Serie di webinar Sezione ANIMP-DIM (Digital & Innovation Management)
IA per l'Impiantistica

22/01/2025 | h. 16:00

Manutenzione evoluta nell'era dell'IA
Digital Reliability Platform: manutenzione proattiva e incremento dell'affidabilità degli asset

The Digital Twin technology

Evolving from original concept to applied solutions

22/01/2025

a cura di:
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ANIMP Sezione DIM (Digital & Innovation Management)
Serie di webinar: IA per l'Impiantistica

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Digital Twin: definition and origin

Definition

Out of the multitude of definitions, a definition from practice's view:

*A **digital representation** that mirrors a **real-life object**, (organizational) **process or system** and is developed in order to support specific business outcomes and drive new **business opportunities**.*

Based on Panetta K (2019) Gartner Top 10 Strategic Technology Trends for 2019.
In: https://www.gartner.com/smarterwithgartner/gartner-top-10-strategic-technology-trends-for-2019

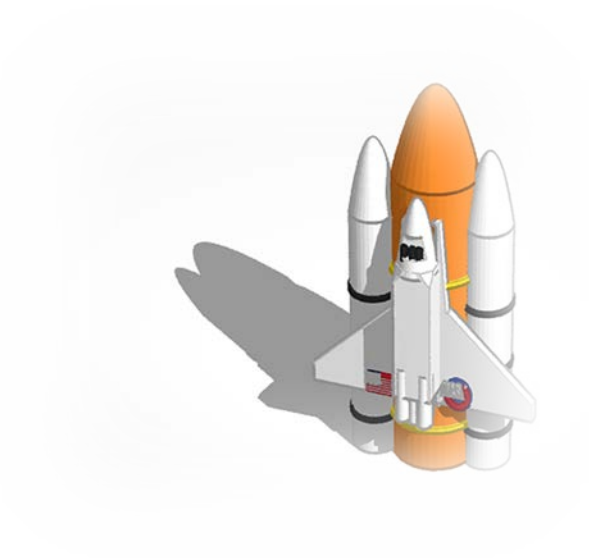
Origin

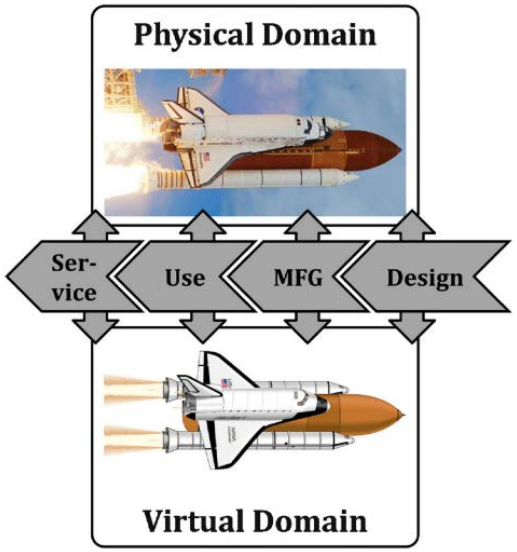
First definition

"An integrated multi-physics, multi-scale, **probabilistic simulation** of a **vehicle or system** that uses the best available **physical models, sensor updates**, **fleet history**, etc., to **mirror the life of its flying twin**. It is ultra-realistic and may consider one or more important and interdependent vehicle systems", taken out from the NASA "*Modeling, Simulation, Information Technology & Processing Roadmap"*, draft 2010 and final release 2012.

MAIN ELEMENTS:

- **Flying vehicles**
- **Simulation**
- **Stochasticity**
- **Mirror real life through:**
  - **physical models,**
  - **sensor data, and**
  - **historical data**





M. Shafto, M. Conroy, R. Doyle, E. Glaessgen, C. Kemp, J. LeMoigne, L. Wang,
Modeling, Simulation, Information Technology & Processing Roadmap. Technology Area 11, 2012

Digital Twin modelling

The Digital Twin modelling in a nutshell, today

It represents physical entities in the physical world with digital models in the virtual word

It resembles the real environment in the “look and feel” to the user

It simulates models forward with varying degrees of modelling fidelity *(this corresponds to the adoption of different types of models)*

It is not just a data model, as it embeds capabilities for integration & interoperability to interact with different sources

It connects with relevant time data to ensure the model mirrors reality

Types of digital twin models

Data-Driven Models (van Dinter et al. 2022)

