Digital Twinning & Virtual Integration

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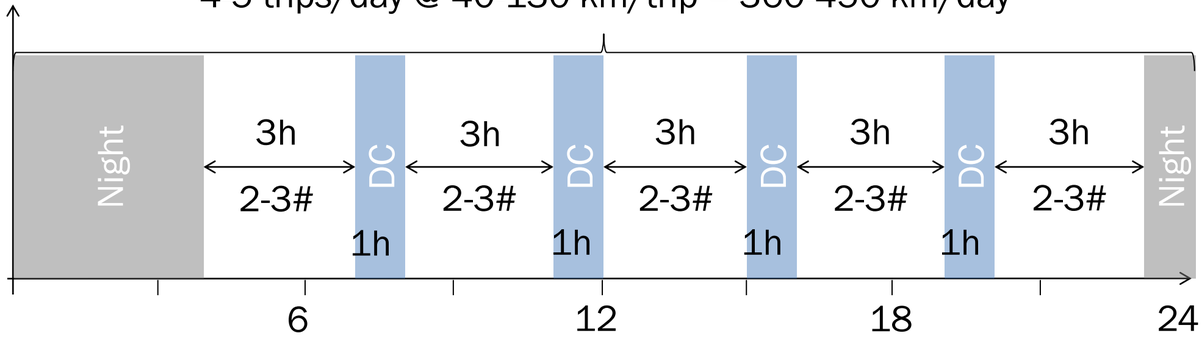
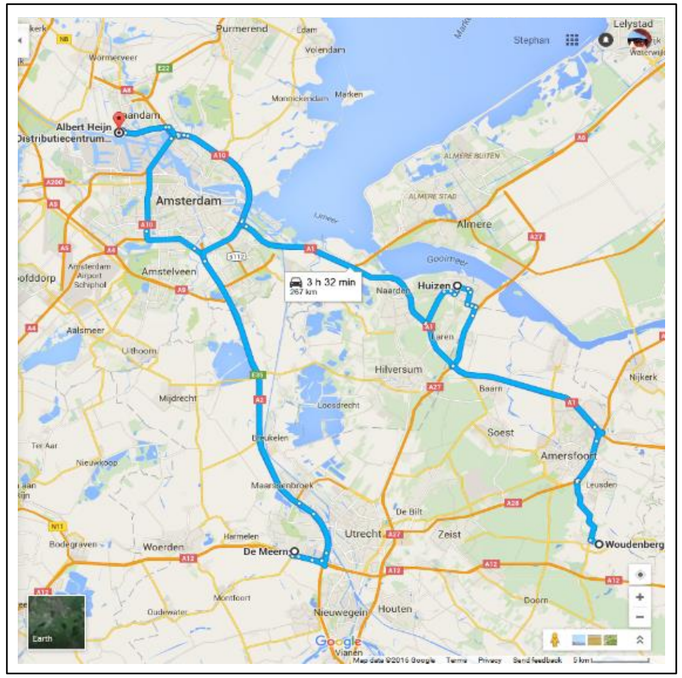
Real-World Operation of E-Trucks

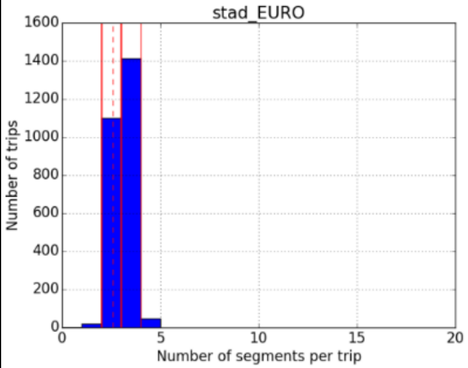
Example End User Operation

4-5 trips/day @ 40-130 km/trip = 360-450 km/day

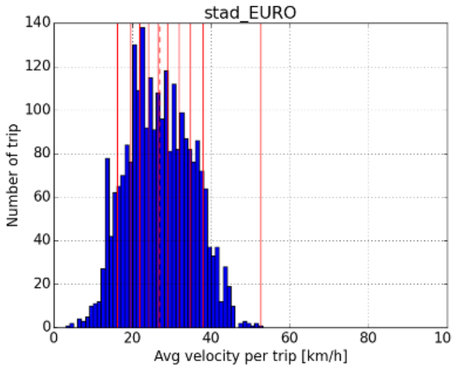


Speed in km/h [segment / trip / day]	35 / 25 / 17
Loading in kg [90% / middle / average / low]	14580 / 11246 / 2770 / 0
Typical usage Diesel [l/100km]	27-29 (+ 9.5)
Typical useage LNG [kg/100km]	23-24 (+ 9.5)
Typical useage Electric [kWh/km]	1.26-1.27 (+ 0.25)

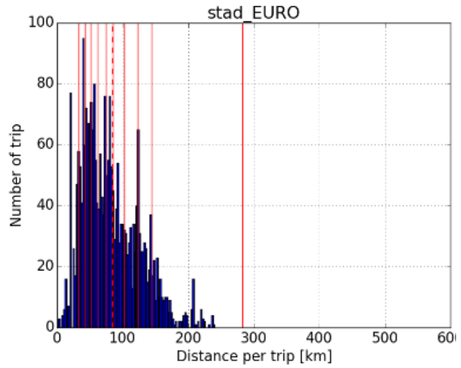


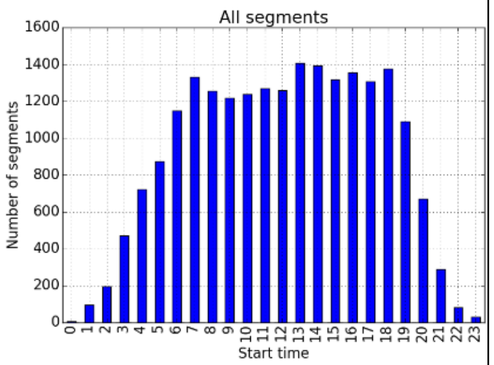


2-3 [stops/trip]



