MECH5170M
Connected and Autonomous Vehicles Systems

Virtual Learning Environment & Digital Twin
SIL, HIL

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Autonomous Vehicle Development

Traditional Design Cycle

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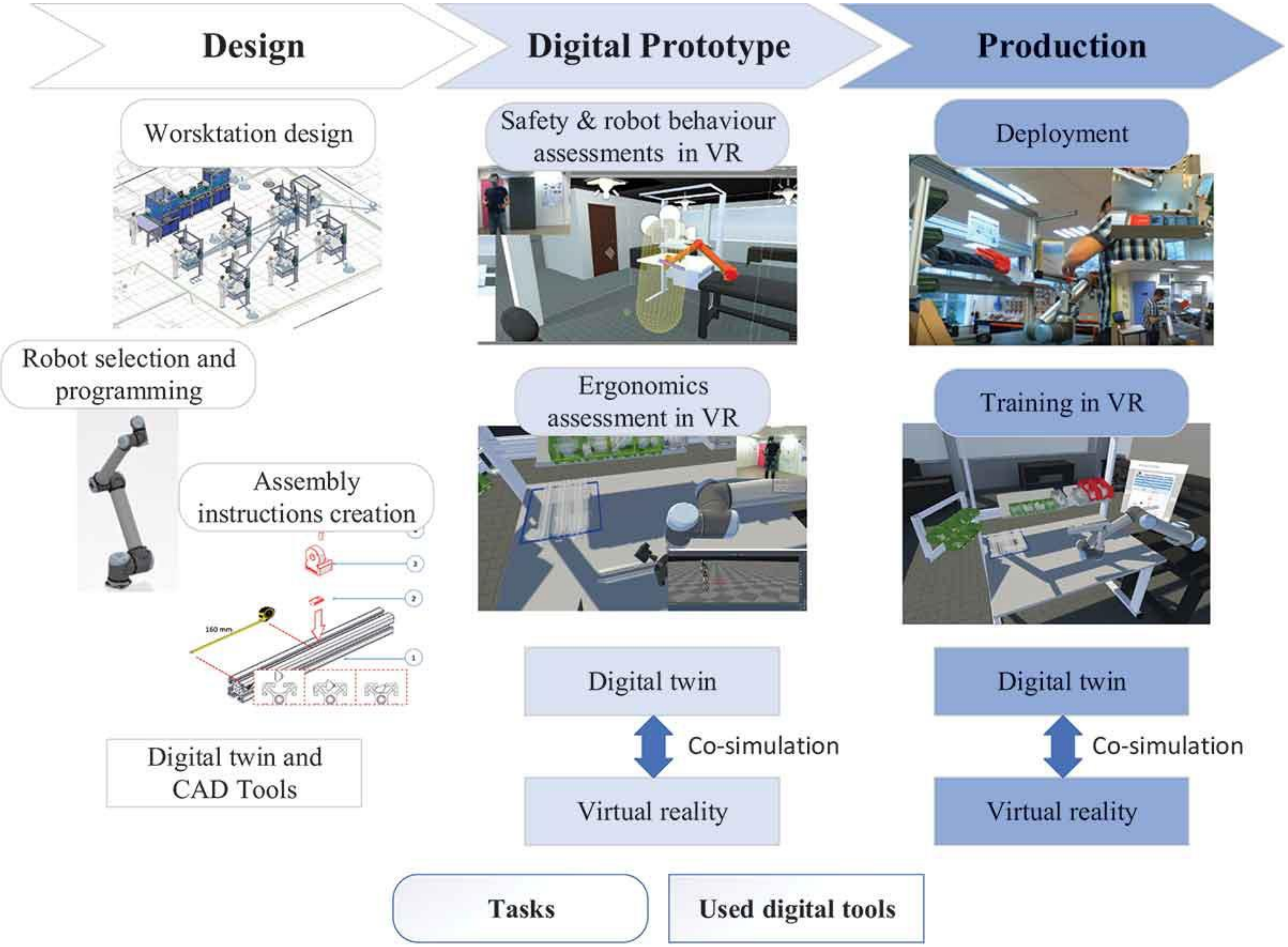
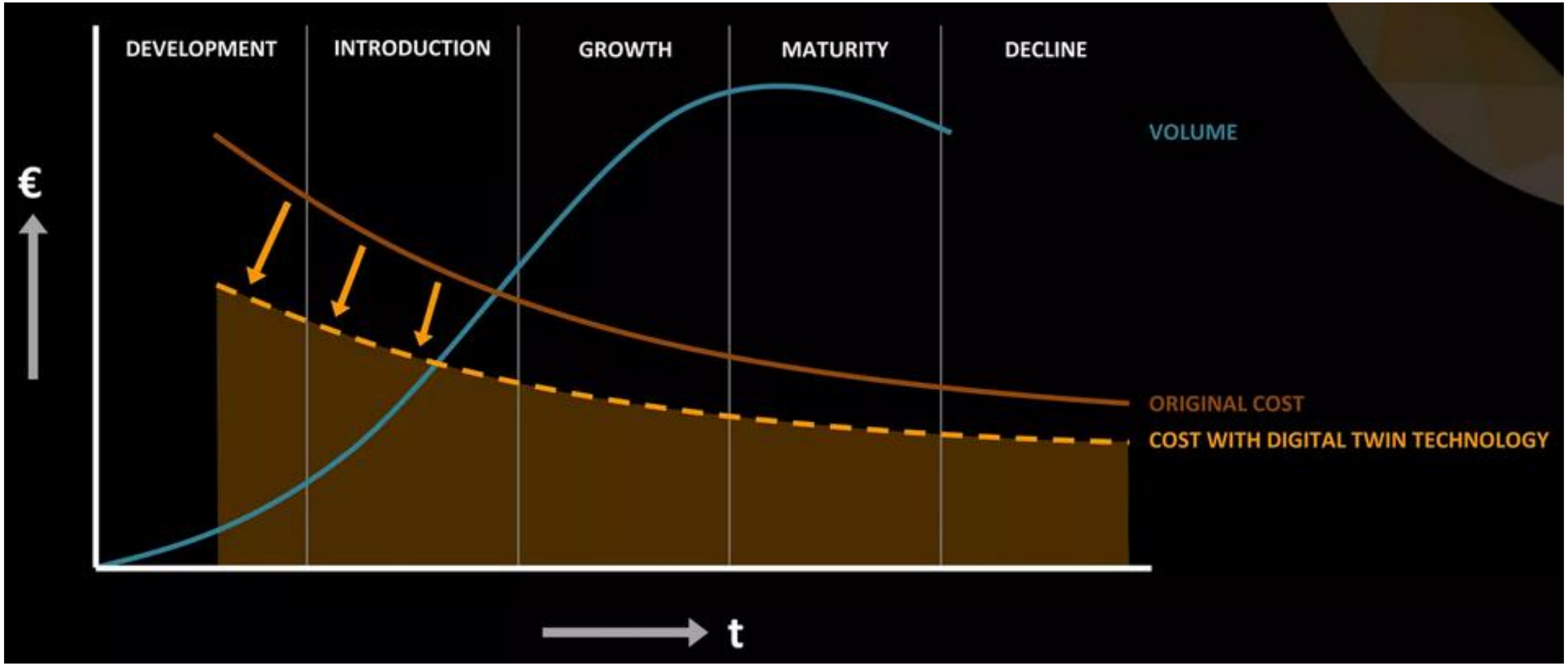
Concept



