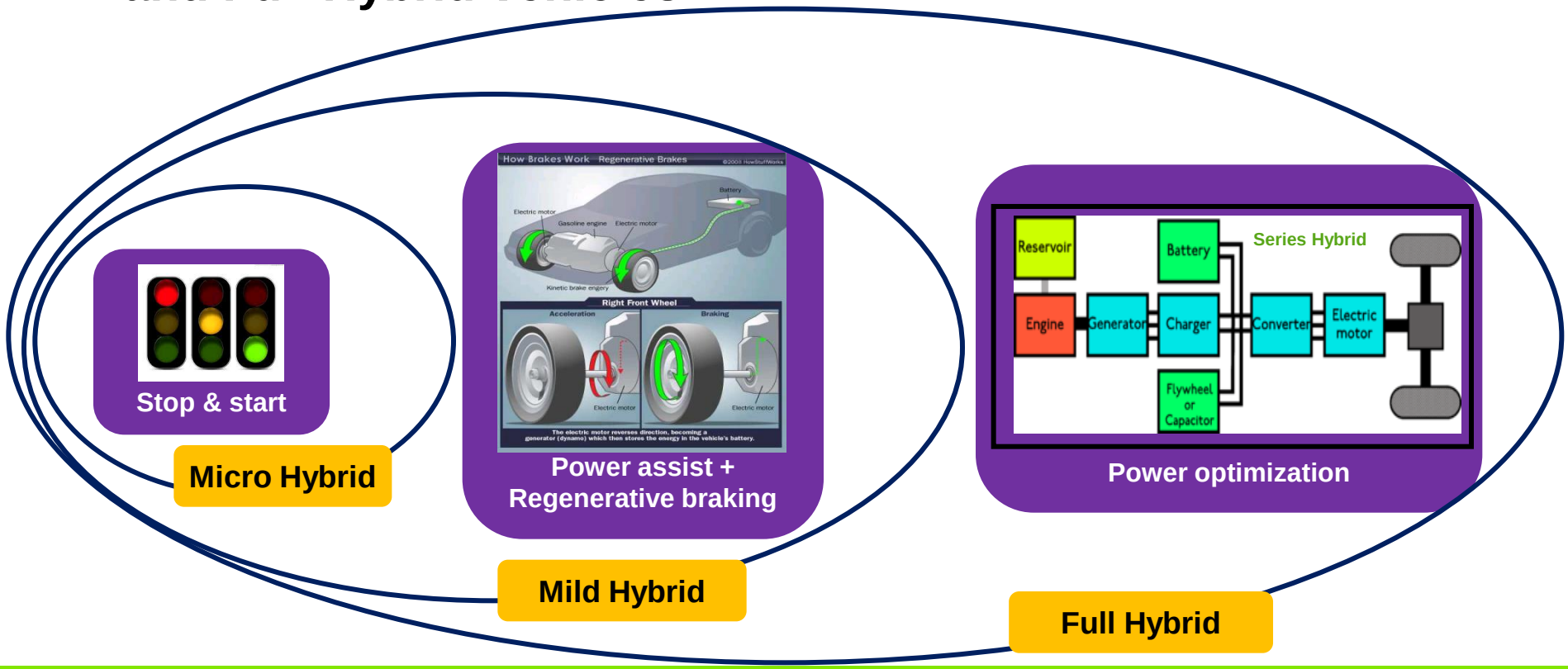
- **Battery-Electric Vehicles (BEV) or simply Electric Vehicles are powered by electric motors that run exclusively on high voltage batteries**

- **Batteries are charged by an external source such as the power grid, or a range extending trailer**



