



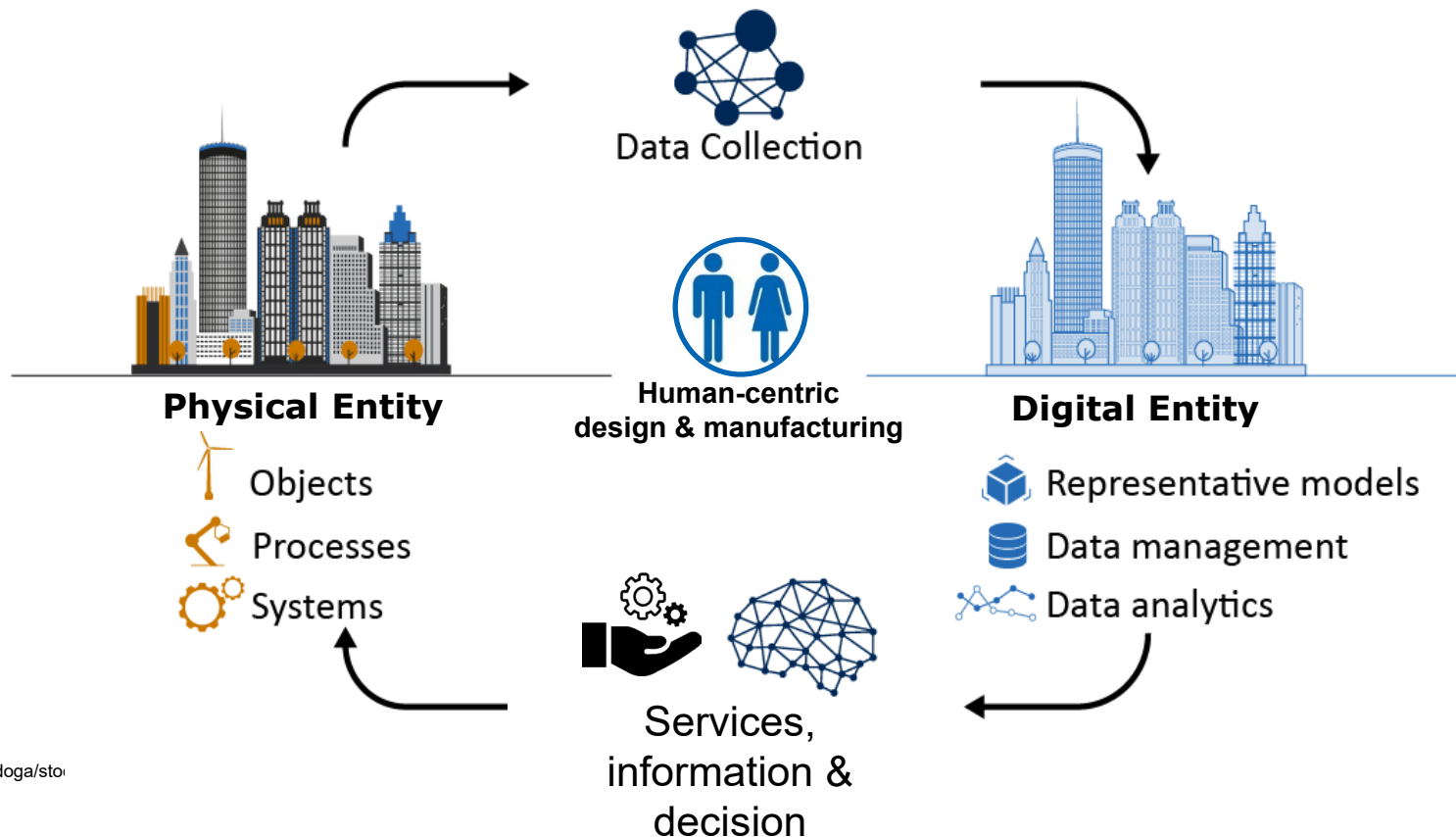
Digital Twins

Hochschule Luzern – T&A
CC FNUM, Research Group System Modeling, Digital Twins

<https://www.hslu.ch/de-ch/technik-architektur/ueber-uns/organisation/kompetenzzentren-und-forschungsgruppen/technik/fluidmechanik-numerische-methoden/dynamische-stroemungs-und-prozesssimulationen/>

Digital Twins?