End of Life
Sustainability
Recycling

New product

New product development costs



Product development tools

Mechanical Design Tools:

- CAD - Solidworks, Autocad
- FEA - Ansys, Abaqus
- CFD - Fluent
- Materials - CES Edupack

Autonomous Vehicles:

CLARA - VLE, Digital Twin

ROS - Robotic Operating System

SIMSCAPE - Matlab

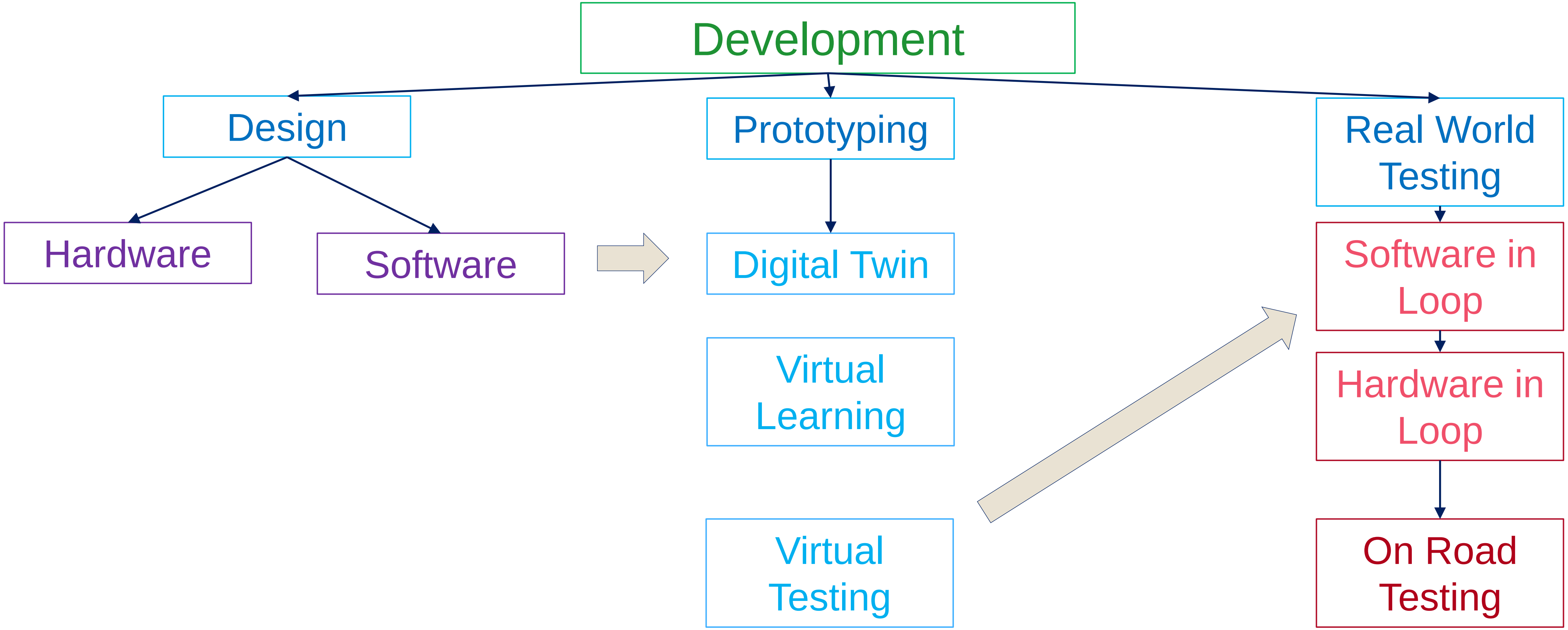
Electrical Design Tools:

- PCB - Altium, LabView Multisim, KiCad
- Simulation - SPICE

AI, Machine Learning:

- TensorFlow - Python, C++
- CUDA - GPU Processing
- MATLAB - ML, Deep Learning

Virtual Learning Environment



Digital Twin

Digital Twin

Definition by IBM:

A digital twin is a virtual representation of a physical object or system across its lifecycle, using real-time data to enable understanding, learning and reasoning.