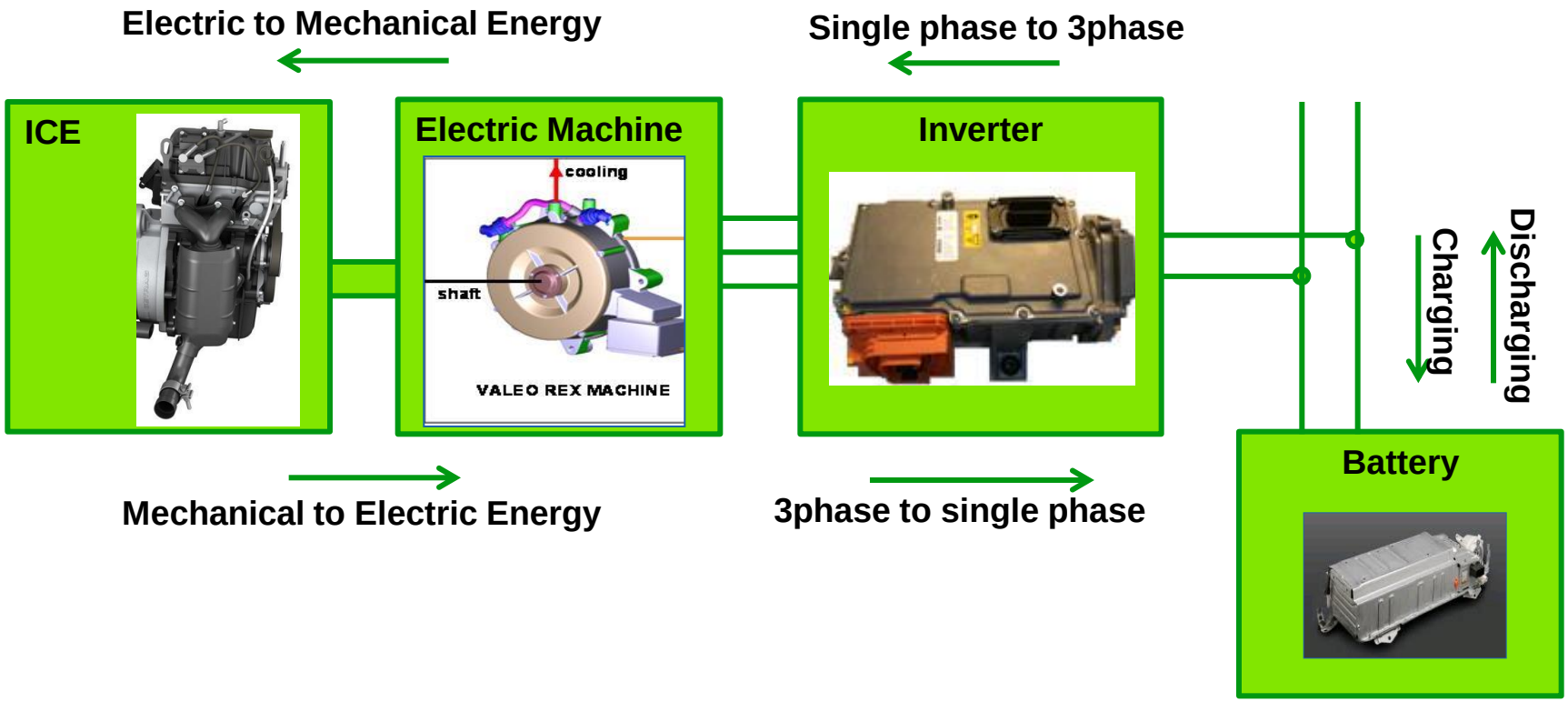
Introduction to electric and hybrid vehicles

- Hybrid vehicles combine both electric motors and ICE motors
- They can be classified into three categories: Micro, Mild, and Full Hybrid vehicles