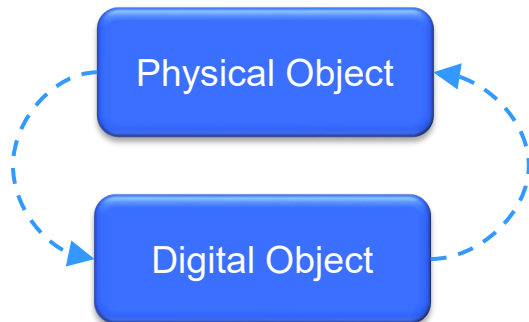
- A digital twin is a **digital representation of an intended or actual physical entity that collects real time data and provides services.**
 - Where the *real world* meets *data science* and *computational engineering*.
 - Enables us to **monitor, analyze, optimize, and predict** in real time during product lifecycle.



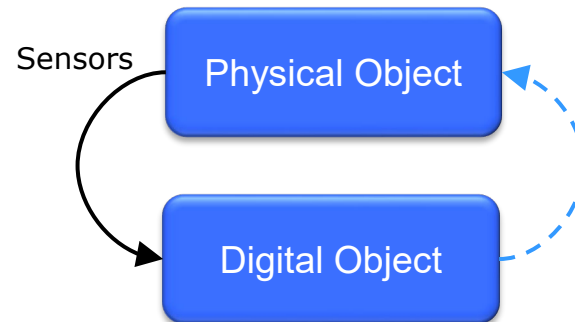
Digital Twin vs. Digital Shadow vs. Digital Model?

- **Digital model (simulation):**
 - No direct connection between digital and physical objects,
 - Validation of the Digital model required manual operations of data transfer.
- **Digital Shadow:**
 - One-way automatic data flow **from a real object to a digital model**,
 - Sensors collect and report data to the digital model automatically. Model parameters and states are adjusted to match the physical state. Services may be offered based on the observed states.
- **Digital Twin:**
 - Fully automated data flow between the digital and physical objects,
 - Changes in state of the physical object lead to the changes in digital object and vice versa.