Digital Twin Infrastructure:

- Historical and real-time data storage
- Large-scale sensor network
- HPC for information processing
- Collaborative platform for modelling
- Analysis and visualization tools
- Secure environment

Digital Twin Concept

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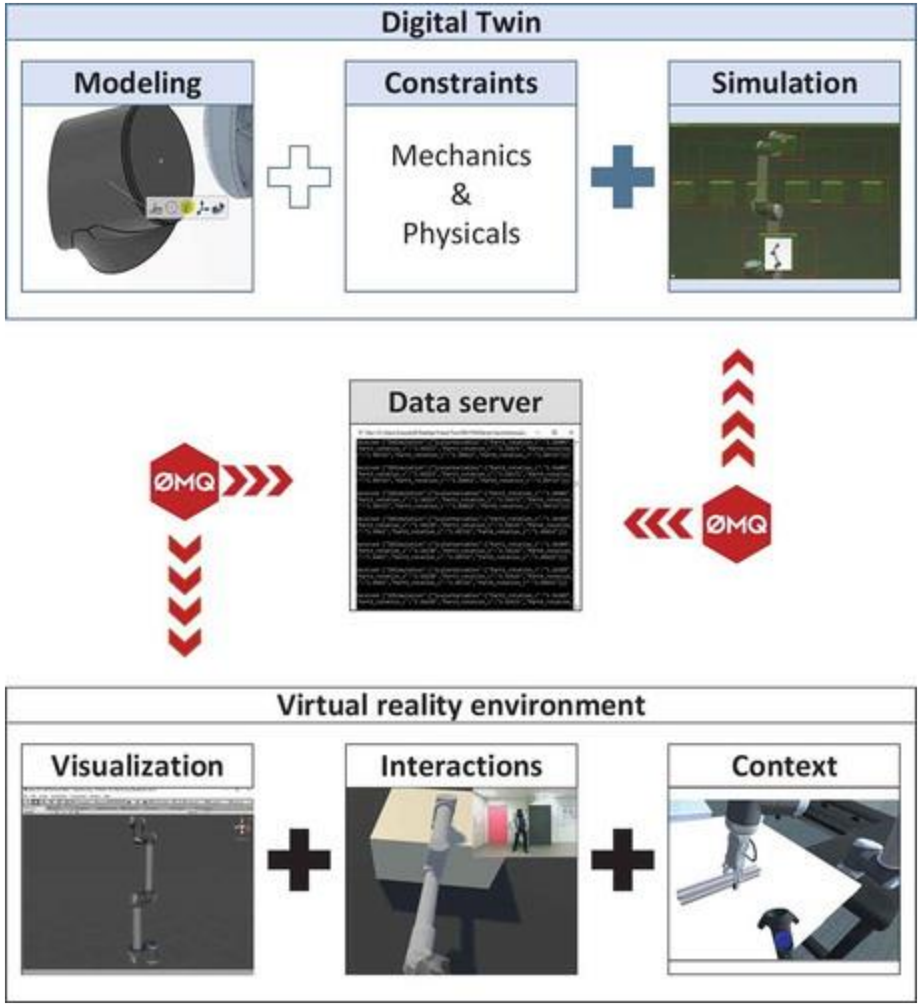
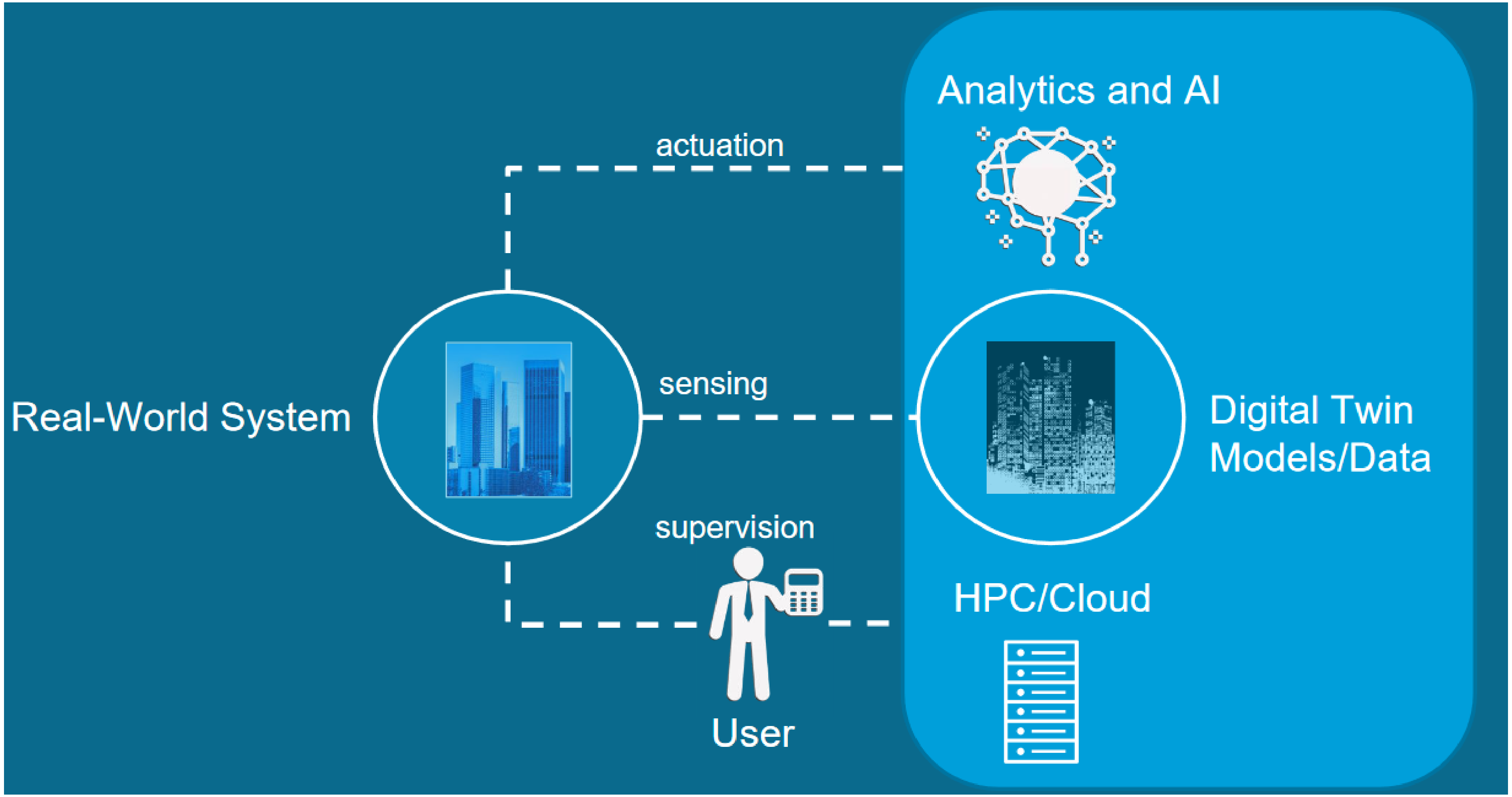
- Conception and simulation of the manufacturing system and components during design stage,
- Virtual reality, based on the 3D engine Unity
- Data server is needed for exchanging real-time data