30 [km/h] ⟶ 3 [h] ⟵ 90 [km]

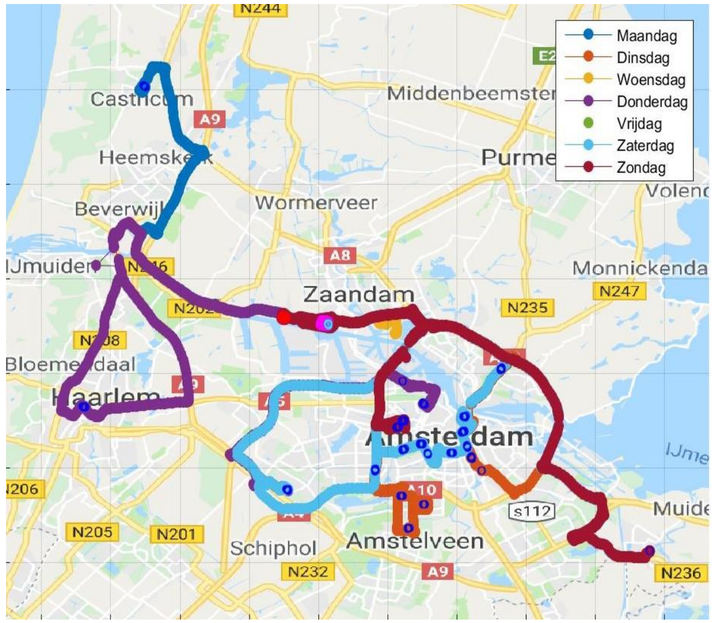


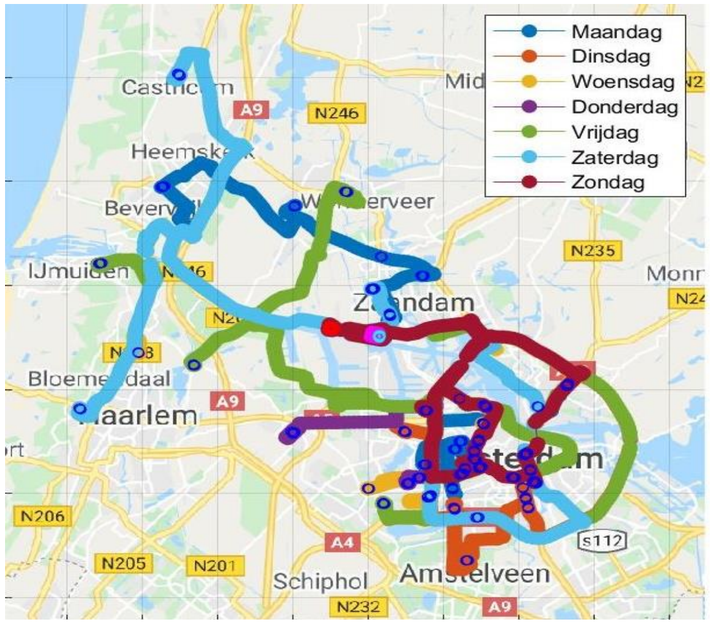


0 – 24 [h]

The use of BEV trucks: the learning curve

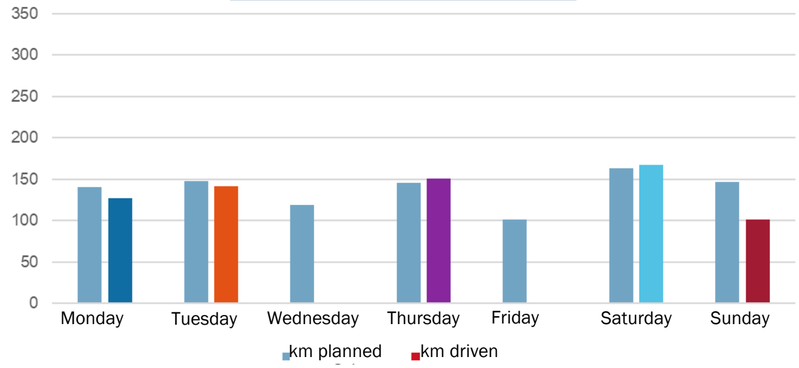
AN EXAMPLE OF THE DEPLOYMENT WITHIN LESS THAN A YEAR