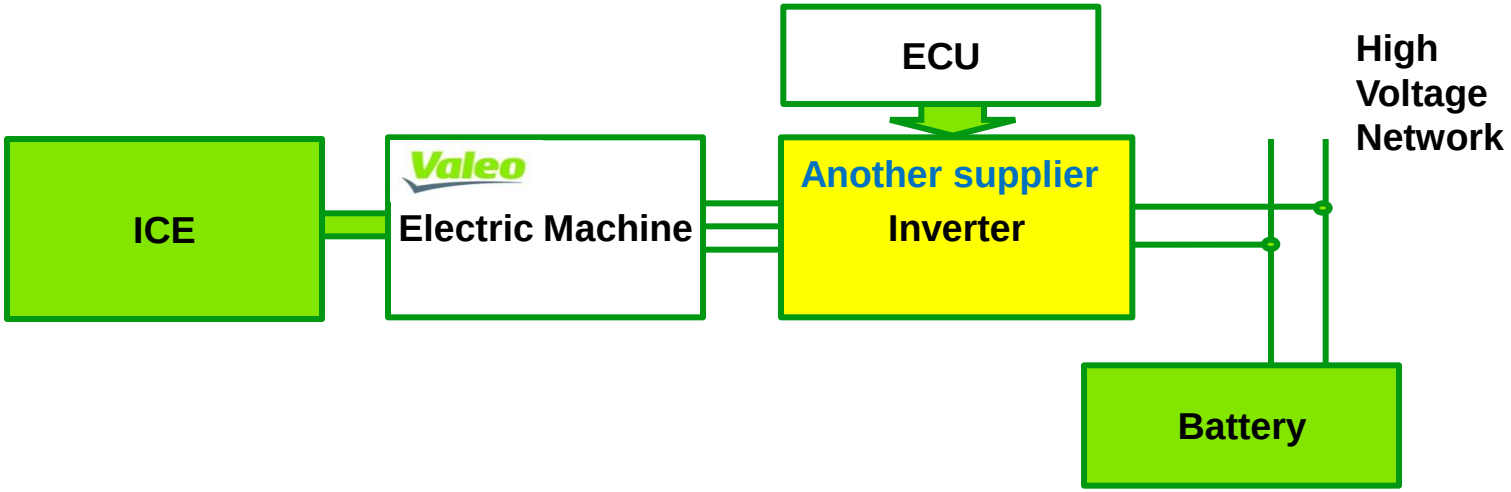
Range extender system

- **A range extender system extends the range of the battery of the electric vehicles using an extra Internal Combustion Engine (ICE)**