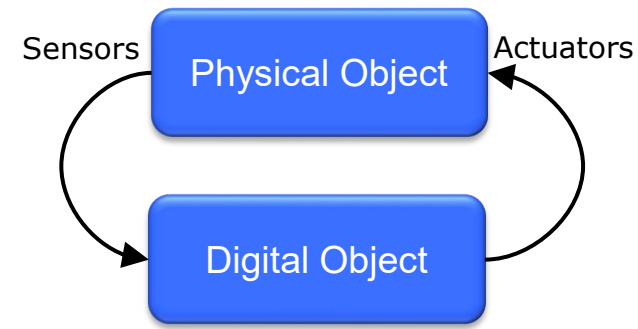
Digital Model



Digital Shadow



Digital Twin

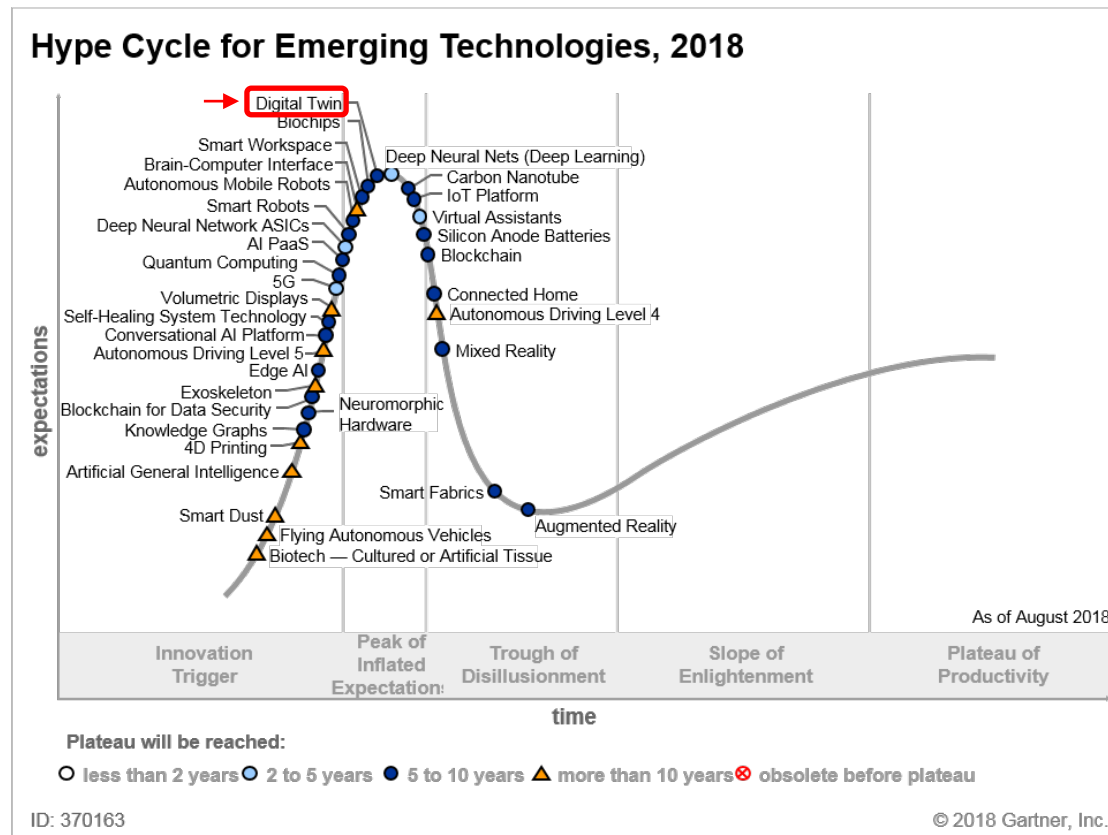


Manual Data Flow
(Offline)

Automatic Data Flow
(Real-time)

Digital Twins in Gartner's annually released Hype Cycle for Emerging Technologies

Gartner predicted that the DTs will be at the Plateau of Productivity between **2023** and **2028**.



Three-level digital twins: From Units to Systems of Systems

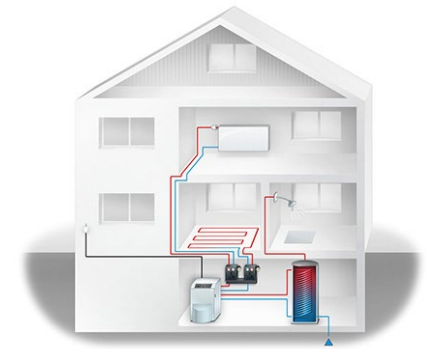
▪ Level 1: Units

- A single entity that can function independently
 - Examples:
 - In manufacturing: a component or product.
 - In construction and building: a radiator.
 - In healthcare: an organ in a body such as heart.



▪ Level 2: Systems

- A collection of units
 - Examples:
 - In manufacturing: production lines.
 - In construction and building: heating system including the boiler, pipes, and radiators.
 - In healthcare: entire blood circulatory systems in a body.

