interTwin

An interdisciplinary Digital Twin Engine for science

2023 CERN openlab Technical Workshop

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What is a Digital Twin?

A digital twin is a virtual representation of an object or system helping in decision-making and prediction. It takes in real-time data and keeps track of the lifecycle of the object or system.

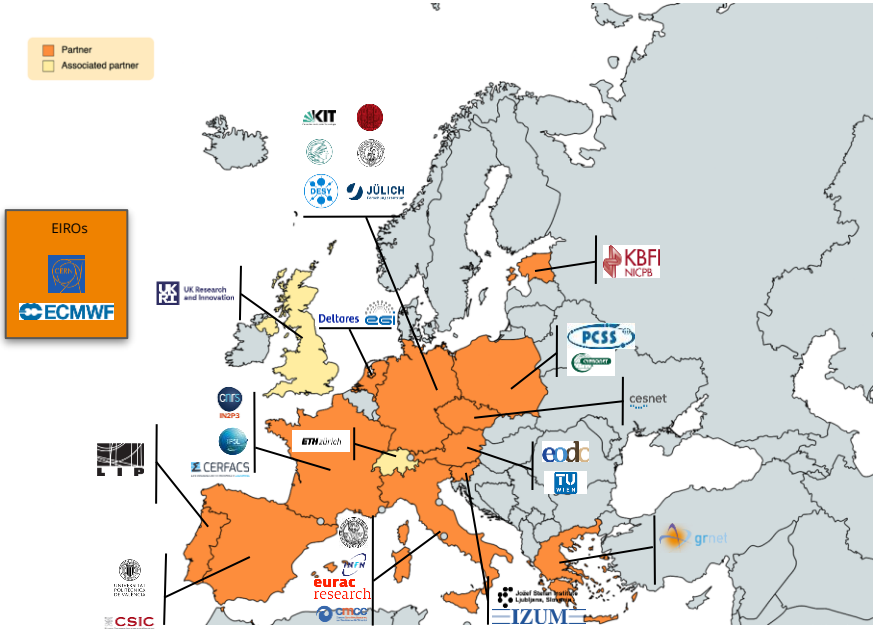
interTwin overall objective

Co-design and implement the prototype of an interdisciplinary Digital Twin Engine.

Digital Twin Engine

- It is an **open-source platform** based on open standards.
- It offers the capability to integrate with **application-specific Digital Twins**.
- Its functional specifications and implementation are based on
  - a **co-designed interoperability framework**
  - conceptual model of a DT for research - **the DTE blueprint architecture**.

Consortium Overview



EGI Foundation as coordinator

29 **Participants**, including 1 affiliated entity and 2 associated partners

Consortium at a glance

10
Providers

cloud, HTC , HPC resources and access to Quantum systems

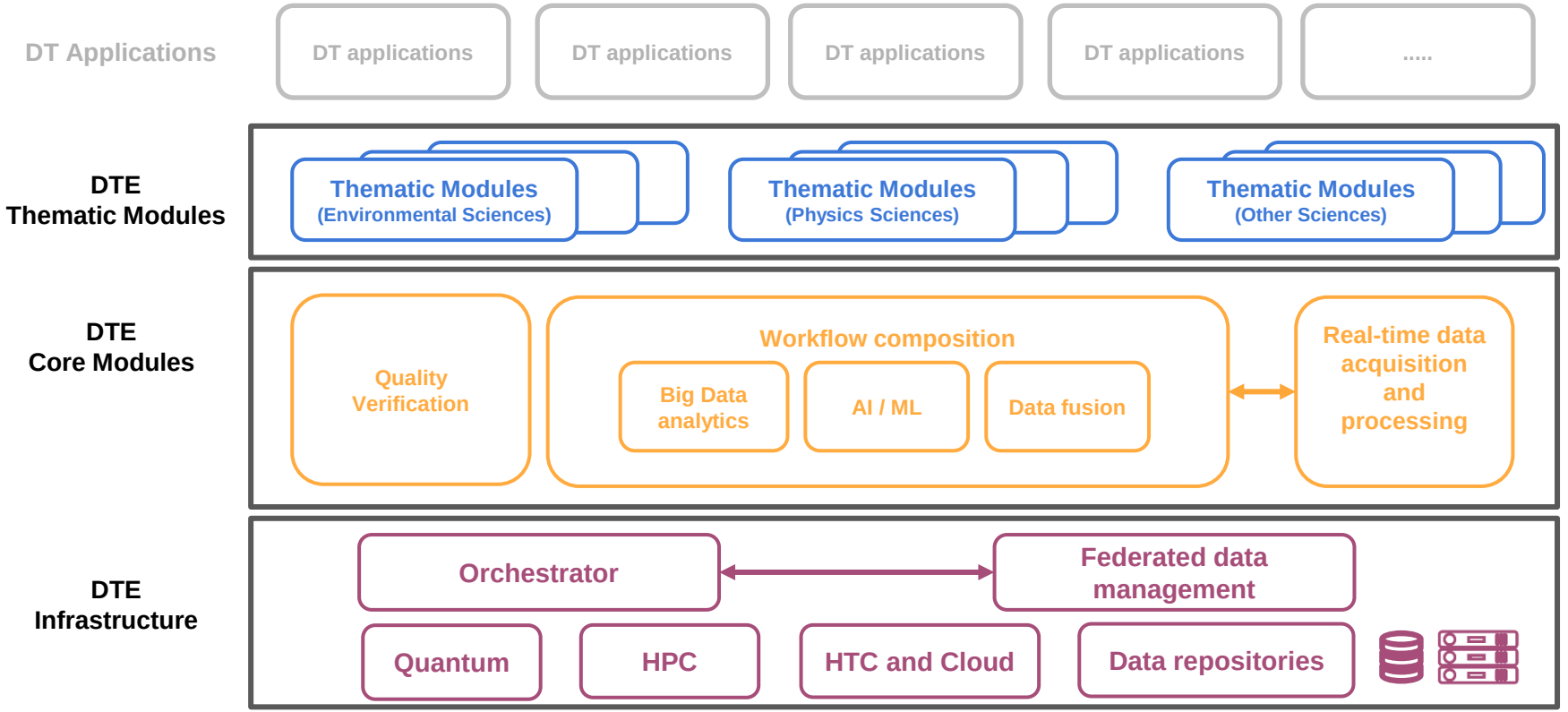
11
Technology providers

delivering the DTE infrastructure and horizontal capabilities

14
Community representants

from 5 scientific areas; requirements and developing DT applications and thematic modules