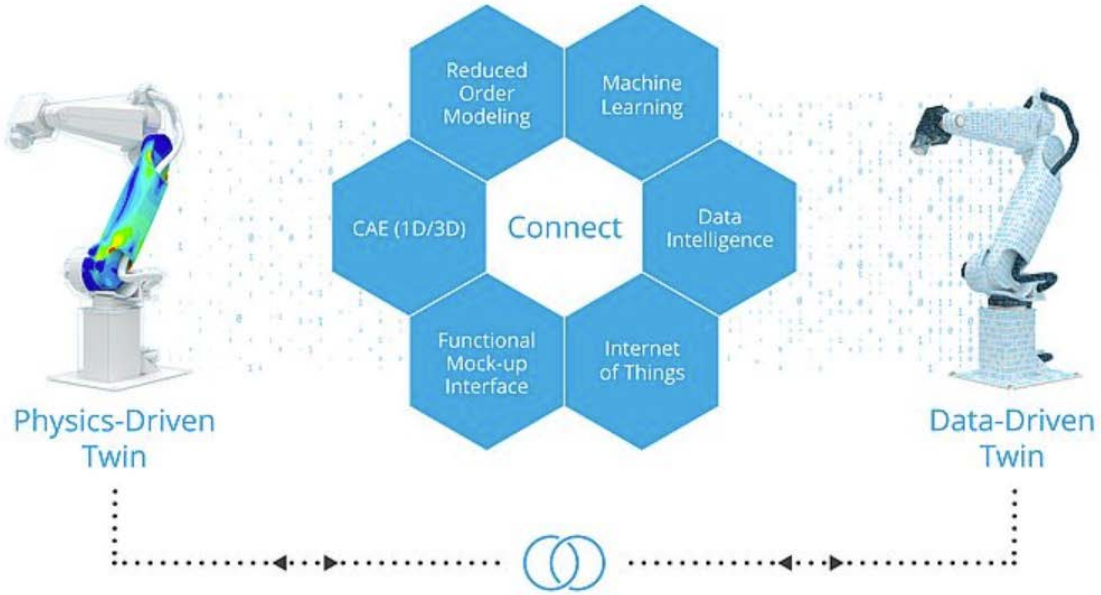
- Machine Learning Models
- Neural Networks
- Regression Models

Physics-based Models (van Dinter et al. 2022) (Tao et al. 2022)

- Geometric Models
- Finite Element Models

Mathematical Models

- Analytical Models (Alam and El Saddik 2017)
- Statistical Models (Mukherjee and DebRoy 2019)



Leveraging Digital Twin Technology to improve Innovation
Source: https://www.ien.eu/article/leveraging-digital-twin-technology-to-improve-innovation/

Types of digital twin models

Simulation Models

- Discrete Event Simulation (Negri et al. 2021)
- Agent-Based Models (Latsou et al. 2021)

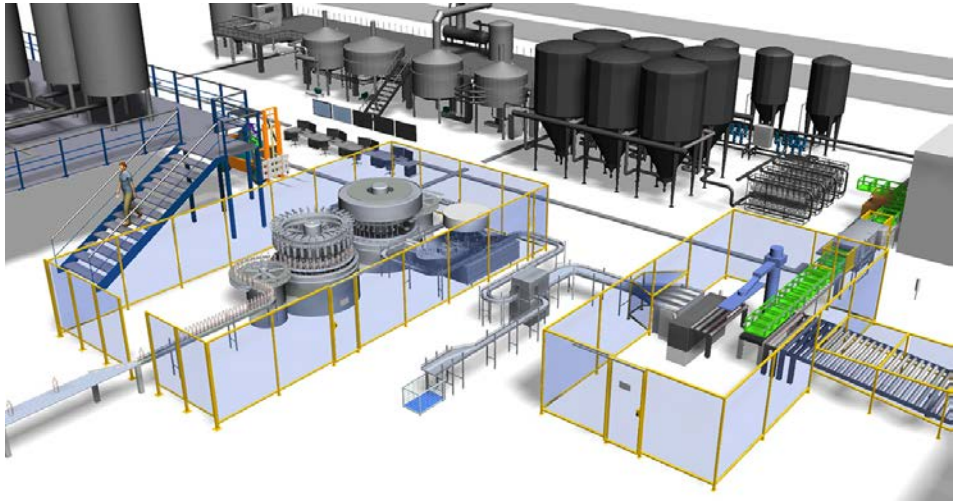
Behavioral Models (van Dinter et al. 2022)(Tao et al. 2022)

- State Machine Models

Information Models

- Rule Models (Tao et al. 2022)
- Asset Administration Shell Models (Cavalieri and Salafia 2020)
- Ontology Models (Jia et al. 2023)

Hybrid Models (van Dinter et al. 2022)