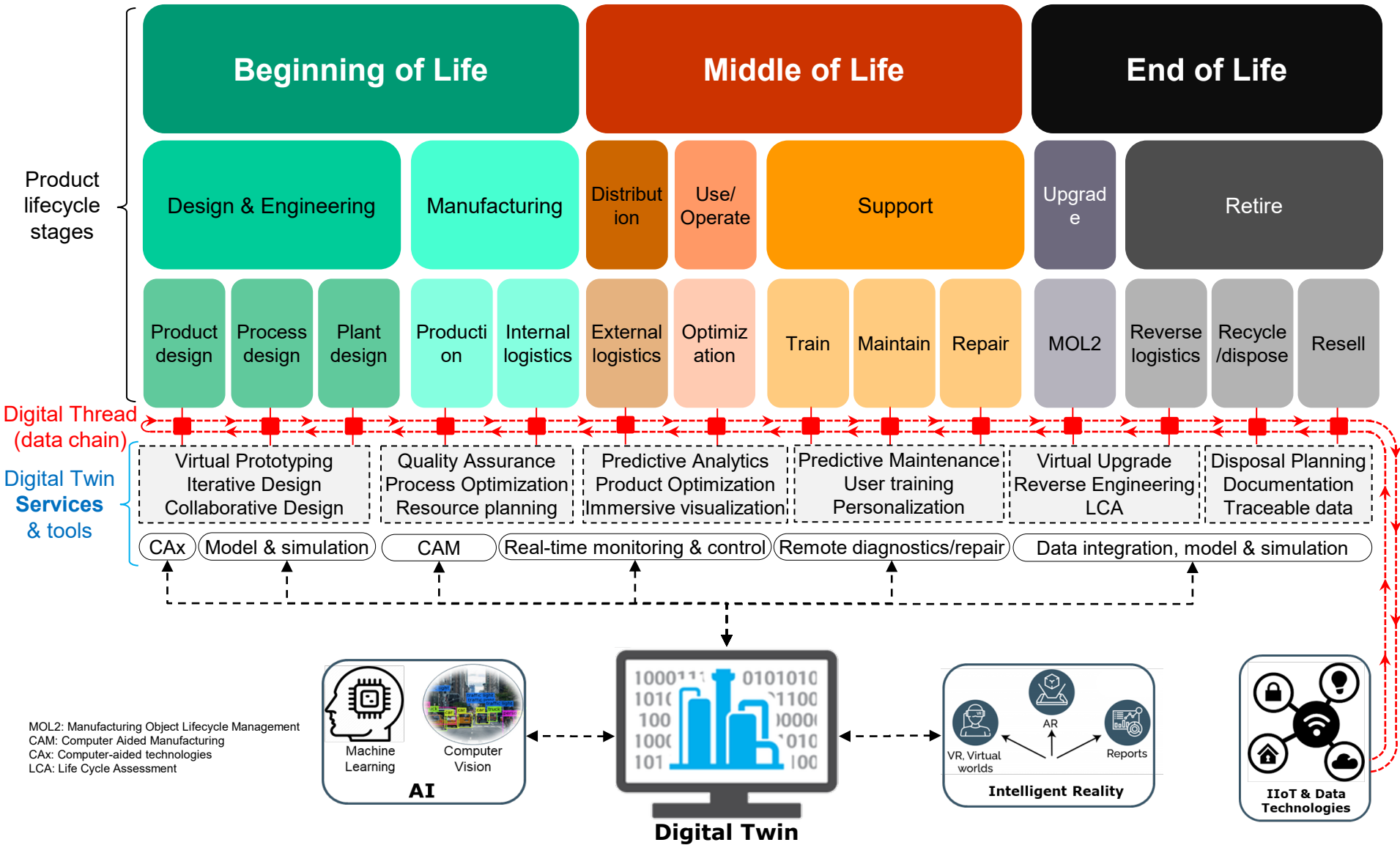


▪ Level 3: Systems of Systems

- A collection of systems
 - Examples:
 - In manufacturing: entire shop floor.
 - In construction and building: a complete building.
 - In healthcare: a body.



Services of Digital Twin during product lifecycle

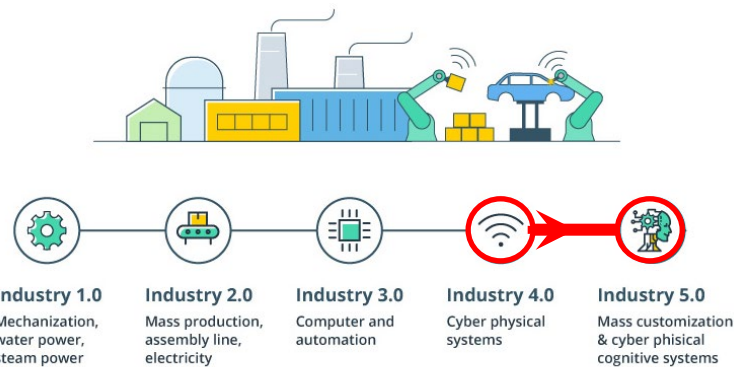


Application areas of Digital Twins

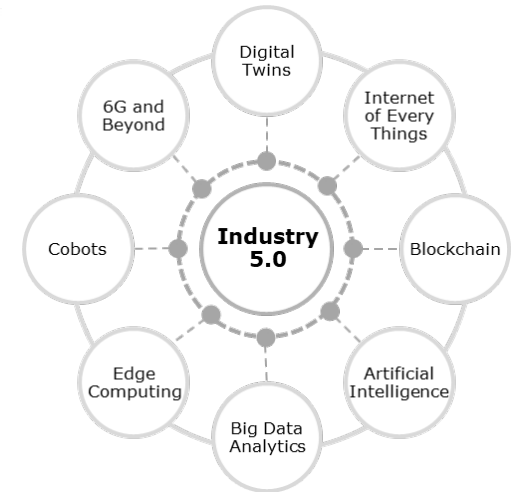
- Manufacturing and Industrial Processes
- Health and medicine
- Construction and Building Management
- Smart Cities and Infrastructure
- Aerospace and Defense
- Automotive
- Energy Systems
- Other emerging application areas:
 - Agriculture,
 - Food supply chain,
 - Transportation and logistics,
 - Commerce,
 - Oil and gas industry,
 - Environmental protection



DTs in Manufacturing: Envisaged future and defined goals for industry



Source: Furniturk Magazine Online — Ready for Industry 5.0



- **Industry 4.0:** integration of advanced digital technologies into manufacturing processes.
- **Industry 5.0:** integration of advanced digital technologies with human-centric approaches to manufacturing.
- **The United Nations Sustainable Development Goals (SDGs):** a set of 17 global goals aimed at ending poverty, protecting the planet, and ensuring peace and prosperity for all.