Digital Twin Ecosystem



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Digital Twin Infrastructure

Real word

Digital Twin

Digital Twins for Autonomous Driving

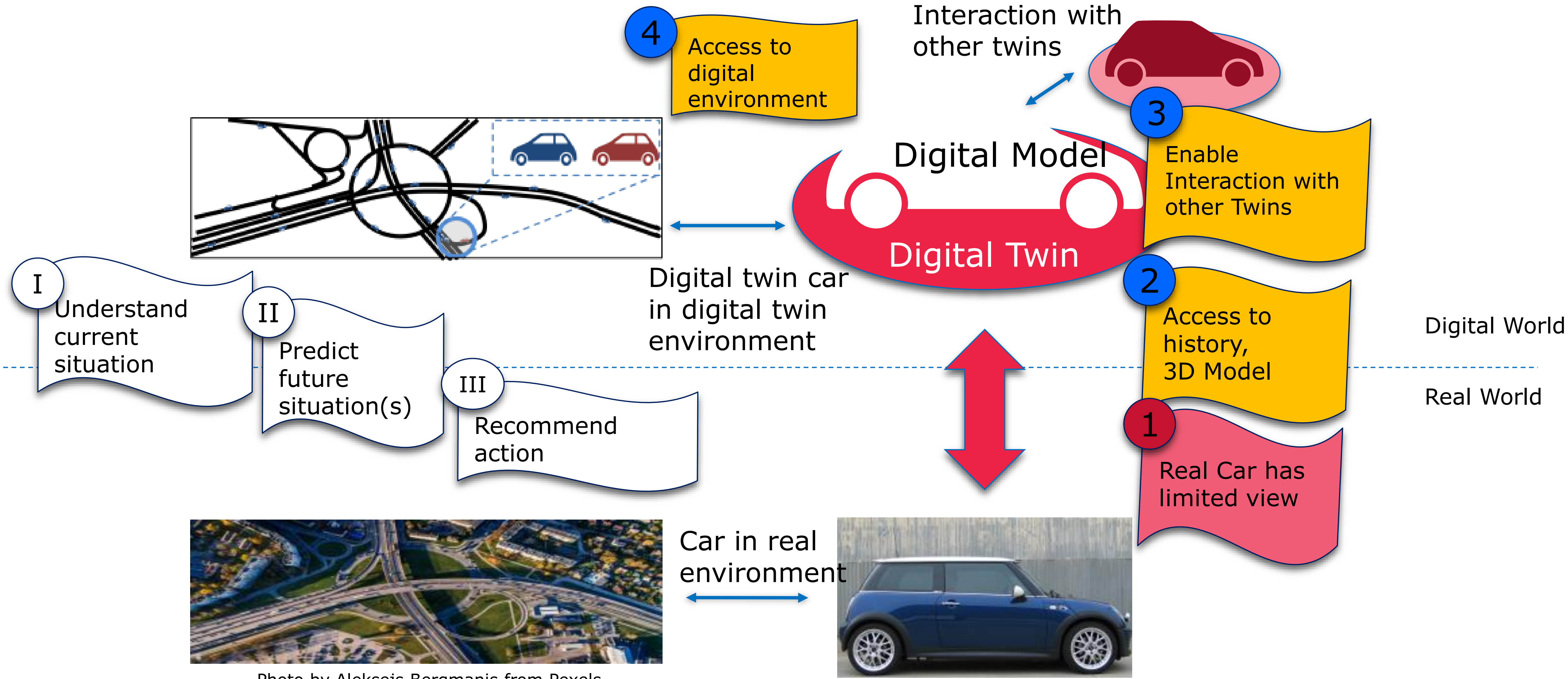

Photo by Aleksejs Bergmanis from Pexels

Digital Twin Model

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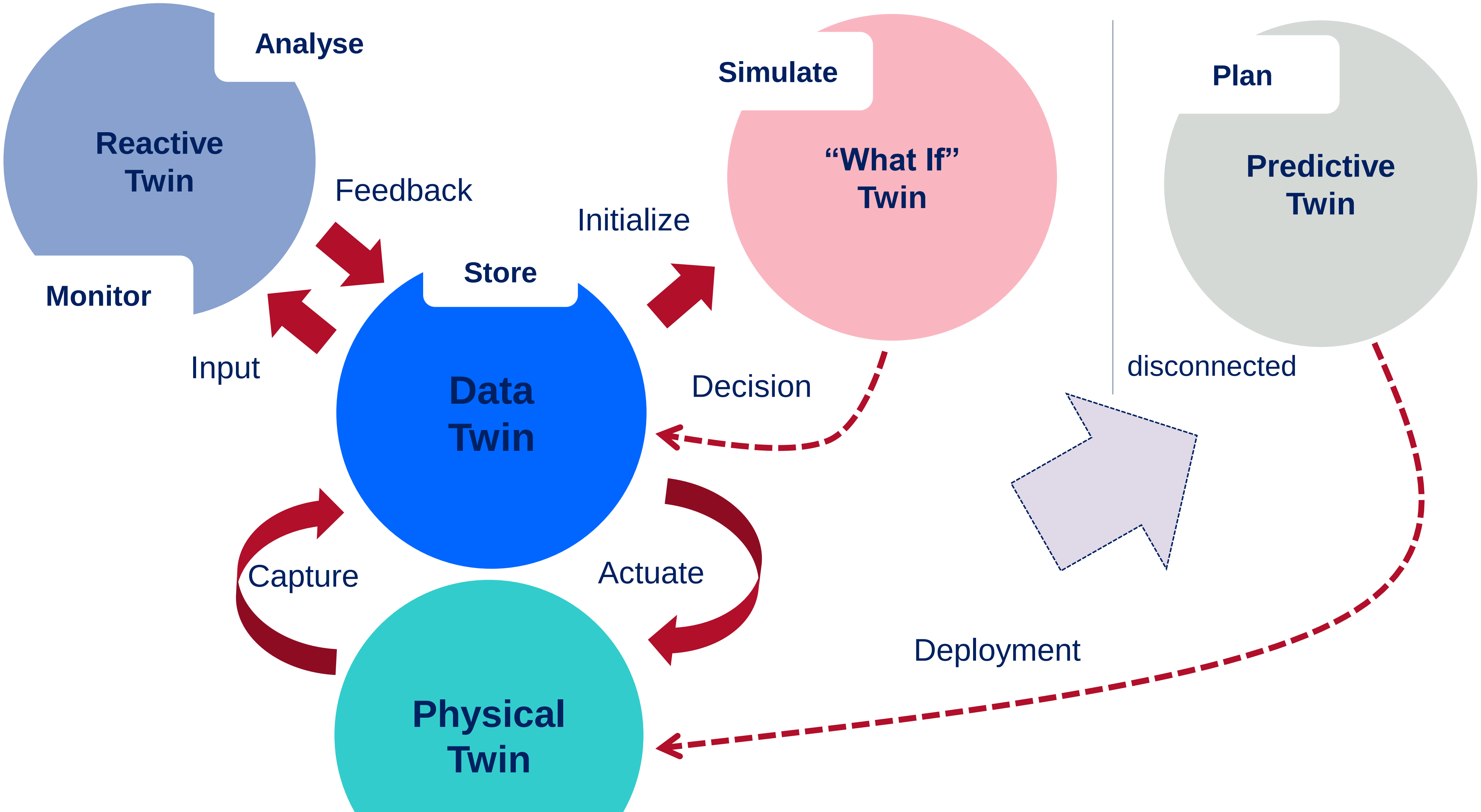