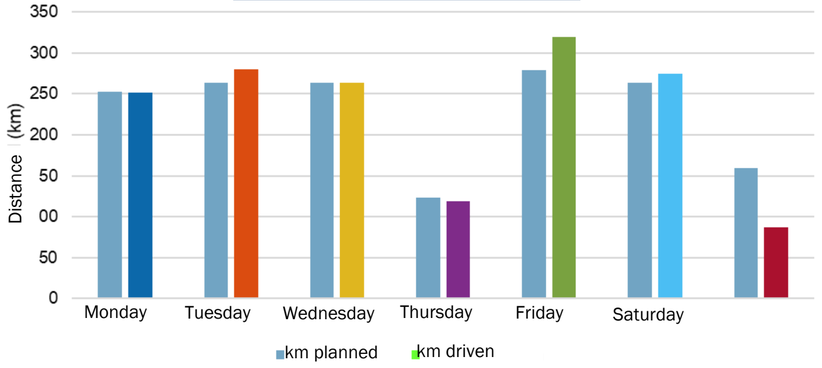


Distance

Week 37 - 2019



Week 22 - 2020



Sunday

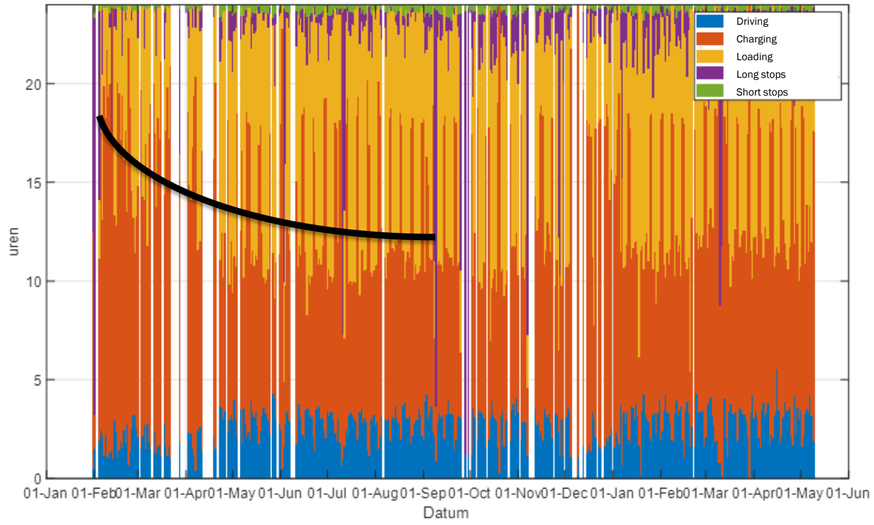
The same e-truck, completely different operation

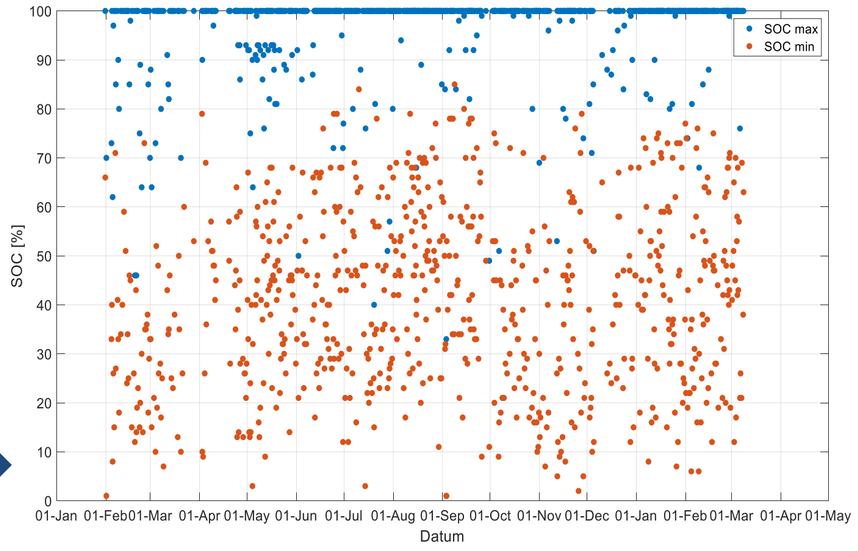
WHAT IF THE OPERATION IS PREDICTABLE AND THE RIDES SHORT

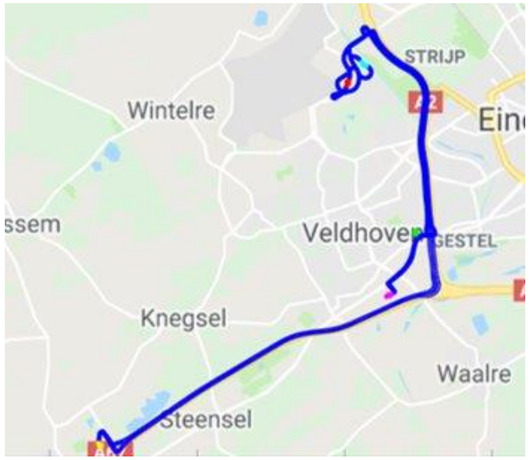
- Go through learning curve here too
- > 50,000 km driven, 7 days / week
- This e-truck is now used almost identically to a diesel truck
- And allows the planning to discharge much deeper

Optimisation is possible:

- Small fleet
- Very predictable rides
- Short trips only
- Drivers were already used to short journeys
- Charging at the dock, so usually no time wasted