interTwin components



Earth Observation

Cyclone Classification

Fire Hazard Map Generation

Early Flood Warnings

Drought Prediction

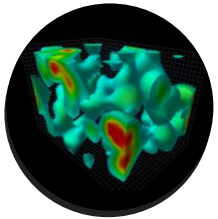
Link with Destination Earth

- **Collaboration with ECMWF**
  Demonstrators of **data handling across interTwin and DestinE DTs** for the Extremes and Climate in production-type configurations.

- **Collaboration with DestinE**
  Development of **common software architecture concepts** that are also **applicable to other major DTs initiatives**.

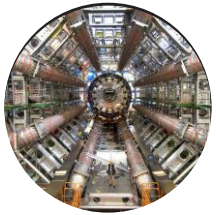
Physics

Radio Astronomy



Quantum Field Theory

Gravitational Wave Astronomy



High Energy Physics

Further use cases at CERN

interTwin is part of a broader effort into digital twins at CERN

- **Detector Prototyping**
  build a DT of a **testbench detector** and test it on conditions that can't be recreated in the lab easily
- **Online ML for Detectors**
  adapt to **real-time property changes** of detector configuration in geometry, temperature, trigger thresholds
- **Environmental Modeling and Prediction Platform**
  Foundation Model for multiple weather and climate related applications
- **Agent-based simulation**
  We are discussing on how to extend core InterTwin capabilities by BioDynaMo - an **agent-based simulation module**

Requirements

- **Online Learning**
  The DTE shall enable handling **stream of data** larger than 10MB/s

- **Federated Learning**
  The DTE shall to able to **transmit/receive data synchronically** (at least aperiodically) between different HPC providers

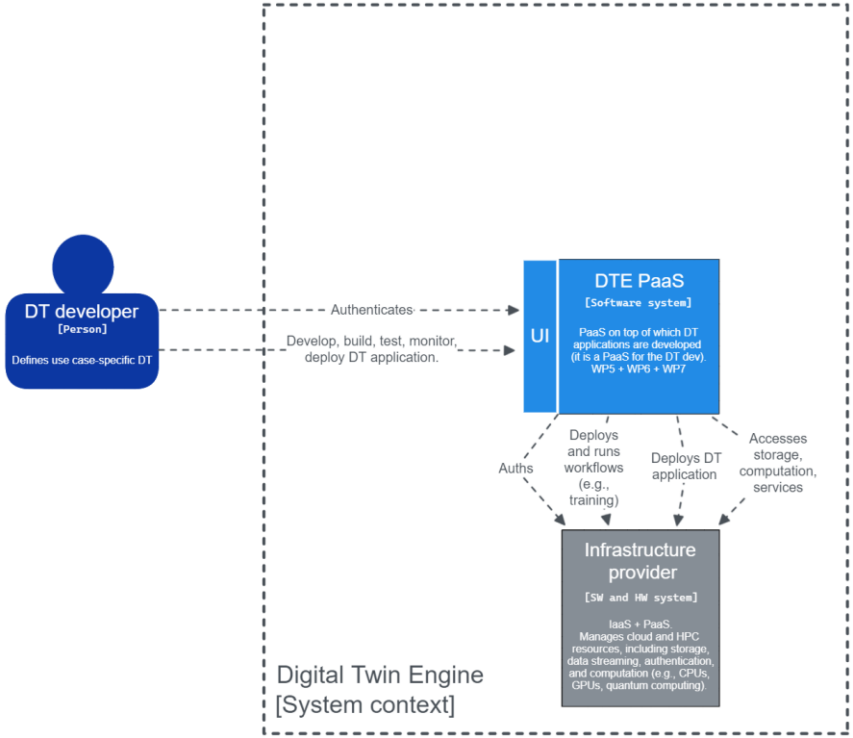
- **Hyperparameter Optimization**
  The DTE shall support HPO frameworks (RayTune, etc).

- **Unified access to infrastructure**
  DTE shall enable **homogeneous security and access policies**, resource accounting to HPC, HTC and cloud providers

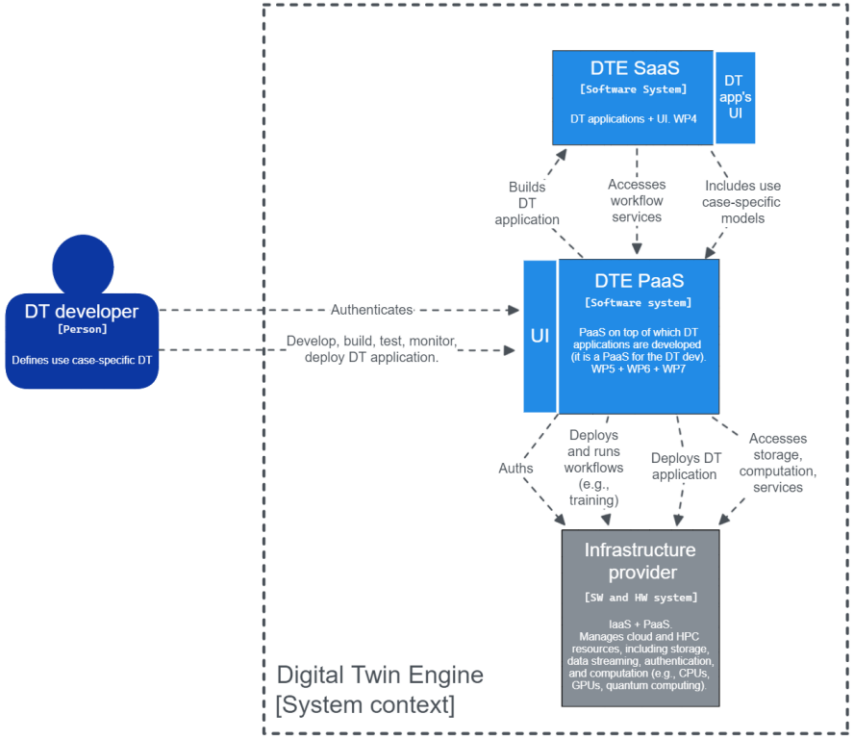
- **Bridge difference in infrastructure needs**
  The DTE shall be usable by sciences with **vast differences in compute/storage** needs