Digital Twin Modelling/Data Twin: NGSI-LD

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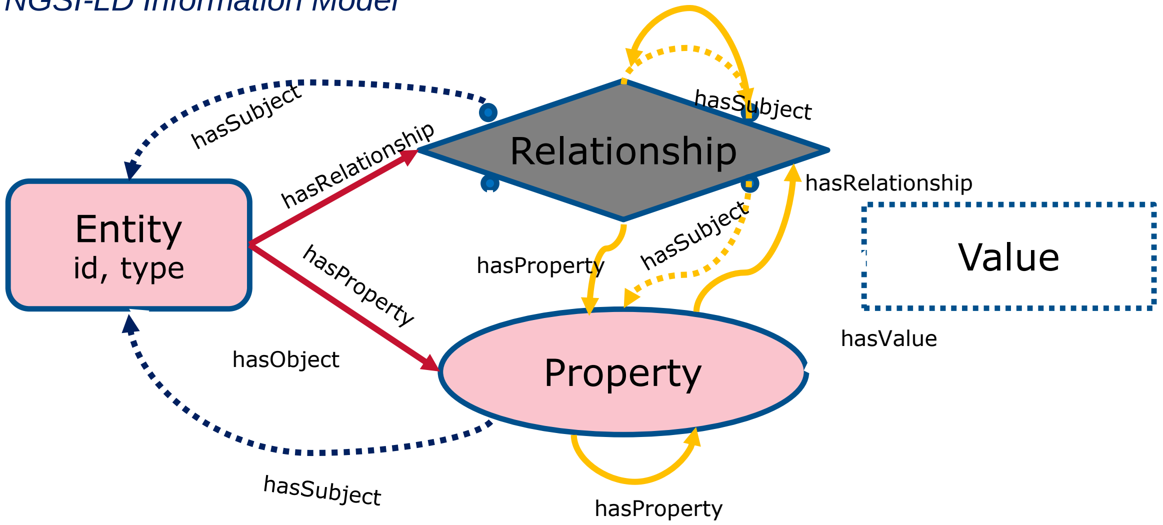
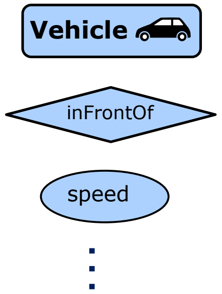
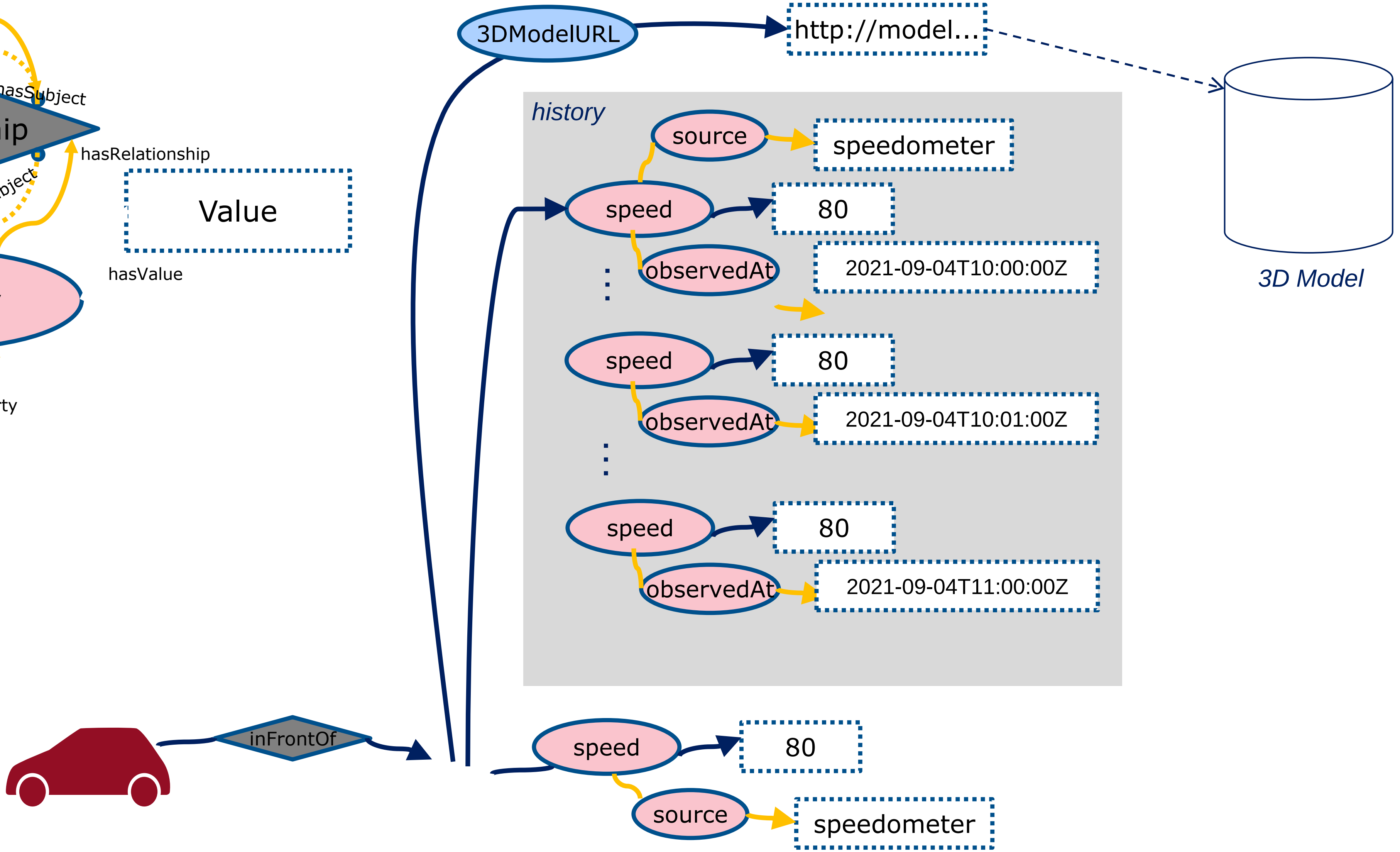
NGSI-LD Information Model