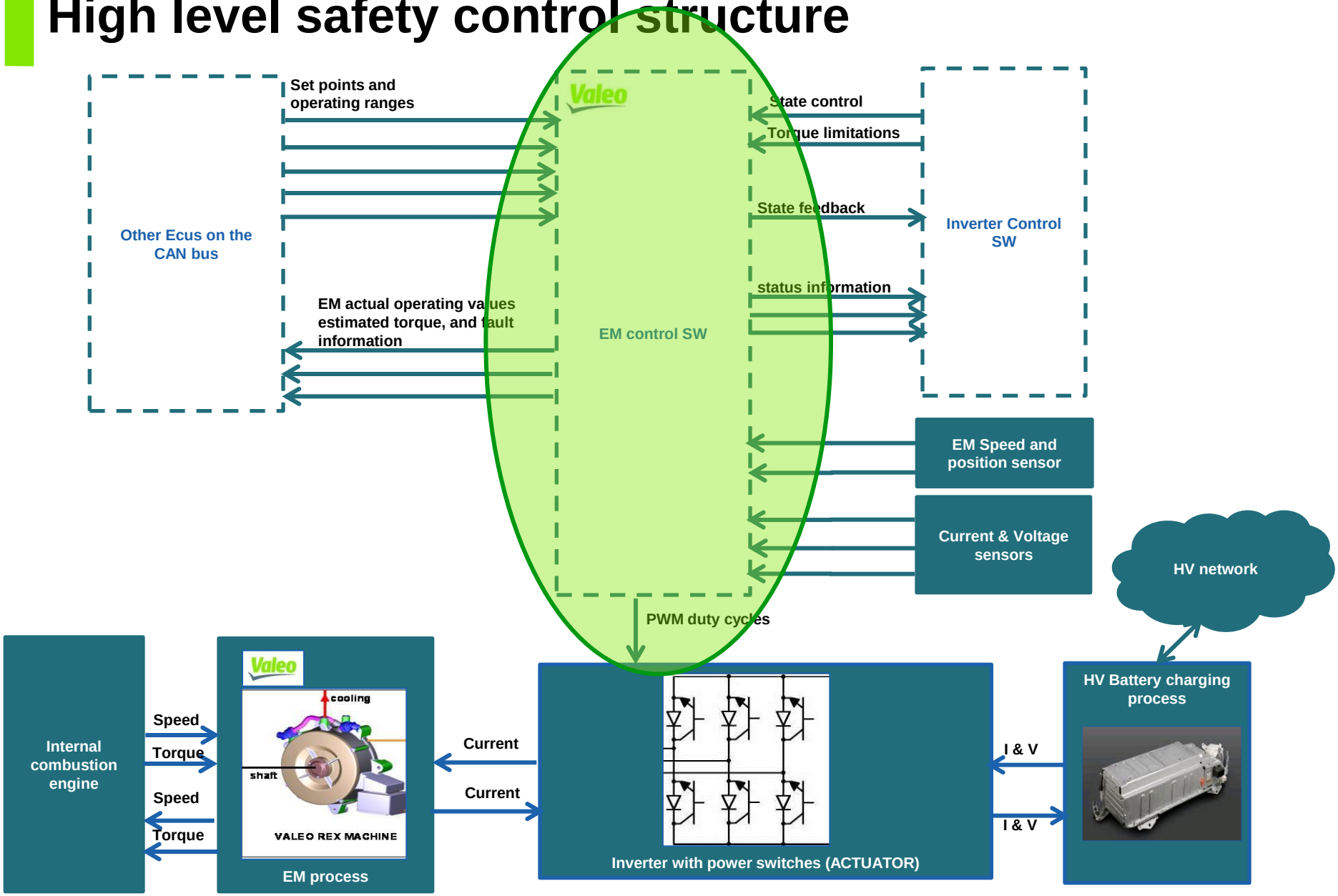
Range extender system

- **Accident / Hazard:**
  - **loss of traction system due to overvoltage on High voltage network**



- **Due to the system design, control on the EM had to be shared with the inverter control software on the same ECU**
- **A single controller with a single actuator acting on two processes**

High level safety control structure



Potentially hazardous control actions

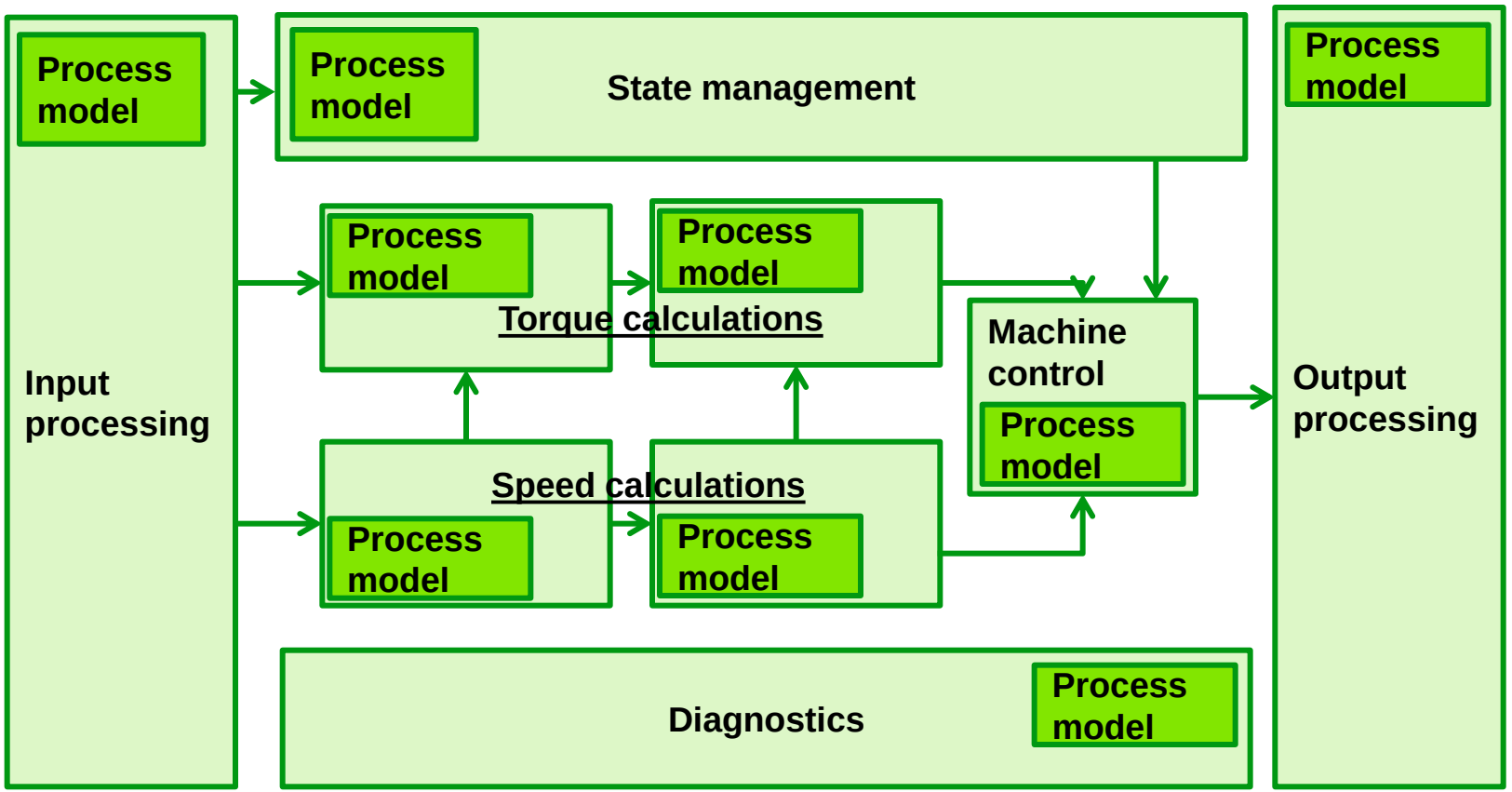
Control Action	Not given	Given inadequately (or unsafely)	Wrong timing or order	Stopped too soon / too late
PWM duty cycles	**Duty Cycles not refreshed. Can lead to overvoltage**	**Incorrectly high duty cycle (max EMF is equivalent to 50% duty) can lead to overvoltage**	**1- If the time Tc needed to update the duty cycles based on new setpoints is greater than the Tov remaining until the Vdc is over the threshold, overvoltage occurs**	**1- If sent during active shot circuit mode,… 2- If sent during freewheel mode, not critical**
Gate driver state	**Not critical**	**Not critical**	**Not critical**	**Not critical**
FreewheelAllowed	**Not critical**	**Not critical**	**Not critical**	**Not critical**
Derating status information	**Not critical**	**Not critical**	**Not critical**	**Not critical**
EM stator I,V,&Vmax	**Not critical**	**Not critical**	**Not critical**	**Not critical**
EM actual operating values	**Not providing the EM actual speed can lead to a wrong speed target. Worst case: Overvoltage**	**wrong EM actual speed can lead to a wrong speed target. Worst case: Overvoltage**	**Not critical**	**Not critical**
EM Torque estimations	**Not providing the EM estimated torque can lead to a wrong torque target. Worst case: Overvoltage**	**Wrong EM estimated torque can lead to a wrong torque target. Worst case: Overvoltage**	**Not critical**	**Not critical**
Inverter diag and fault information	**Not critical**	**Not critical**	**Not critical**	**Not critical**