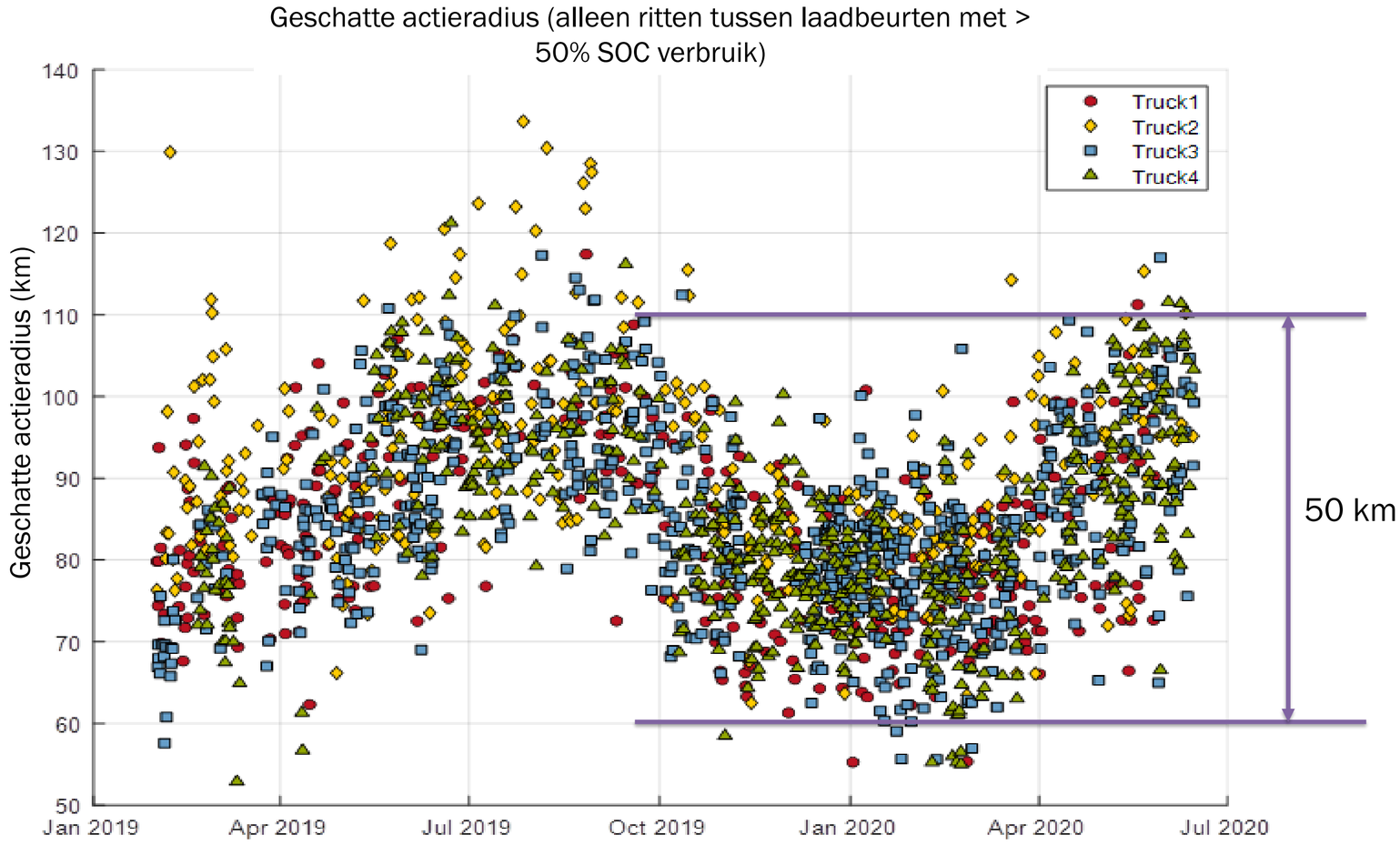


The Range in Practice

LEVEL AND RANGE VARIATION STRONGLY INFLUENCES OPERATION

- Obvious seasonal influence
- Estimated range in practice can differ almost by a factor of 2
- Main influences: combination weight, ambient temperature, city/highway distribution
- All these influences are known separately, not part of this presentation

Standstill due to an empty battery is not accepted, which is why planning is often based on the worst-case range. This means (much) shorter journeys than theoretically possible (= improvement potential)