Data Model





Applications for digital twins

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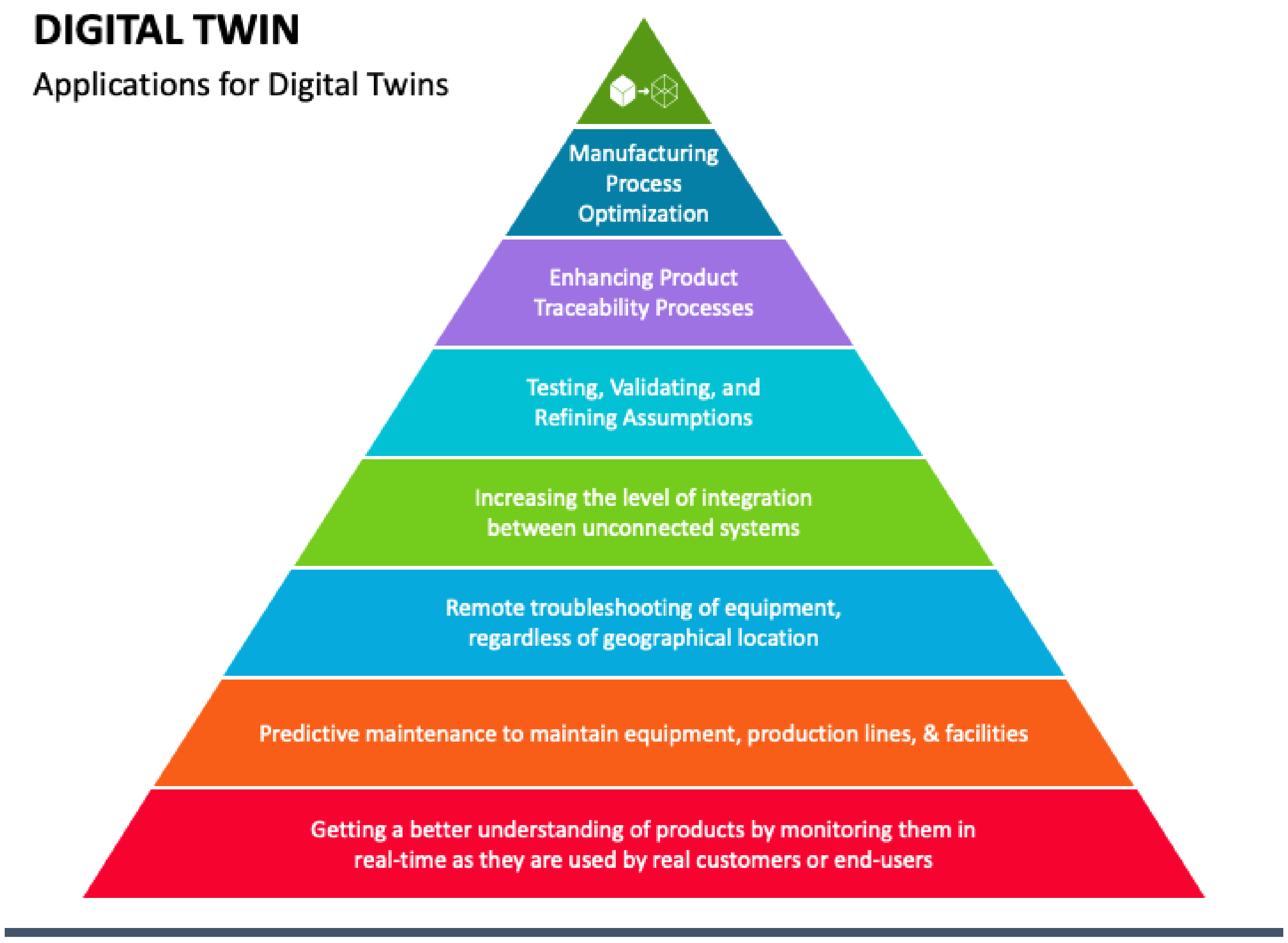
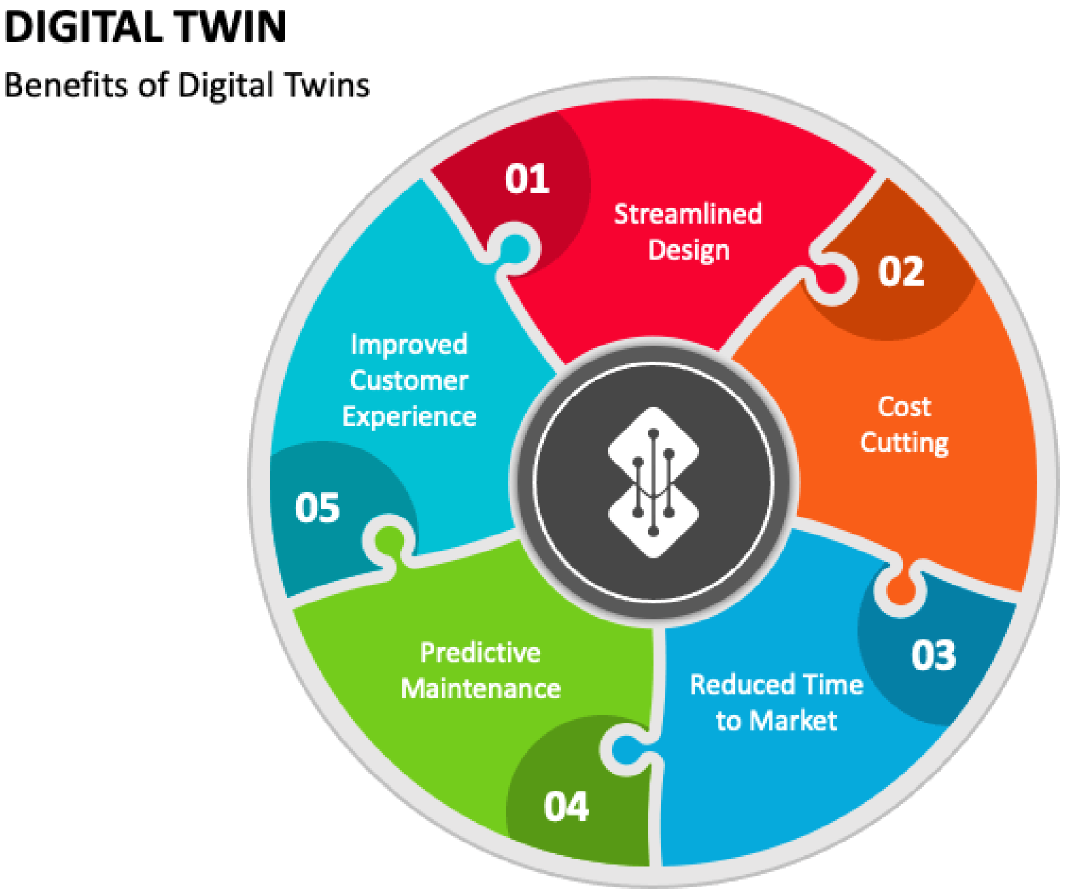


Benefits of digital twins



Digital Twin Maturity Levels

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Level 1 - Basic Reporting and Analysis

- Dynamic low fidelity model
- Linked to the real-world system
- Model updated at regular intervals but not necessarily in real-time
- No capability for autonomous decision making
- Basic learning, data assimilation capability
- Basic analytics and visualisation functionality of the current state

Digital Twin Maturity Levels

Level 2 - Advanced Reporting, Analysis and Forecasting

- Real-time, dynamic high fidelity models developed from first principles
- Model updated in real-time
- Standard pre-defined control/decision-making capability
- Advanced data assimilation capability to ensure convergence and accuracy
- Advanced predictive analytics

Digital Twin Maturity Levels

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Level 3- Support for Strategic Decision Making

- Real-time, dynamic, multi-fidelity hybrid models of cyber-physical systems
- Real-time operation
- Advanced, adaptive control/decision-making.
  Can recommend interventions within a particular domain.
- Advanced spatio-temporal analytics and visualisation
- Advanced learning and data assimilation from multiple data sets