United Nations Sustainable Development Goals

Current and future needs of industry

(During transition from Industry 4.0 to 5.0, and reaching the United Nations Sustainable Development Goals)

- Sustainable Manufacturing,
- Human centric design & manufacturing,
- Digitalization & Automation,
- IoT & Data communication
- Collaborative robots/machines,
- Training, design, and collaboration via AR and VR,
- Circular economy,
- Servitization and Service Economy
- etc.

Smart manufacturing & processing (Smart factory)



Industry 1.0 Mechanization, water power, steam power	Industry 2.0 Mass production, assembly line, electricity	Industry 3.0 Computer and automation	Industry 4.0 Cyber physical systems	Industry 5.0 Mass customization & cyber physical cognitive systems
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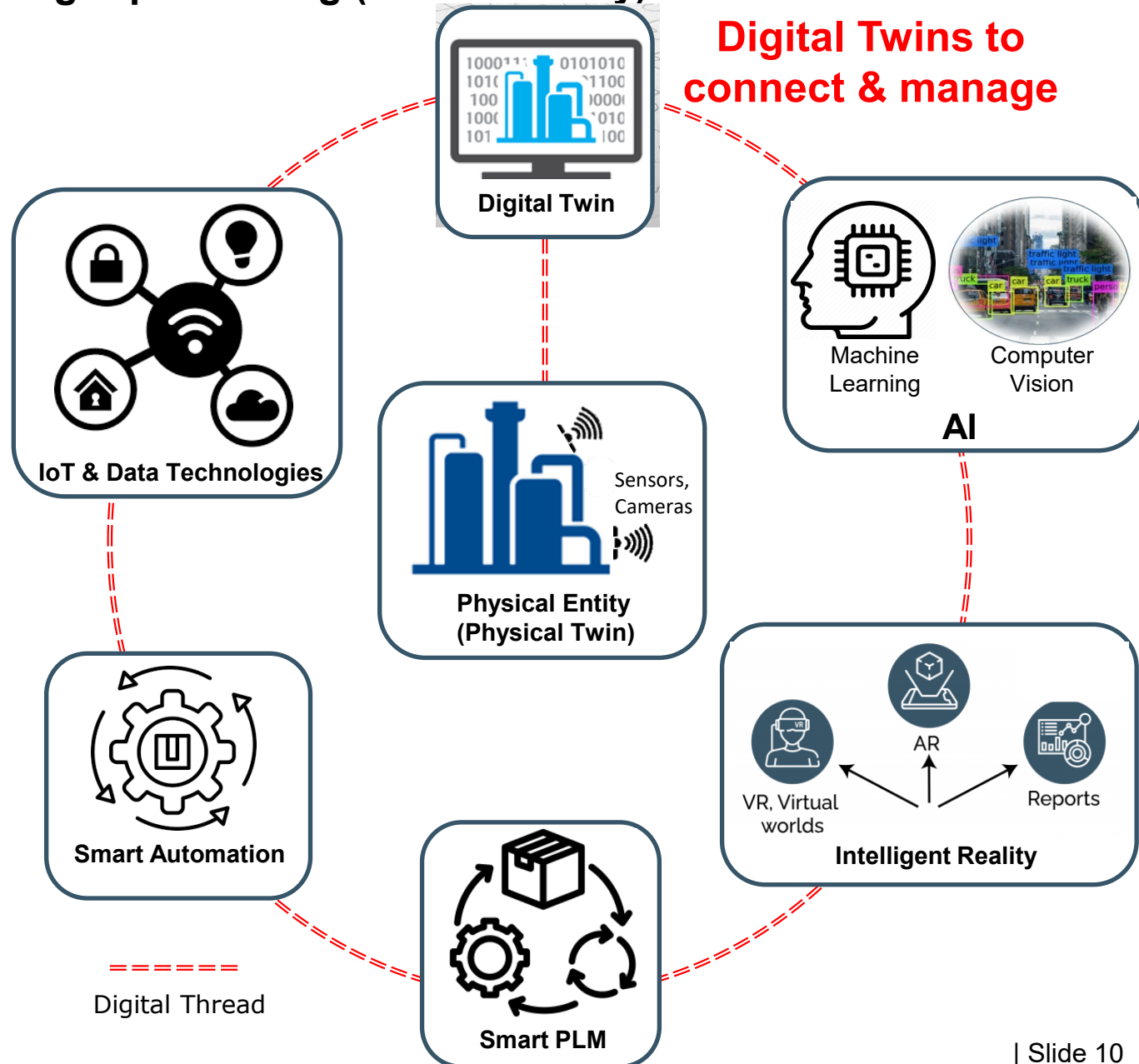
Source: Furniturk Magazine Online — Ready for Industry 5.0