First level safety Constraints

- We could identify at that level 7 constraints
  - 5 of them are in the form of normative requirements (SW shall do…)
  - 2 of them in the form of undesirable events (SW shall not do)
  - 1 of the normative requirements is related to a hazard caused by a real-time error

Detailed control structure

- **Matlab / SimuLink model analyzed only for the two undesirable events**



Detailed safety Constraints

- The 2 undesirable events were analyzed down to 16 normative software constraints

- So, total number of 5 + 16 = 21 software constraint

Comparison between STPA & FTA for the same project

- **Introduction:**

- **Before applying STPA, the project was analyzed with a mix of critical path analysis (CPA) and FTA**

- **CPA starts by the critical output signals and traces back to input signals, while assigning a criticality level for each signal (S0,S1,S2,S3) and for each respective module (C0,C1,C2,C3)**

- **Safety constraints were assigned on C2,C3 modules and were analyzed with FTA to identify the root causes**

Comparison between STPA & FTA for the same project

Comparison	STPA	CPA / FTA	comments
Effort	X	3X	CPA ≈ X FTA ≈ 2X
Critical modules	6	8	Less efforts needed
Normative SW constraints	21	37	CPA/FTA contained redundant constraints
Constraints allocated to inverter control software	2	None	
Example constraints	Duty cycle refresh task shall be alive monitored to ensure output duty cycles are refreshed correctly	Module z shall ensure correct calculation of engine speed of the REX e-Machine	The constraint was more efficient at the first time