DTE architecture

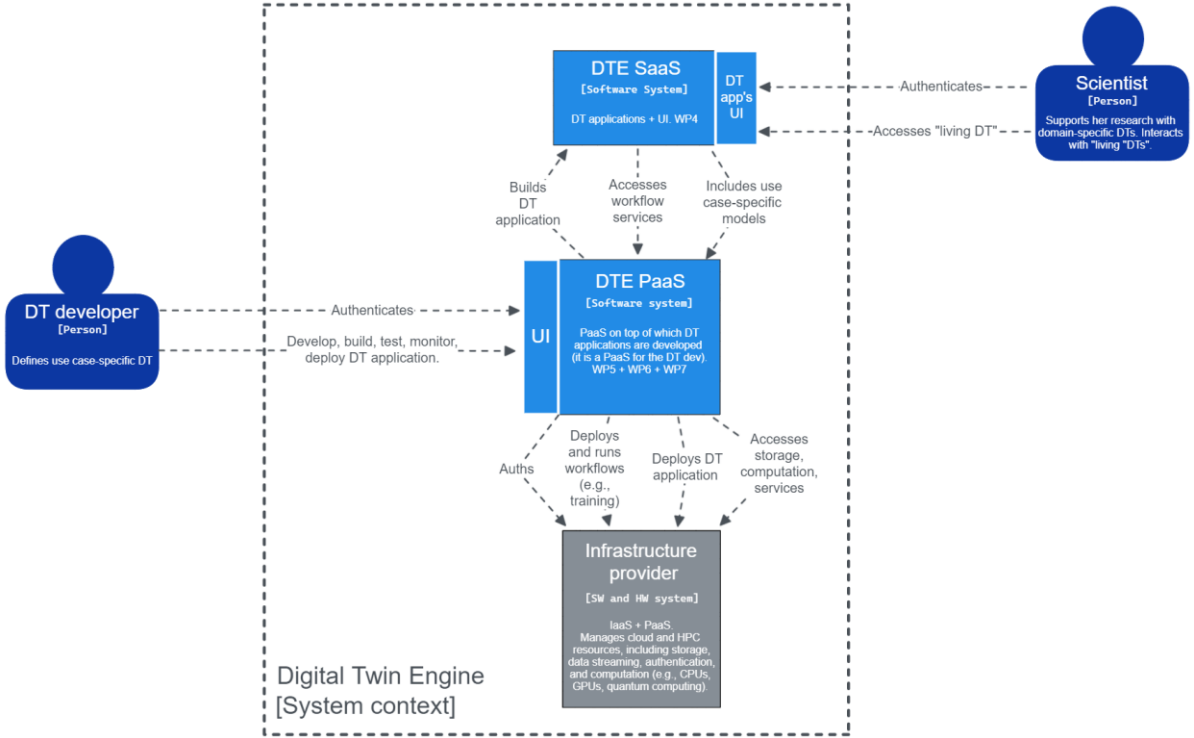
Digital Twin Engine



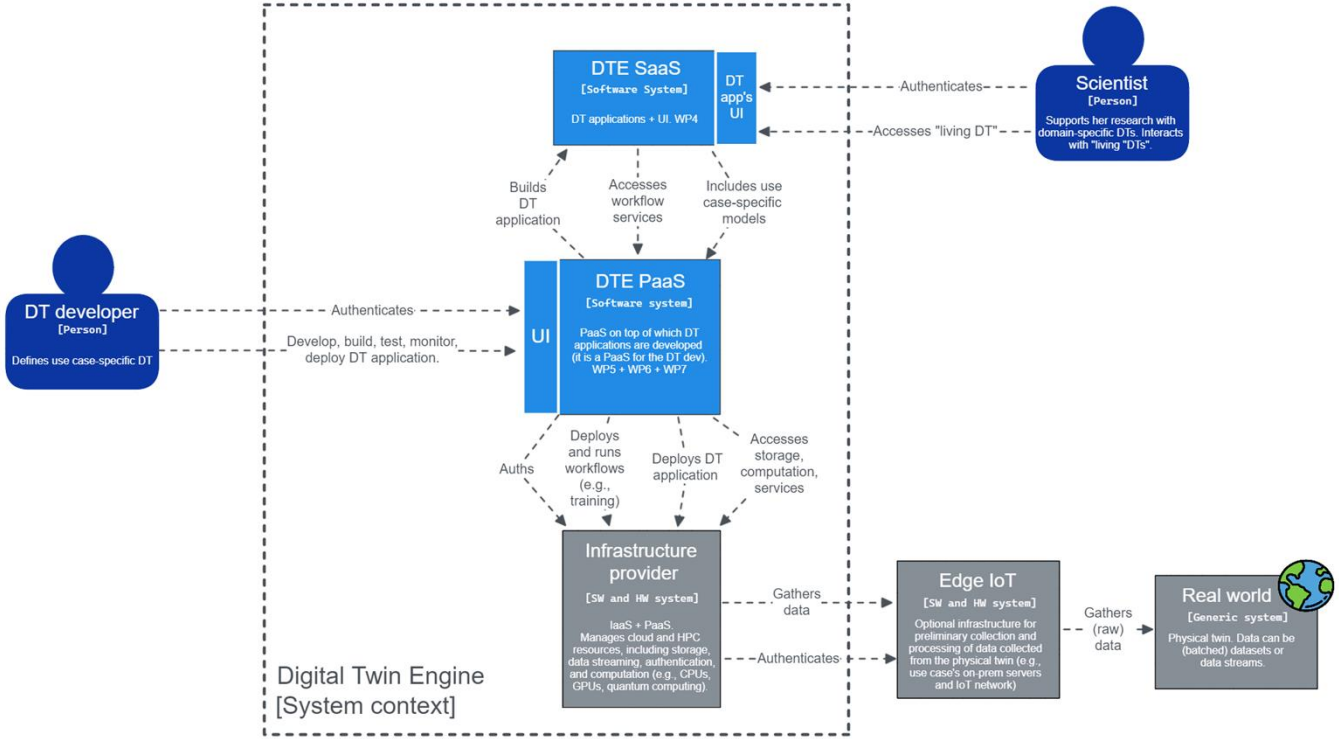
Digital Twin Engine (2)