Digital Twin Maturity Levels

Level 4- Autonomous Decision Making

- Dynamic multi-scale, multi-domain, multi-system models
- Real time operation
- High-level of autonomy - can perform most human operator functions, make interventions and take new courses of action autonomously
- State-of-the-art analytics and visualisation
- State-of-the-art AI/machine learning capability

Existing Standards for Digital Twins

Existing Standards for Digital Twins

- Modelling: NGSI-LD Information Model
- Storage and Access (also distributed): NGSI-LD API

Gaps, Opportunities *and Prototypes*

- Processing and Orchestration → reuse, Plug&Play
  - Monitoring
  - Analysis
  - Simulation
  - Planning
  - Orchestration of Processing: *FogFlow (based on NGSI-LD)*
- Actuation *(extension of NGSI-LD under discussion)*
- Interaction between twins

Benefits of digital twins

Provides a representation of operational data

- Analysis of historical trends and potential causes for performance deterioration
- Support for decision making and optimisation of day-to-day operations
- Identify abnormal behaviour
- Modelling future behaviour based on analysis of operational parameters
- Predictive maintenance to minimise disruptions
- Agile decision making in response to changes and interventions
- Enhance efficiency, safety and reliability

Software-in-Loop (SIL)
Hardware-in-Loop (HIL)

Controller development stages

Controller development stages:

1) Model-in-the-Loop (MIL) simulation or Model-Based Testing
2) Software-in-the-Loop (SIL) simulation
3) Processor-in-the-Loop (PIL) or FPGA-in-the-Loop (FIL) simulation
4) Hardware-in-the-Loop (HIL) Simulation
5) Actual Hardware Testing

Hardware-in-Loop

Automotive HIL Systems Using a Modular Test Platform

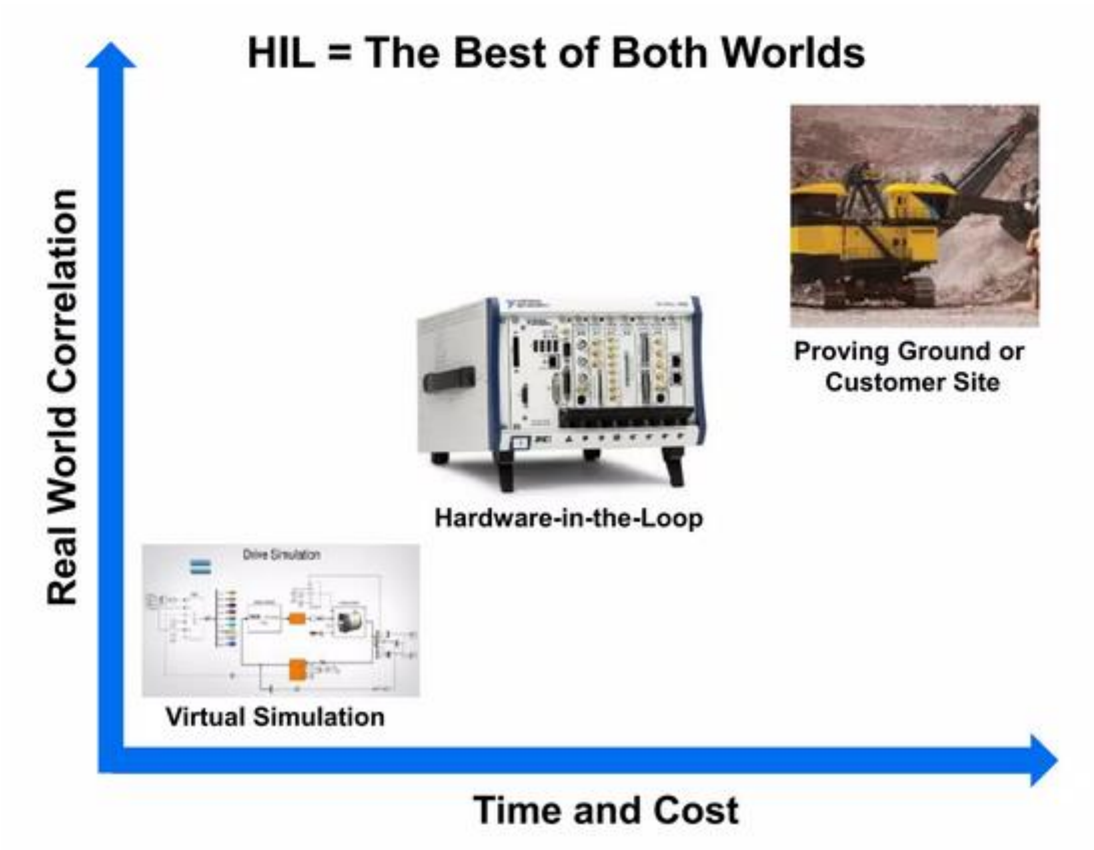
HIL is a testing methodology

HIL tests help validate embedded software on automotive ECUs using simulation and modelling techniques to shorten test times and increase coverage, especially for test cases that are hard to reliably replicate in physical lab/track/field testing.

HIL testing is needed now more than ever to ensure the reliability of rapidly evolving EV and ADAS/Active Safety systems.

HIL is crucial for testing the increasing connectivity and interdependence between systems and vehicle domains as they jointly contribute to key vehicle attributes.

Hardware-in-Loop



Conclusions

- Conclusions
- Transferring and processing all information in the car is not feasible
- NGSI-LD can be used for modelling of the digital twin
- IoT infrastructure connects the real twin with the digital twin
- Digital twin provides information representation and intelligent processing

Q&A

ANY QUESTIONS

???

References

References:

- Digital Twins at the Edge - Martin Bauer, NEC Laboratories Europe, Workshop on IoT
- Matlab Answers - What are MIL, SIL, PIL, and HIL (Link)