<https://instrumental.com/>

Smart manufacturing & processing (Smart Factory)

Industrial 4.0 & 5.0 Technologies

- Smart PLM
- CAx, Modeling, Simulation
- Smart Automation
- Virtual & Augmented Reality (AR/VR)
- Cloud Computing
- Collaborative Robots (Cobots)
- Industrial Internet of Things (IIoT)
- Artificial Intelligence (AI) & Machine Learning (ML)
- Application Development
- Data Network & Digital Thread
- Data Storage
- Big Data Analytics



Digital Twins;

An essential tool to address industry 4.0, 5.0, and UN SDGs needs

▪ Roles of digital twins in Industry 4.0 and 5.0:

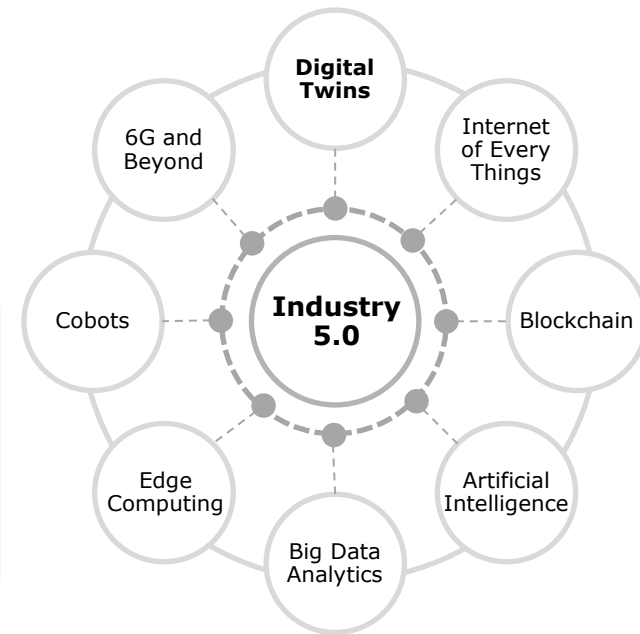
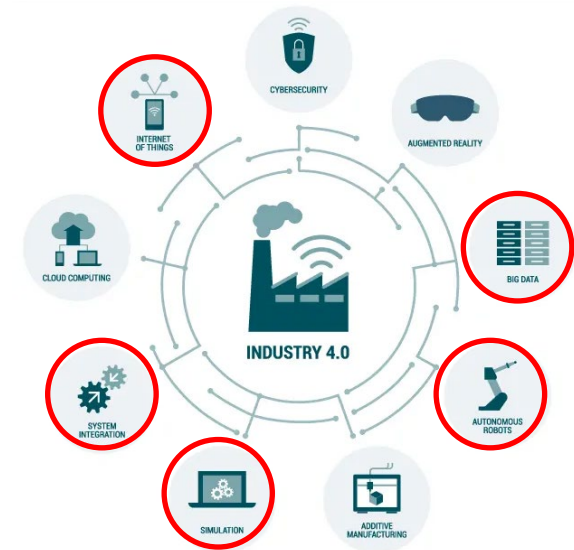
- Enabling **Cyber-Physical** systems.
- **Smart Factories**: design, simulate and optimize.
- Generating **Big Data** via simulation of high-fidelity models.
- Enabling better control, management, and monitoring of **IoT** devices.
- Enabling **Augmented Reality** experiences.
- Enabling **Human-Centric Design**.
- Optimizing the behavior of **collaborative robots**.