Digital Twinning

Different types of digital twins

Digital Model

Virtual representation of a physical system

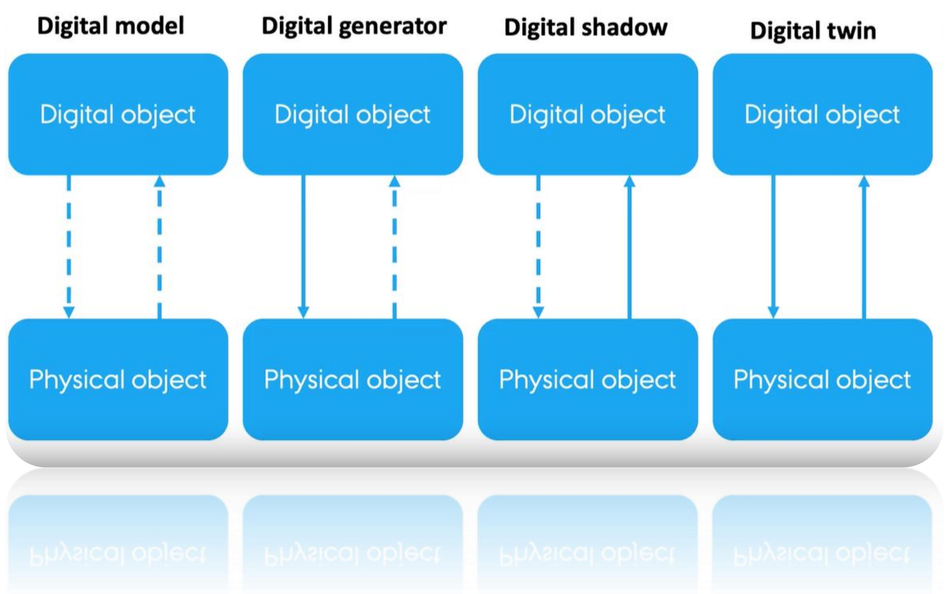
No interaction between system and model

Digital Generator

Physical system follows the model

Digital Shadow

Model follows physical system



Digital Twin

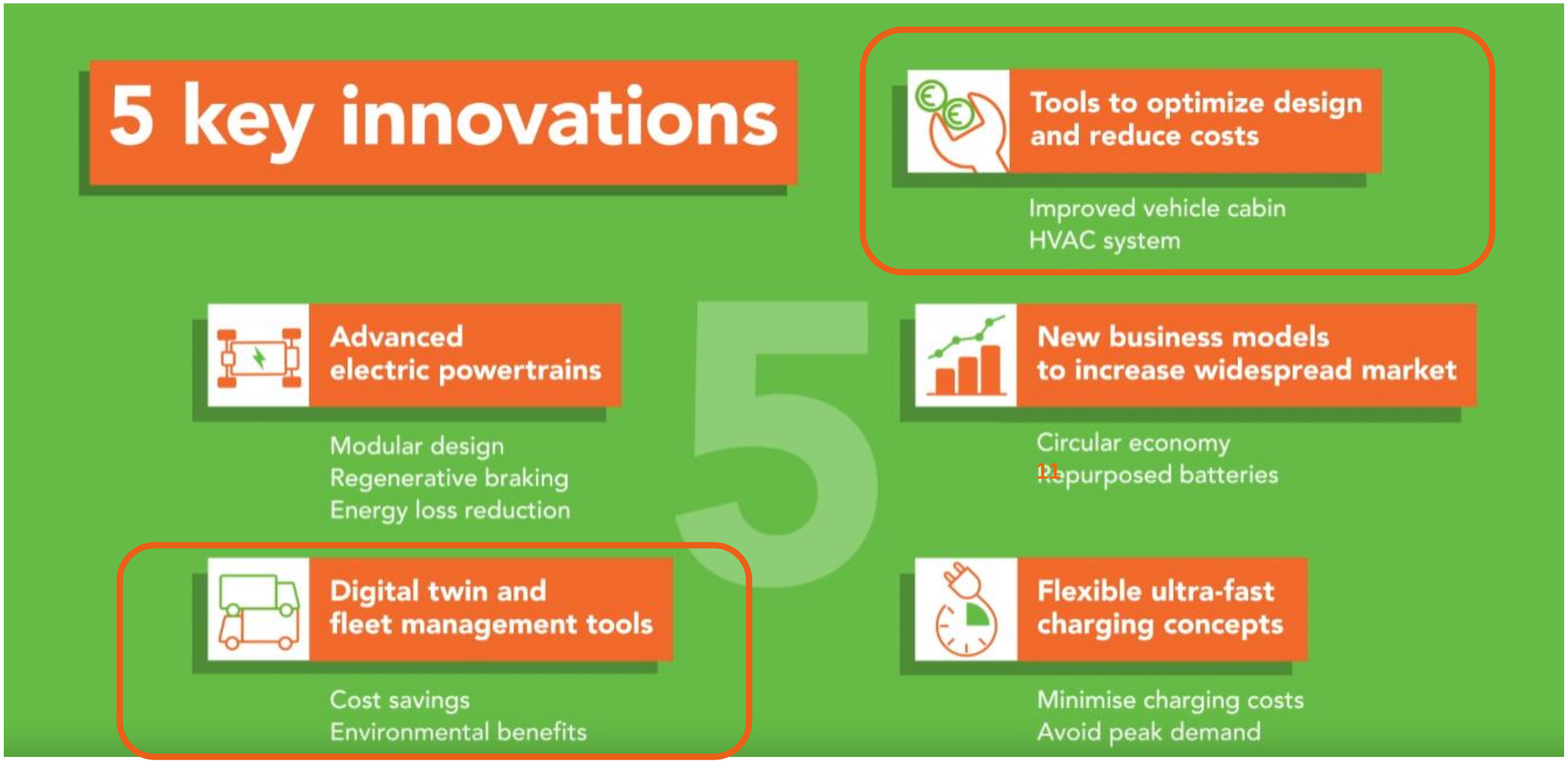
Virtual representation of a physical object or process