Digital Twin Engine (3)



Digital Twin Engine (4)



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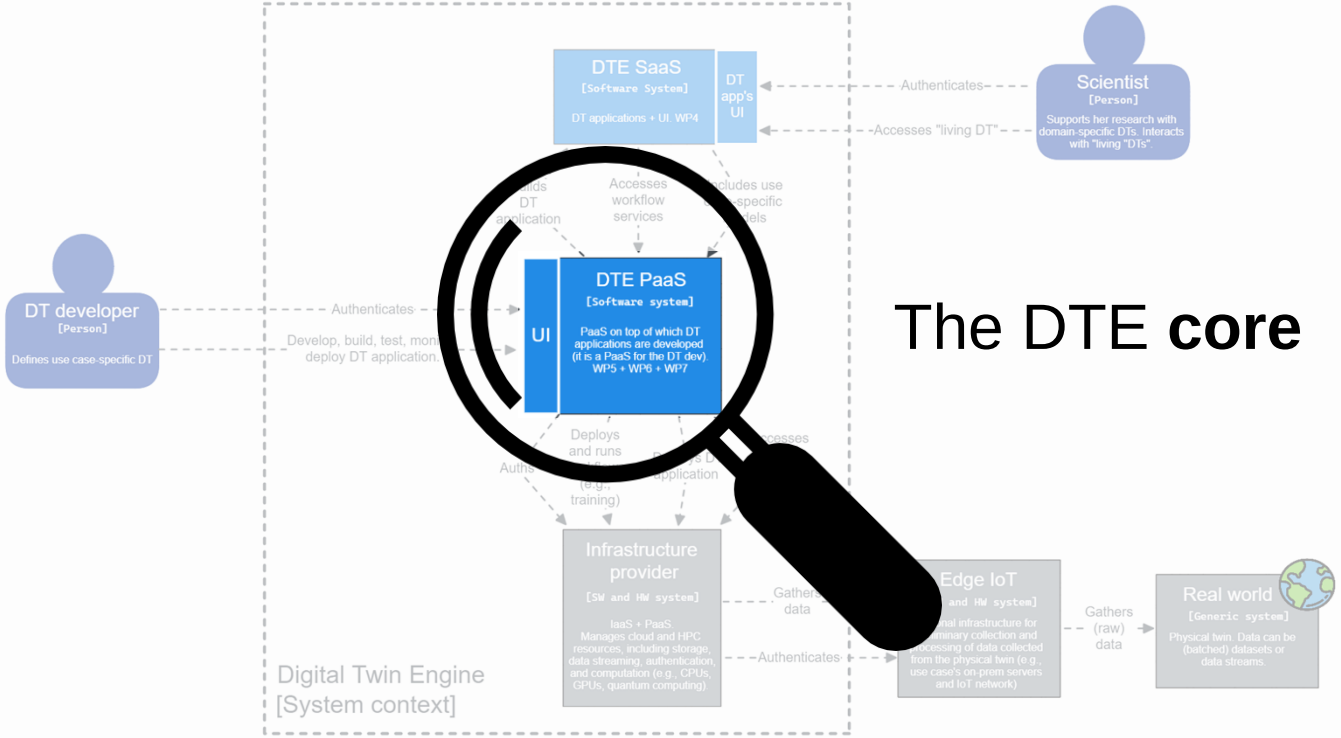
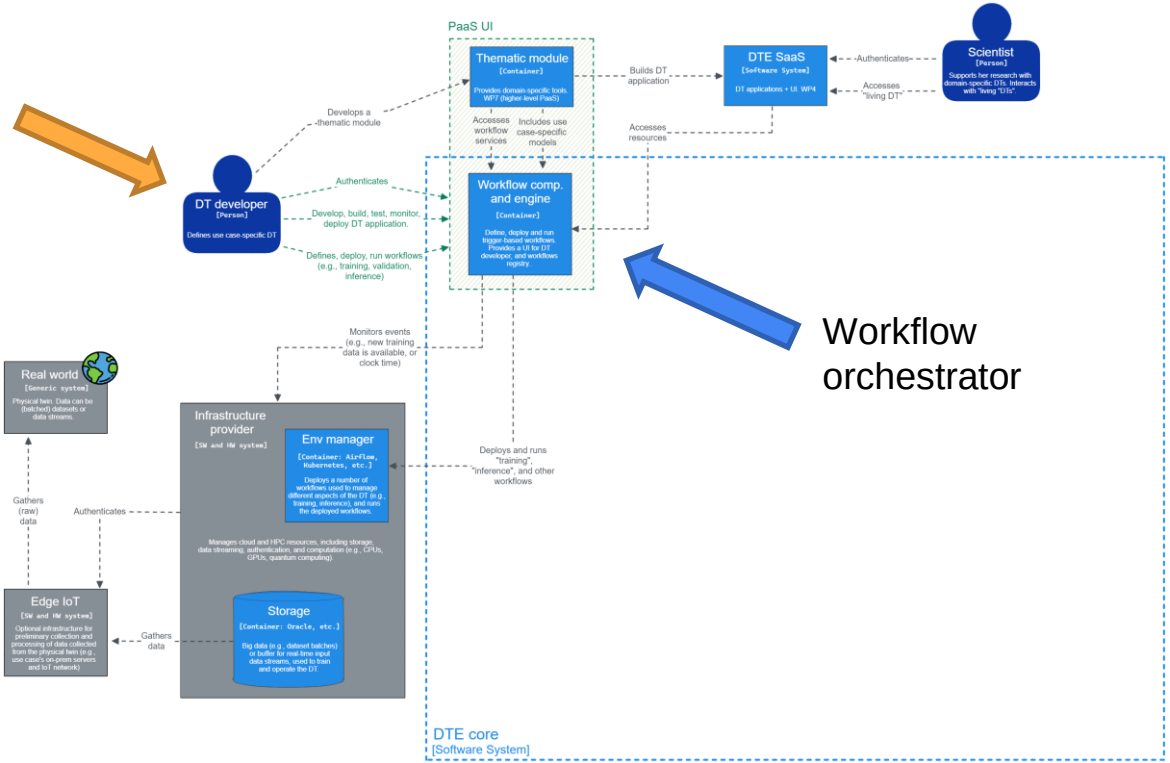
Digital Twin Engine (4)