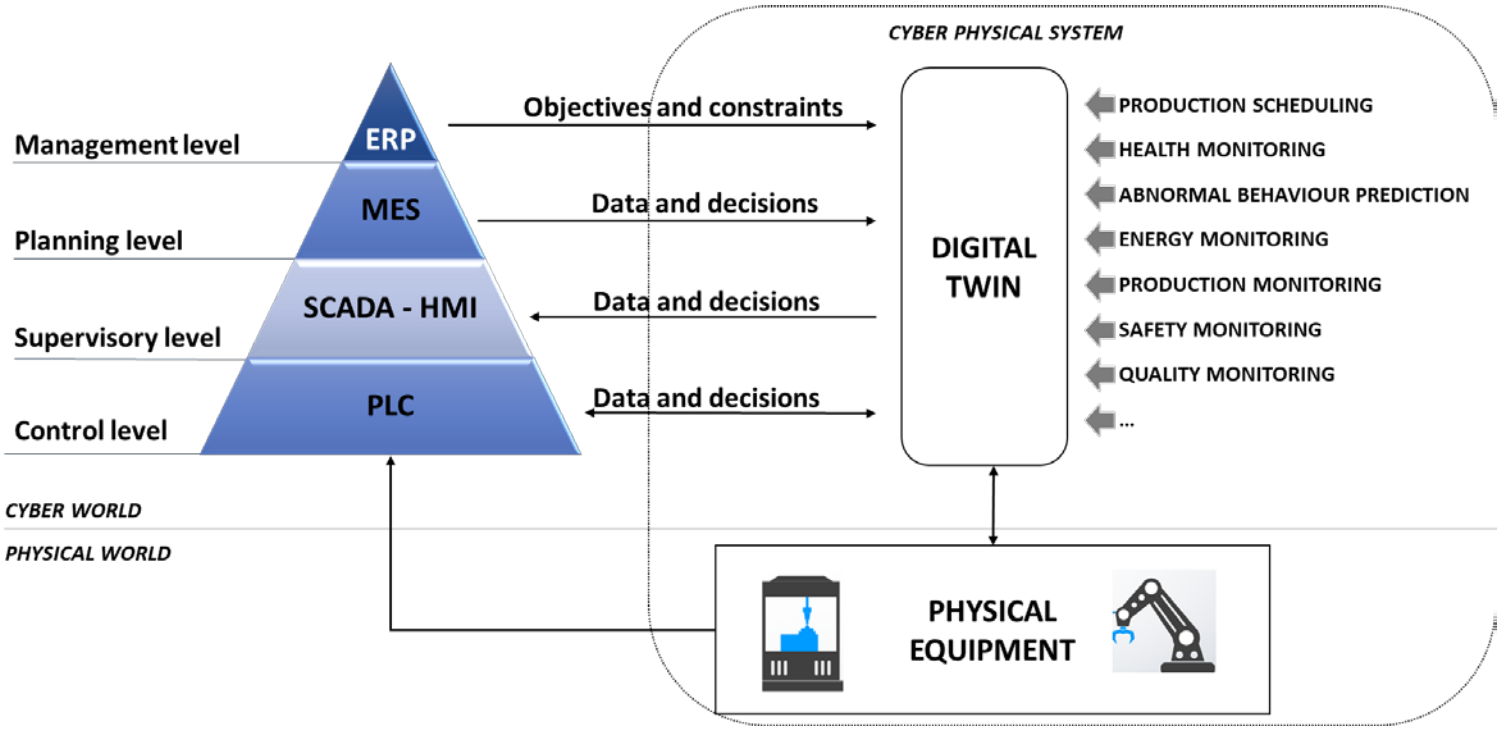
Discrete Event Simulation Digital Twin of a production line
Source: https://plm.sw.siemens.com/en-US/tecnomatix/products/plant-simulation-software/

Digital Twin applications

Digital Twins in manufacturing (focus on management & control)

The extant enterprise architecture can be extended through the Digital Twin adoption

Digital Twins integrate the extant capabilities in order to manage and control the plant operations at different levels, by providing an advanced decision support.



Negri E., Pandhare V., Cattaneo L., Singh J., Macchi M., Lee J.. Field-synchronized Digital Twin framework for production scheduling with uncertainty, Journal of Intelligent Manufacturing, vol. 32, 1207-1228, 2021

Digital Twins in manufacturing (focus on the asset lifecycle)