Bidirectional exchange of data between physical and virtual system

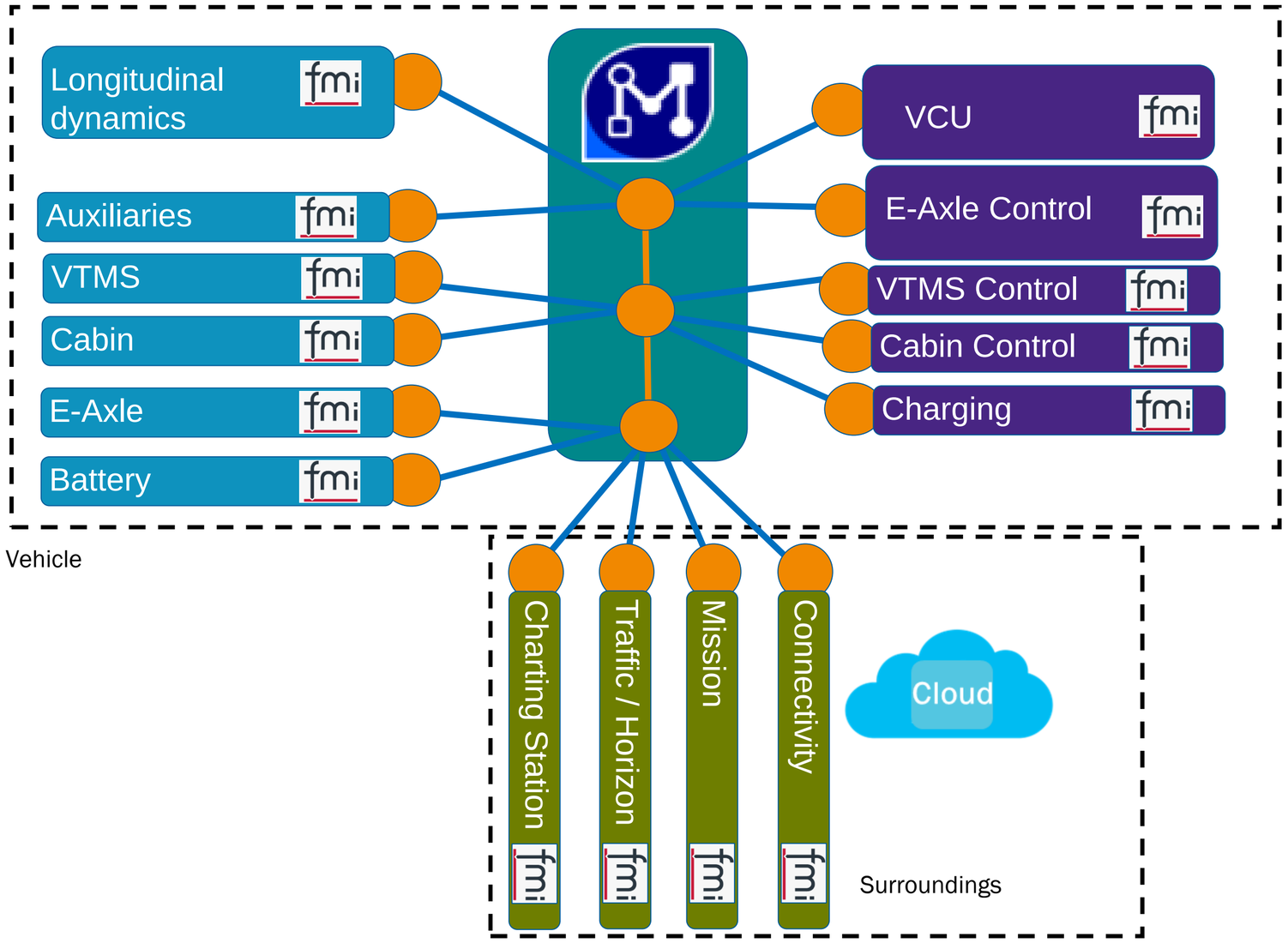
Used for process optimisation, observation, prediction,…

Example`A model whose parameters and states are concurrently updated based on live data, such that the model represents the physical system, in such a way that it can be used to interact with that system in a bidirectional manner`

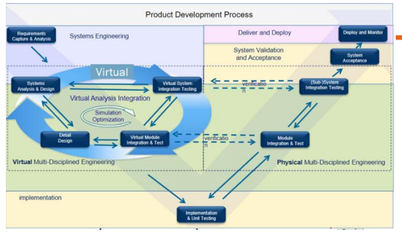
Why Digital Twin(s)?



DGT-concept



NextETruck
Digital Twin
Status 10.03.2023



System definition

- System modeling/ SysML
- Use cases
- Architecture/ interface

Model calibration

- Sub-system model identification and verification
- Autonomous calibration

Simulation

Simulation parameters

- Vehicle parameters
- Ambient parameters
- Depot locations
- Charging facility locations
- Grid, schedules

Matlab/Simulink Simulation Model (Powertrain, thermal, E/E, ECU)

MATLAB

ECU_1 (BMS) ECU_2 ... ECU_n

battery PE EM gear DF

Thermal management system

Update design variables

Optimization loop

- Objective functions
- Constraints
- Searching algorithm

No

Terminating condition?

Yes

Optimal sizing solutions

Simulation results

- Energy consumption
- Vehicle states (SoC, power, ...)
- Charging states (occupation, power)
- Depot states

TCO calculation

Cost parameters

- Unit cost data
- Component service life
- Discount rate
- Interest rate
- Cost escalation/ degression per component

TCO model

- CAPEX model (vehicles, batteries, infrastructure)
- OPEX model (driver, energy, maintenance)