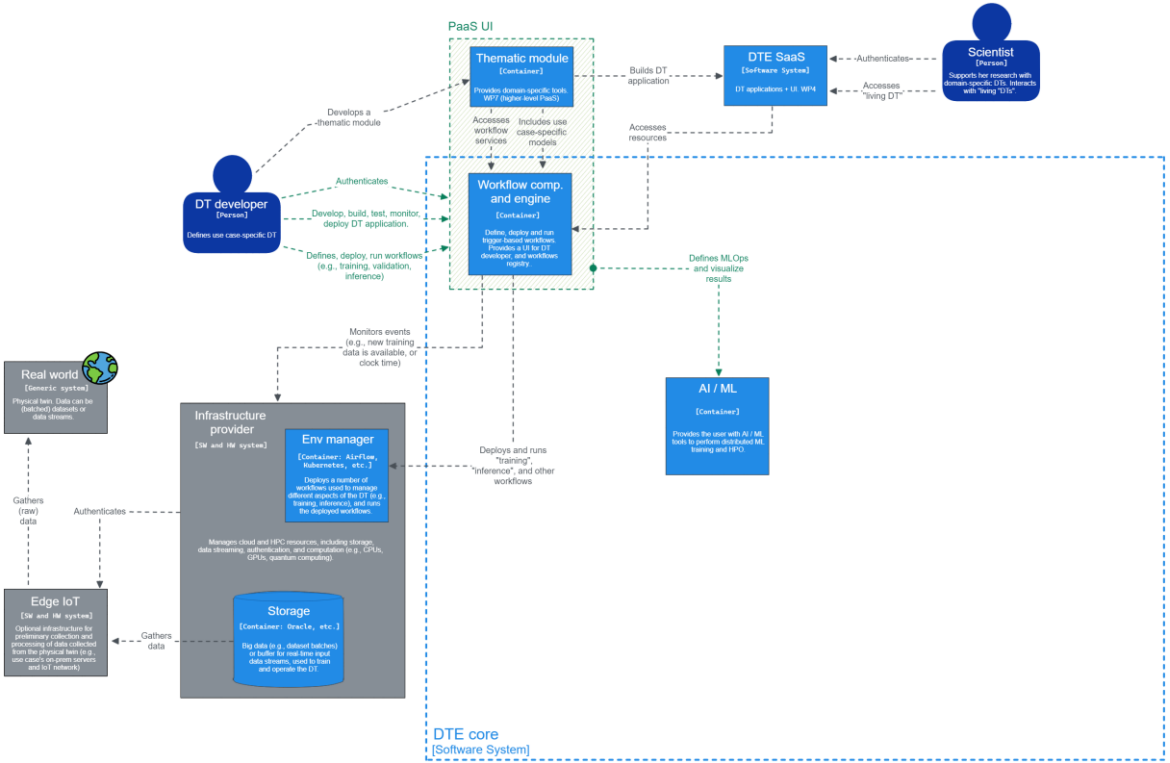
The DTE **core**

DT workflow composition

DT developer



DT workflow composition (2)