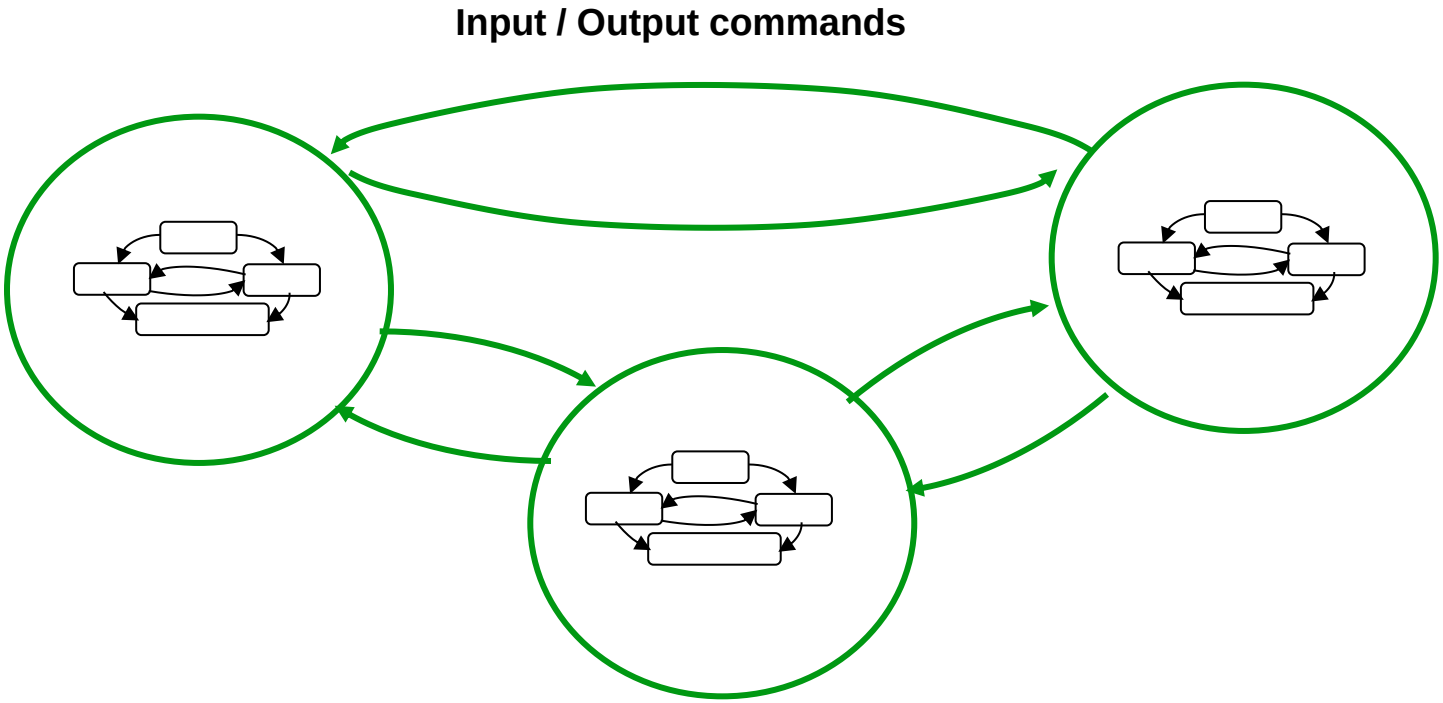
Conclusion

- **Challenges**
  - **Valeo does not own the complete system**
    - No technical safety concept for the whole system
    - Shared control with inverter software
  - **One controller on two processes**
    - Side effects on battery voltage during speed control
  - **No torque sensor (feedback is estimated)**
    - Software complexity to estimate torque

Conclusion

- **STPA was more efficient in terms of effort and quality than CPA with no need for further FTA**
- **STPA is missing application guidelines**
  - **How to develop detailed constraints in step 2 ?**
  - **How to apply STPA a supply chain?**
  - **How to develop efficient safety constraints without redundancy ?**
  - **How to develop real-time constraints?**
  - **A proposed approach to close this gap can be:** A.C. Shaw, “Communicating Real-Time State Machines.” in IEEE Trans. Software Engineering, Vo1.18. No. SE-9 (Sep. 199’2) 805-816

Conclusion



Communicating Real-Time state machines - CRSM was first published in 1992 by Alan C. Shaw, and introduced to be a "*New, complete, and executable notation for specifying concurrent real-time systems including the monitored and controlled physical environment. They are essentially state machines that communicate synchronously in a manner much like the input-output in Hoare's CSP*."

Q & A

Enabling a better automotive world