python

Web-based

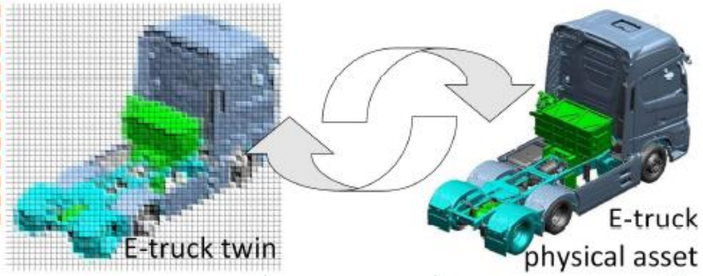
Co-simulation

fmi Functional Mock-up Interface

- Real-time capability models
- Scalable models
- Model.CONNECT™ platform

Cloud/ edge computing/ IoT setup

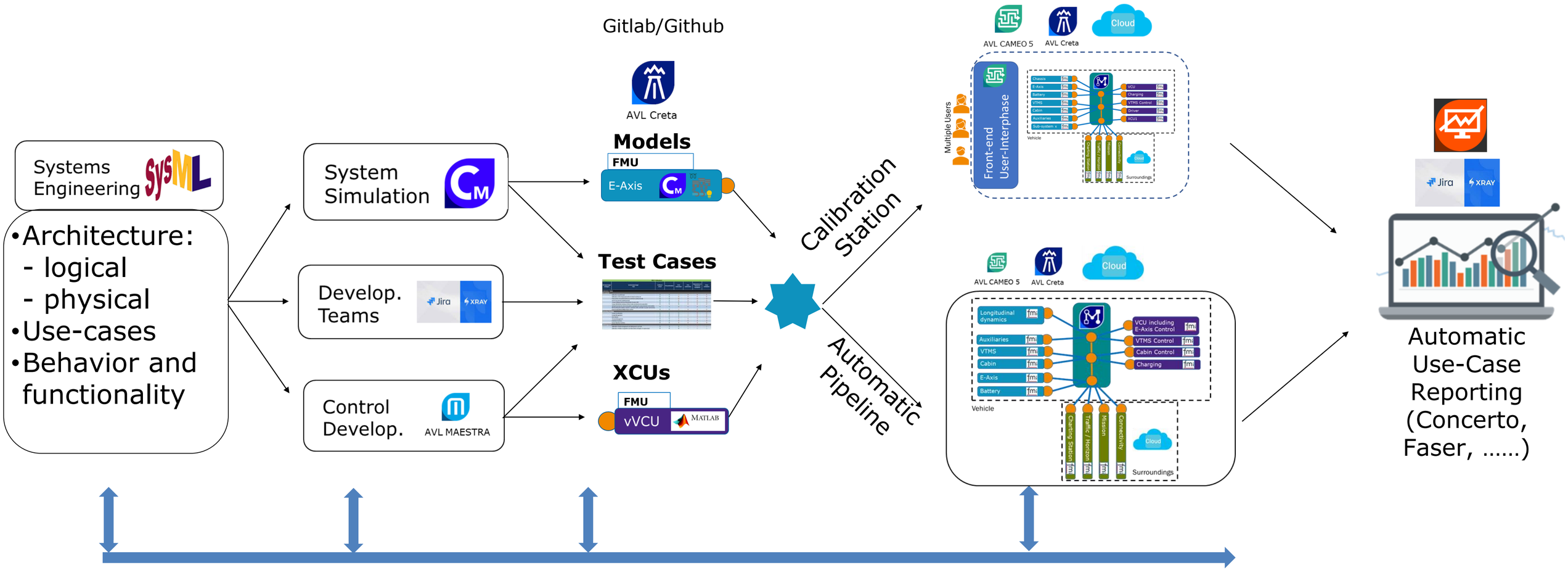
Data fusion



Pre-sizing optimization → MiL/HiL/Model Calibration → Data/IoT → Sensors

NexT ETRUCK

Example of SiL setup (as development and test tool)