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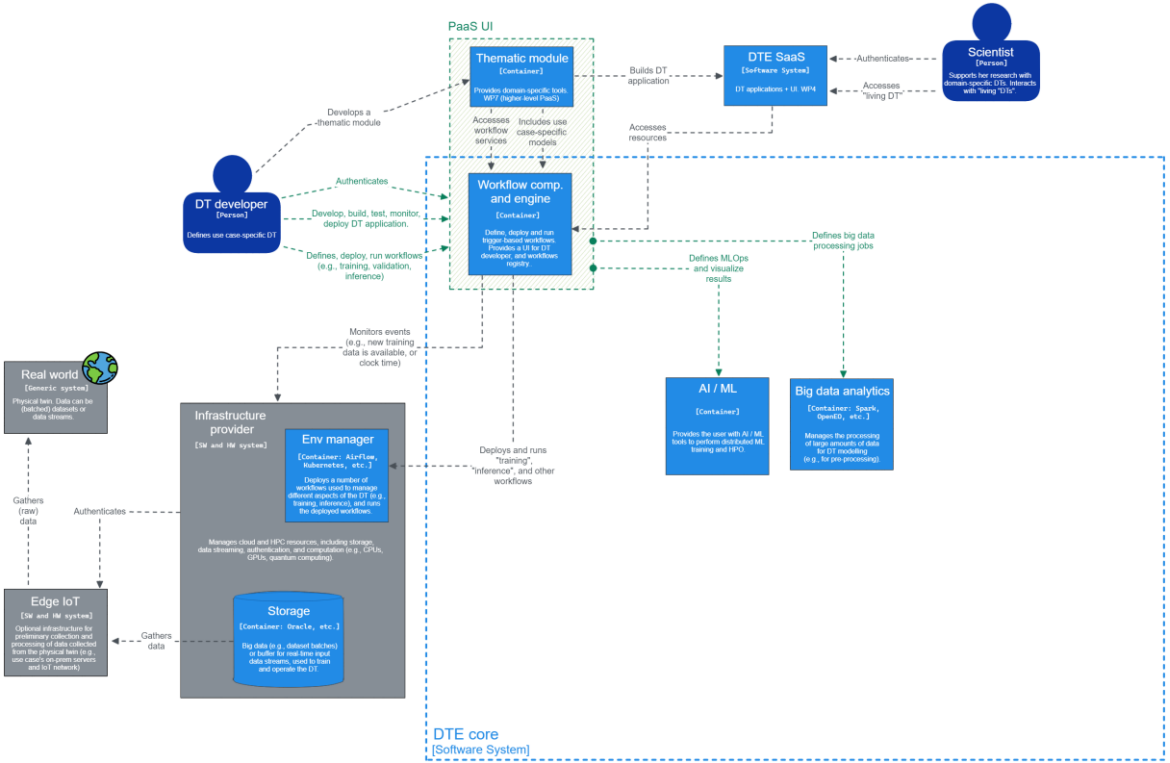