▪ Targeted SDGs:

- SDG 7
- SDG 9
- SDG 13
- SDG 11
- SDG 4 & 3

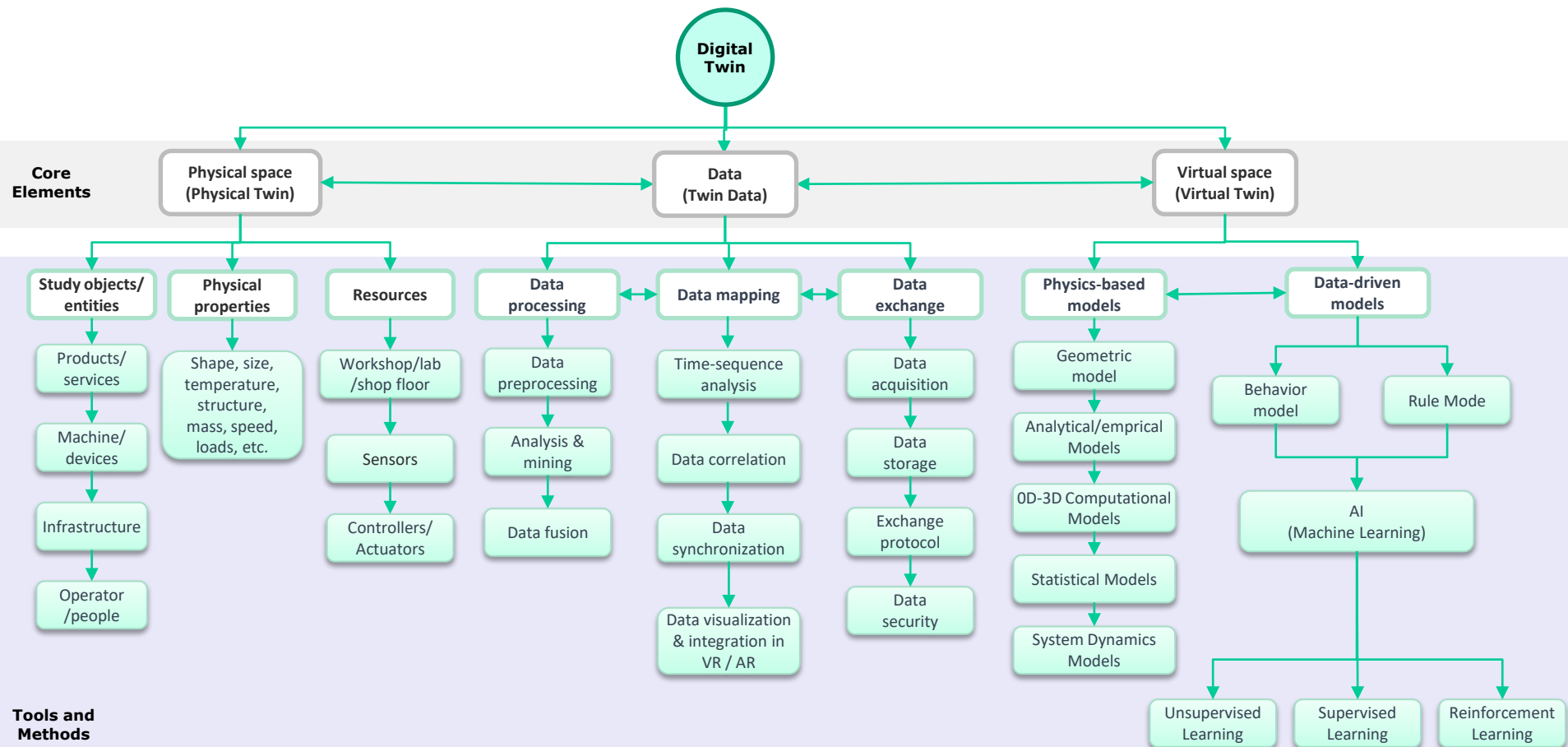


United Nations Sustainable Development Goals

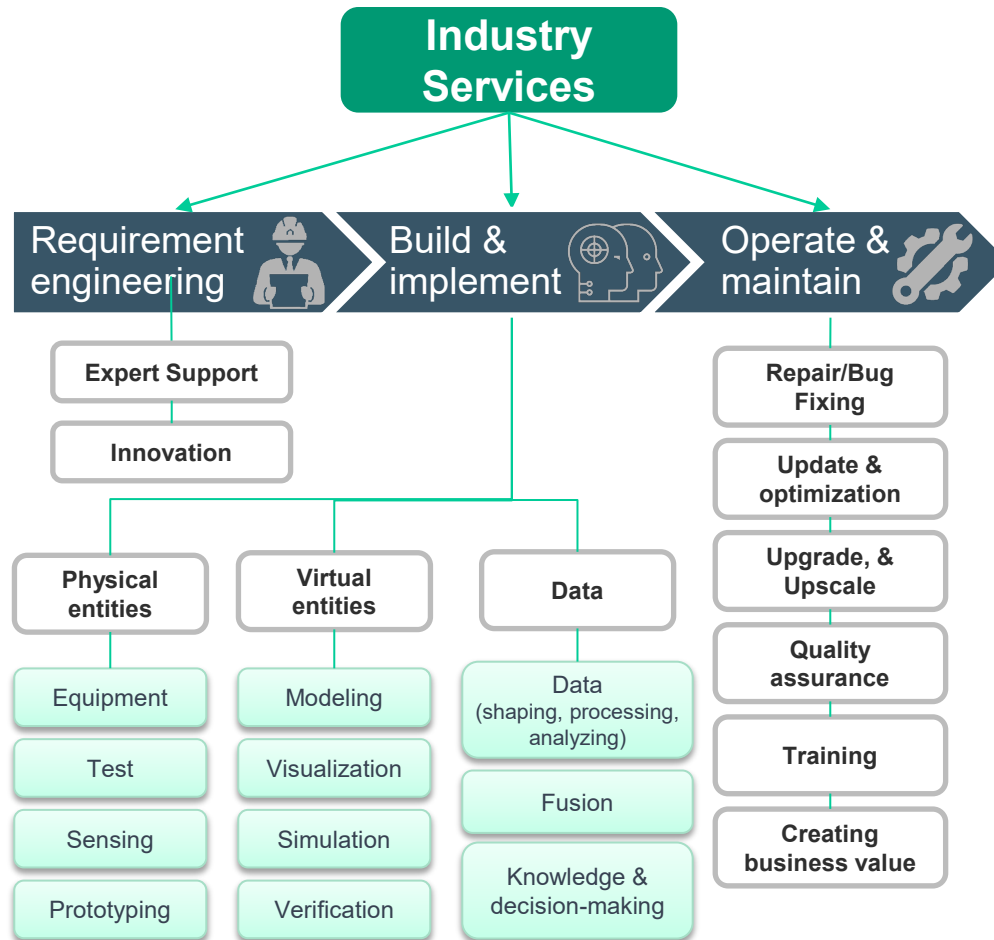


Digital Twin Core Elements

1. Physical space,
2. Virtual space: physics-based or data-driven models, virtual sensors,
3. Information/data processing layer

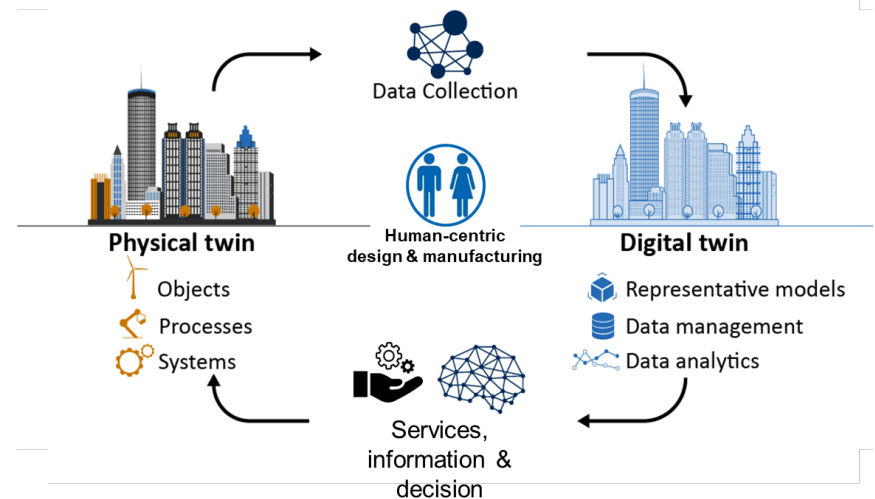


Digital Twin Services



Implementing Digital Twins

- Creating a digital twin requires different expertise and resources such as:
 - **Modeling and simulation** (physics-based and/or data-based models);
 - **Data science, Artificial Intelligence (AI) and machine learning** for Digital Twins;
 - **Laboratories and experimentation**;



✅ These skills and resources are available at HSLU!