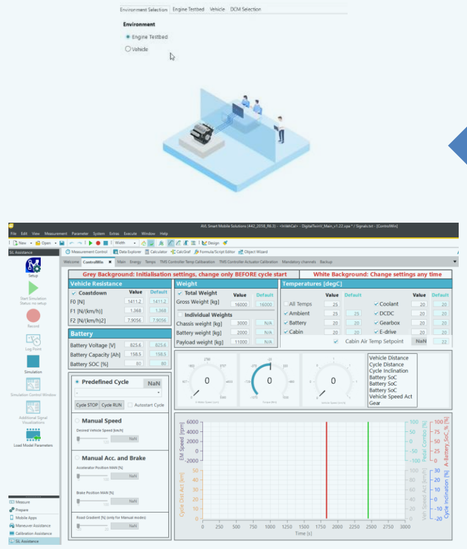


NextETRUCK Baseline Vehicle environment

Multiple Users

DB Managers

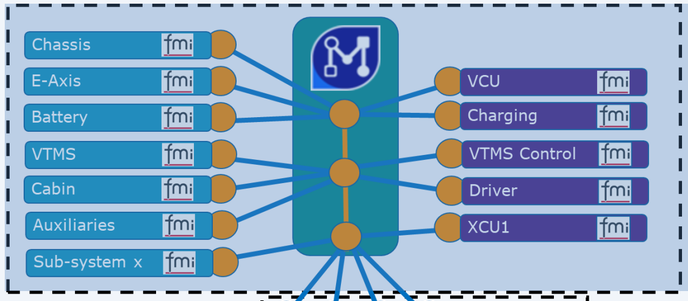
Front-end User-Interface



CAMEO & SMS

Simulation Environment

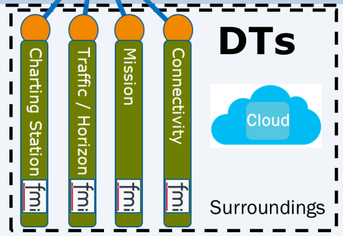
Local or Cloud deployment



Vehicle

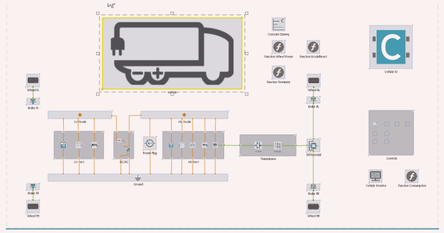
OR

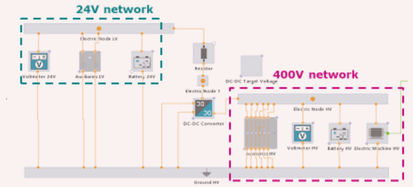
FMU



Model.CONNECT

Model Creation





Overview of electrical network in CruiseM

MATLAB & SIMULINK

CRUISE M

Model & Parameter Management

Parameter Management

Model Management

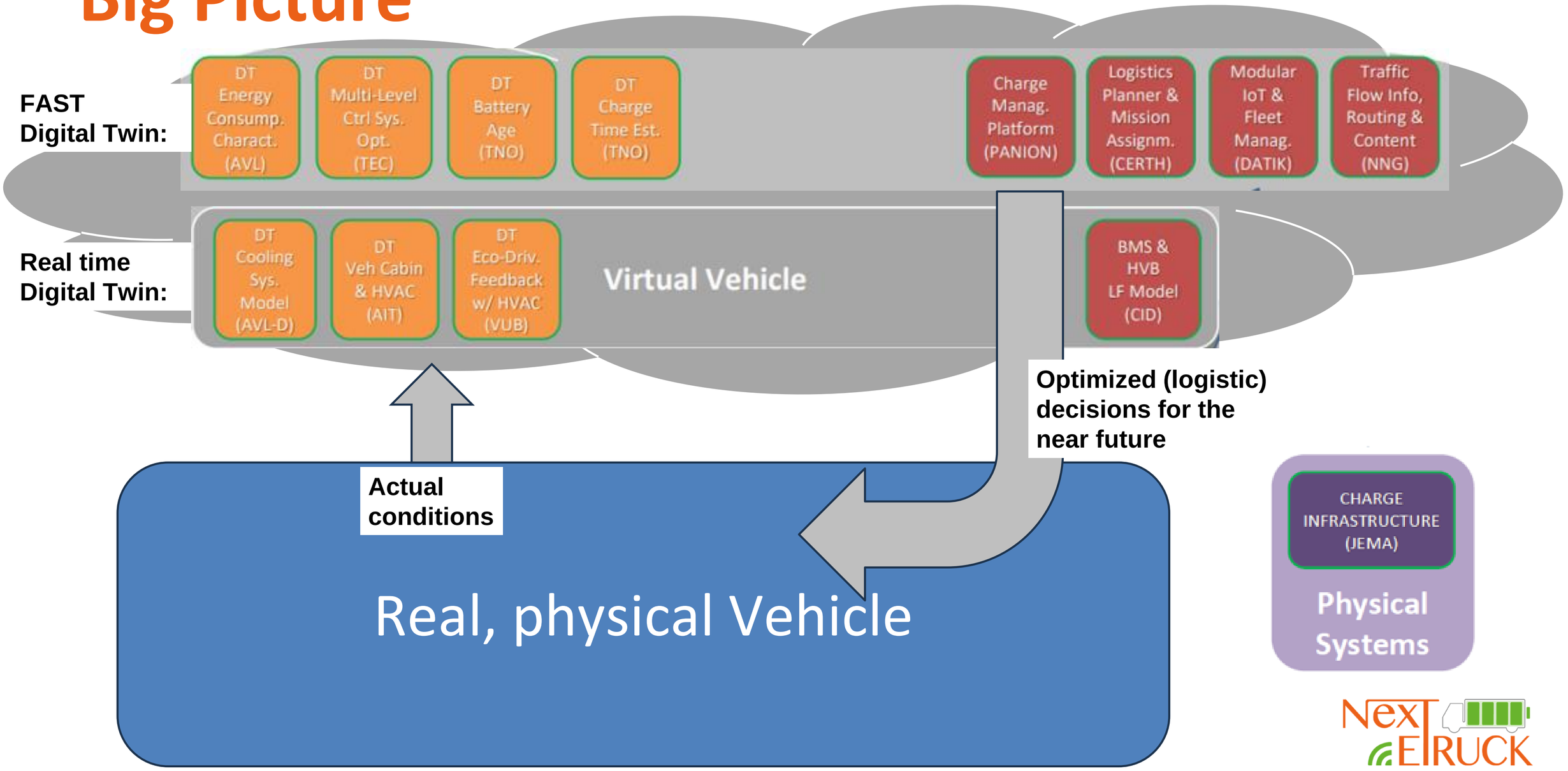
CRETA

Initialization and Calibration variables

GitHub

FMUs and Whole Vehicle projects

Big Picture


FAST
Digital Twin:
DT Energy Consump. Charact. (AVL)
DT Multi-Level Ctrl Sys. Opt. (TEC)
DT Battery Age (TNO)
DT Charge Time Est. (TNO)
Charge Manag. Platform (PANION)
Logistics Planner & Mission Assignm. (CERTH)
Modular IoT & Fleet Manag. (DATIK)
Traffic Flow Info, Routing & Content (NNG)
Real time
Digital Twin:
DT Cooling Sys. Model (AVL-D)
DT Veh Cabin & HVAC (AIT)
DT Eco-Driv. Feedback w/ HVAC (VUB)
Virtual Vehicle
BMS & HVB LF Model (CID)
Optimized (logistic) decisions for the near future
Actual conditions
Real, physical Vehicle
CHARGE INFRASTRUCTURE (JEMA)
Physical Systems

Summary

- Challenges in upscaling towards zero emission vehicles – timescale, maturity of technology, policy
- Real-word testing teaches us that data and modelling will be much more important than for conventional vehicles
- Digital twinning offers a way for monitoring, optimisation
- Standardisation (e.g. via FMUs) could provide a standard Digital Twin – especially for mixed fleets or interactions with charging infrastructure
- NextEtruck is one of a set of projects realising solutions – more collaboration is possible beyond
- Answering the research question “How big the TCO reduction can be , Applying IOT-Approaches supporting the logistic decisions by DGTs?”

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