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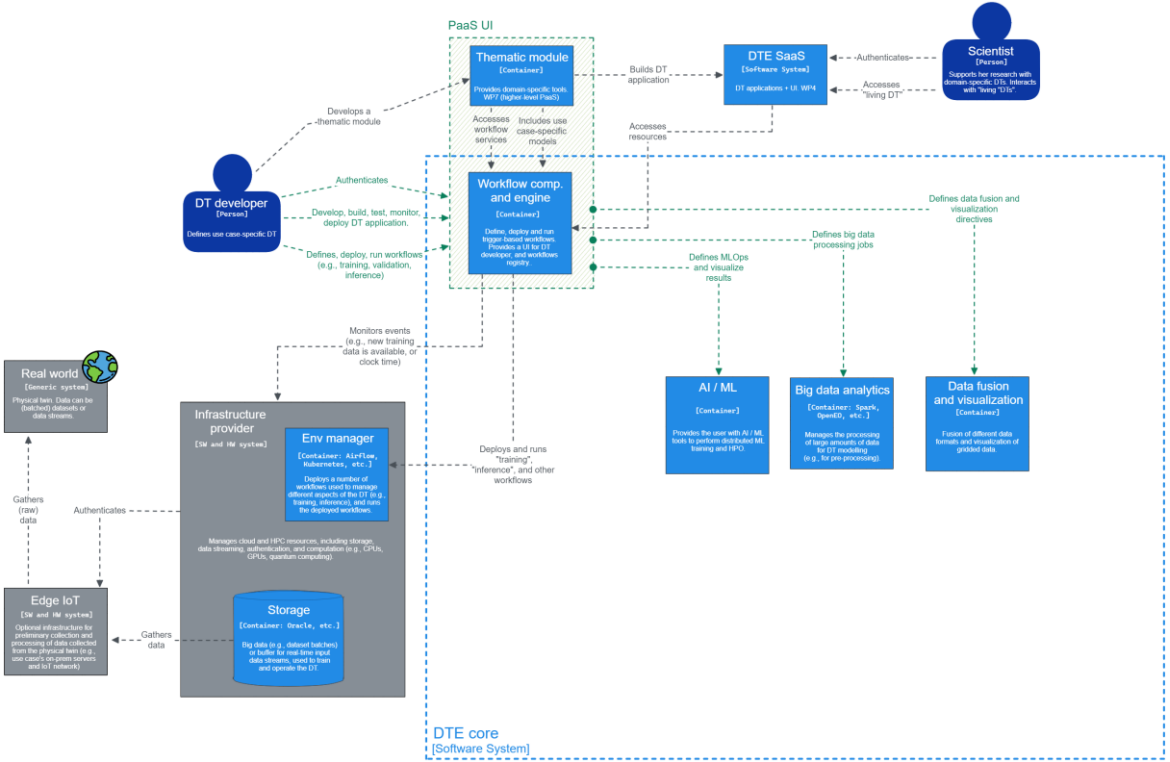
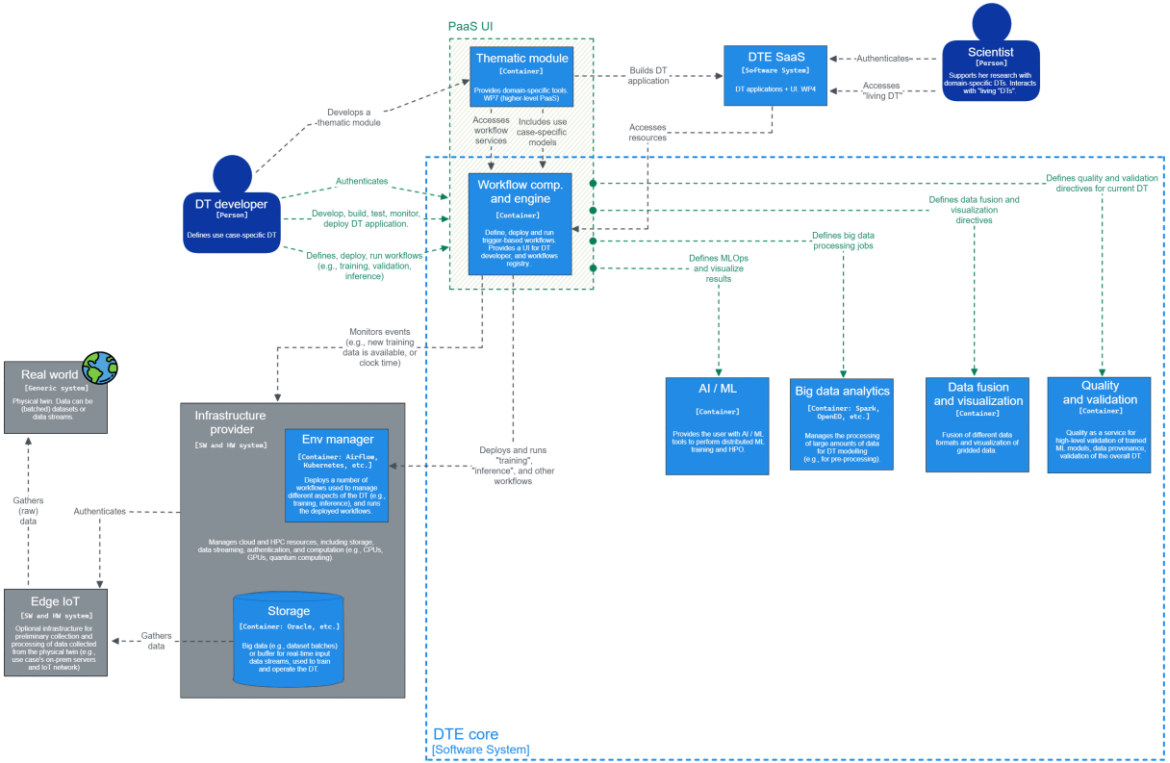
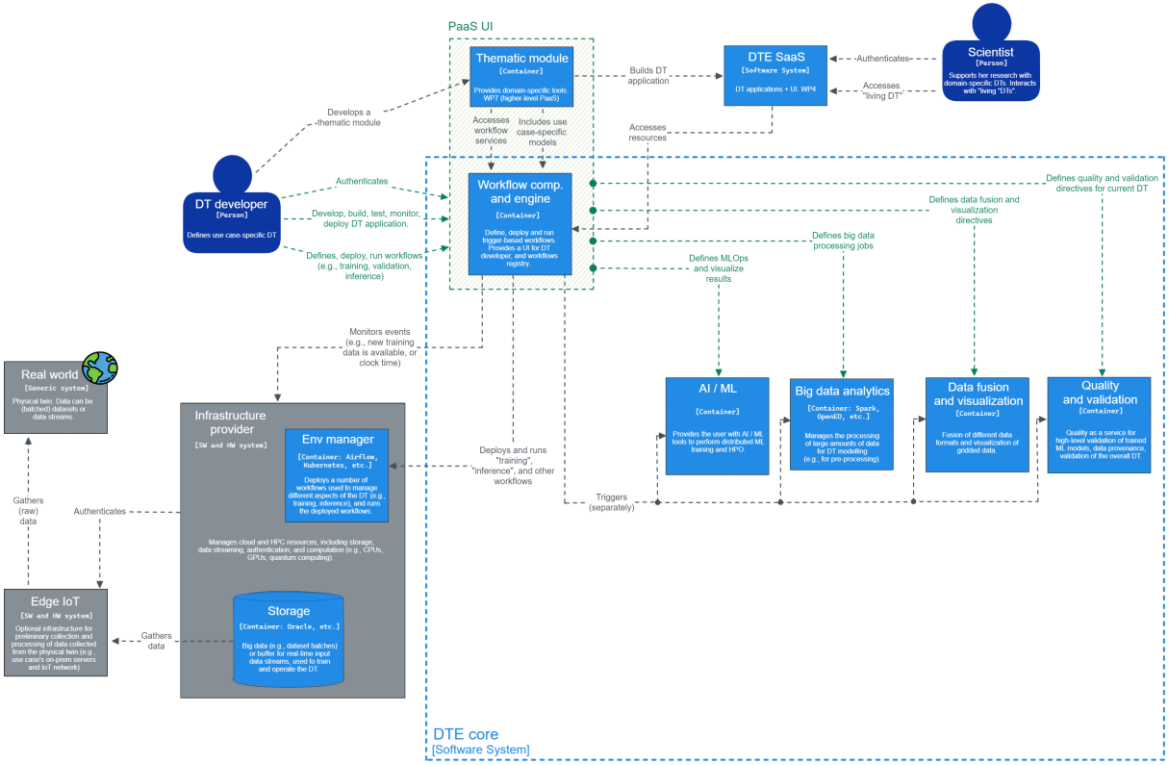