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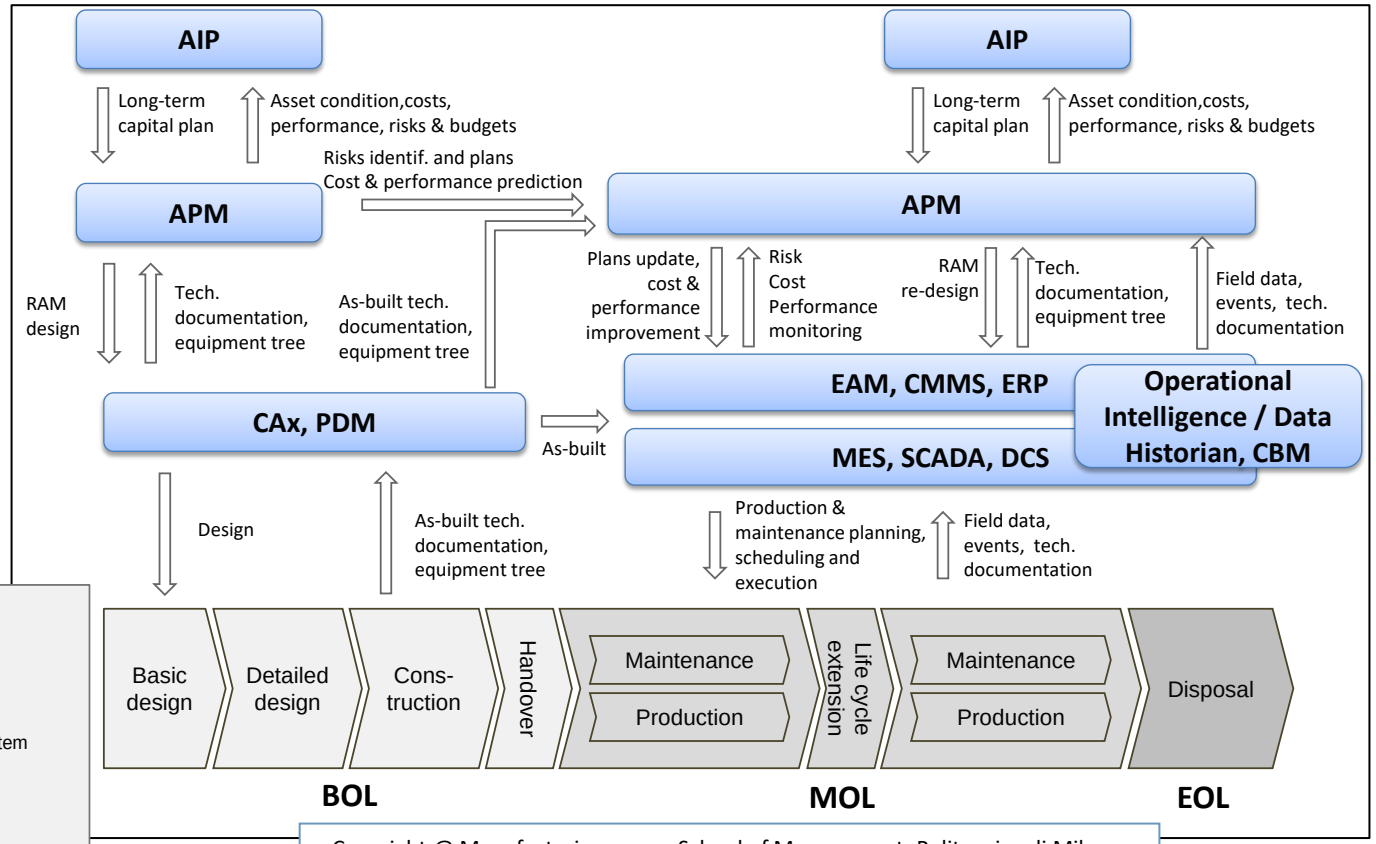
The applications of Digital Twins can be developed at different levels, extending the extant digital environment

Three main layers:
- APM/AIP
- EAM/CMMS/ERP
- MES/SCADA/DCS

correspondent to the asset control levels:
- Strategic
- Tactical
- Operational



AIP	Asset Investment Planning
APM	Asset Performance Management
CAx	Computer Aided x
PDM	Product Data Management
EAM	Enterprise Asset Management
CMMS	Computerized Maintenance Management System
ERP	Enterprise Resource Planning
MES	Manufacturing Execution System
SCADA	Supervisory Control And Data Acquisition
DCS	Distributed Control System

Digital twins are **digital representations of physical assets and systems** adopted with the purpose to support **through-life engineering and management decisions** at different asset control levels

Polenghi, A., Roda, I., Macchi, M., Pozzetti, A.. A Conceptual Model of the IT Ecosystem for Asset Management in the Global Manufacturing Context, Adv. Prod. Manag. Syst. Towar. Smart Digit. Manuf., Springer International Publishing, Cham, 2020: pp. 711–719. https://doi.org/10.1007/978-3-030-57997-5_82
Macchi, M., Roda, I., Negri, E., Fumagalli, L... Exploring the role of Digital Twin for Asset Lifecycle Management, in IFAC-PapersOnLine, Volume 51, Issue 11, 2018, 790-795, ISSN: 2405-8963, https://doi.org/10.1016/j.ifacol.2018.08.415 .

Thank you for your attention!

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