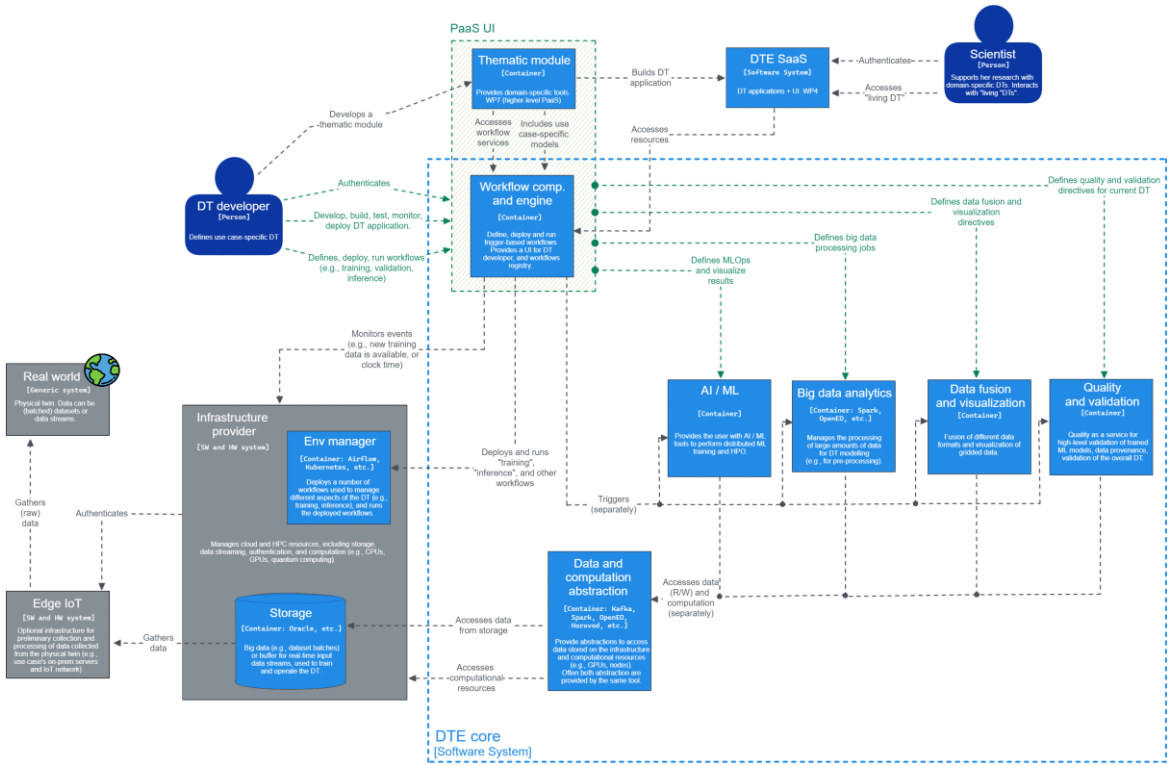
DT workflow composition (5)



DT workflow composition (6)



DT workflow composition (7)



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In a nutshell

- DTs are not just...[1,2]
  - Big data / ML
  - Physics-based models
  - Optimisation
  - Simulation or agent-based modelling
  - Data streaming

- DTs for science:
  - Highly flexible (e.g., fast prototyping)
  - HPC-oriented
  - Open-source community
  - One engine for many sciences

DTE for science – Today

- DTs developed in isolation
- Community-specific technologies and standards
- Great engineering overheads (i.e., reinventing the wheel)

Boils down to… **need for improvement**

Today: we are limited by the technology of our time

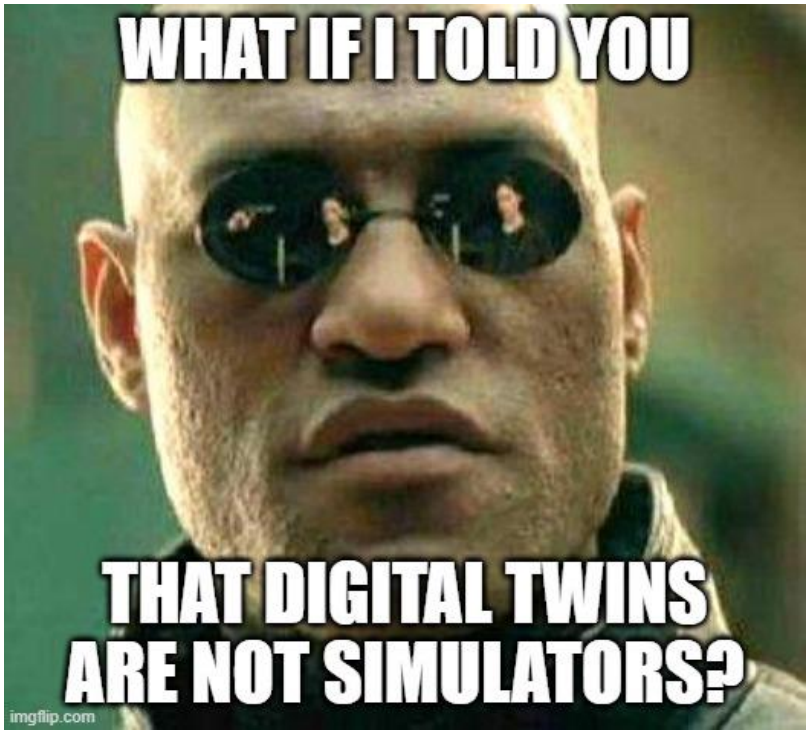
DTE for science – Tomorrow

- Unified DTE framework
- Standard DT lifecycle management, thanks to co-design
- Low (engineering) overheads

Results into… **accelerated science**

Tomorrow: we get the best out of research

Are you ready for digital twins?



For follow-up discussions…
Meet us at the **poster**

Thank you!

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References

- [1]: Sharma, Angira, Edward Kosasih, Jie Zhang, Alexandra Brintrup, and Anisoara Calinescu. 'Digital Twins: State of the Art Theory and Practice, Challenges, and Open Research Questions'. *Journal of Industrial Information Integration* 30 (1 November 2022): 100383. https://doi.org/10.1016/j.jii.2022.100383.
- [2]: [EPFL] Predictive Digital Twins: From Physics-Based Modeling to Scientific Machine Learning, n.d. https://www.youtube.com/watch?v=ZuSx0pYAZ_I&ab_channel=CenterforIntelligentSystemsCISEPFL