Third Workshop from CATCH_VR Project

DIGITAL TWIN TRAINING 2025

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Biofuels and Microfluidics Lab

About me

Expert in Microsystems, Fluid Mechanics, Biofuels, Sensors and Actuators, Medical Diagnostics.

H-Index: 16

Research Grants worth ~ 1 Million USD

TTSF

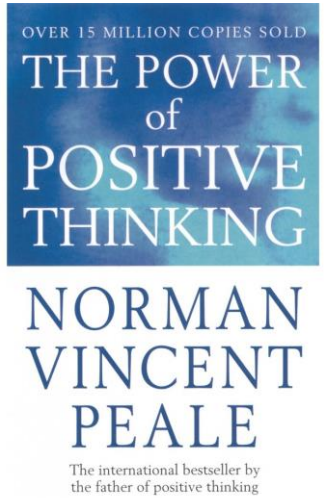
NRPU

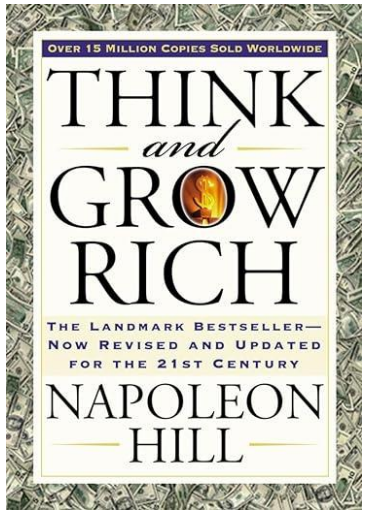
RTTG

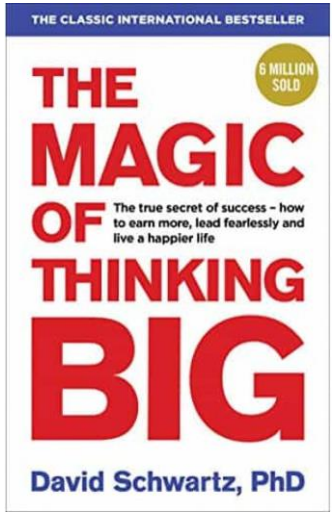
Mindset Development

Must Reads:

- ❑ The Power of Positive Thinking
- ❑ Think and Grow Rich
- ❑ The Magic of Thinking Big



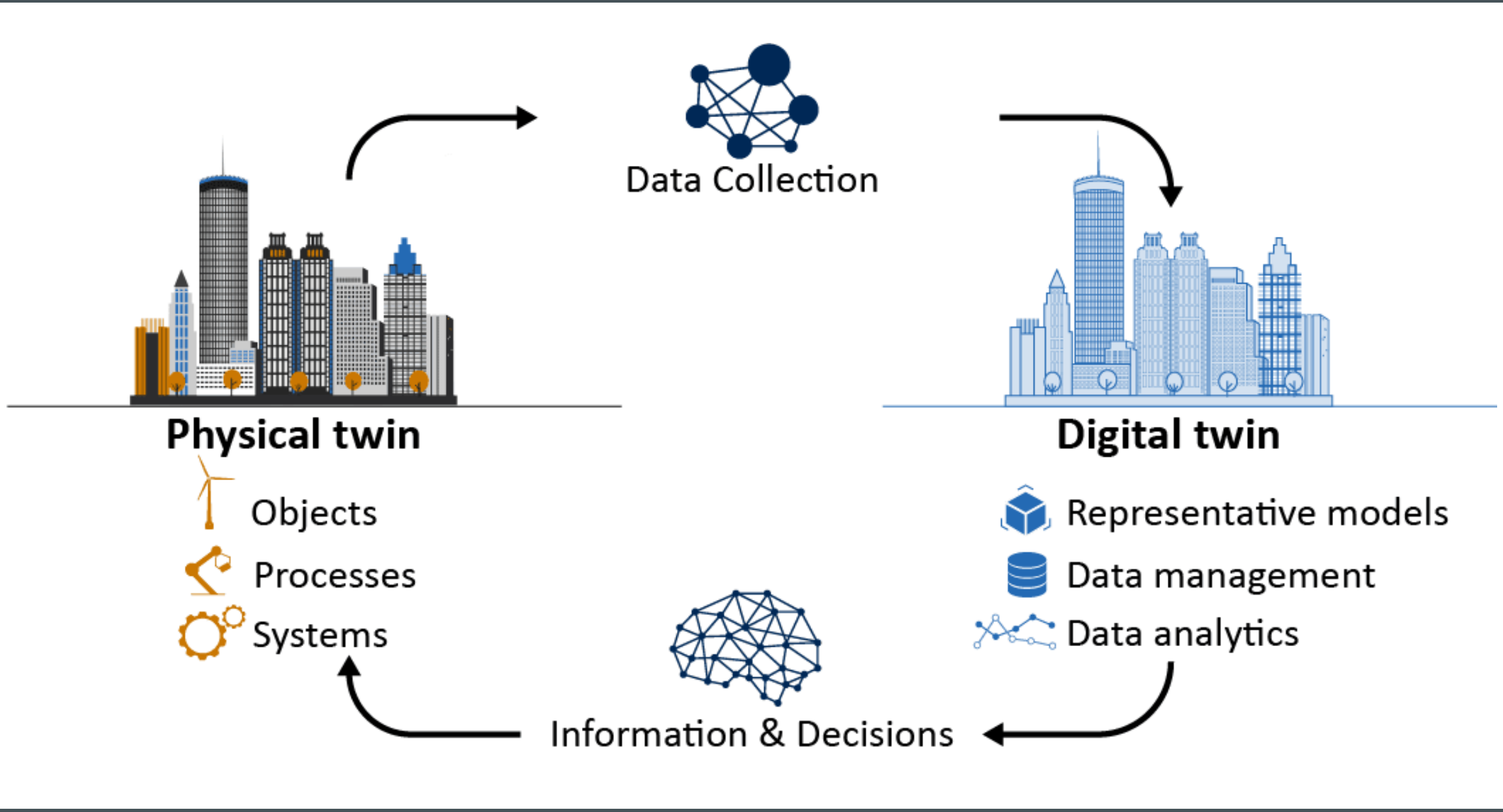




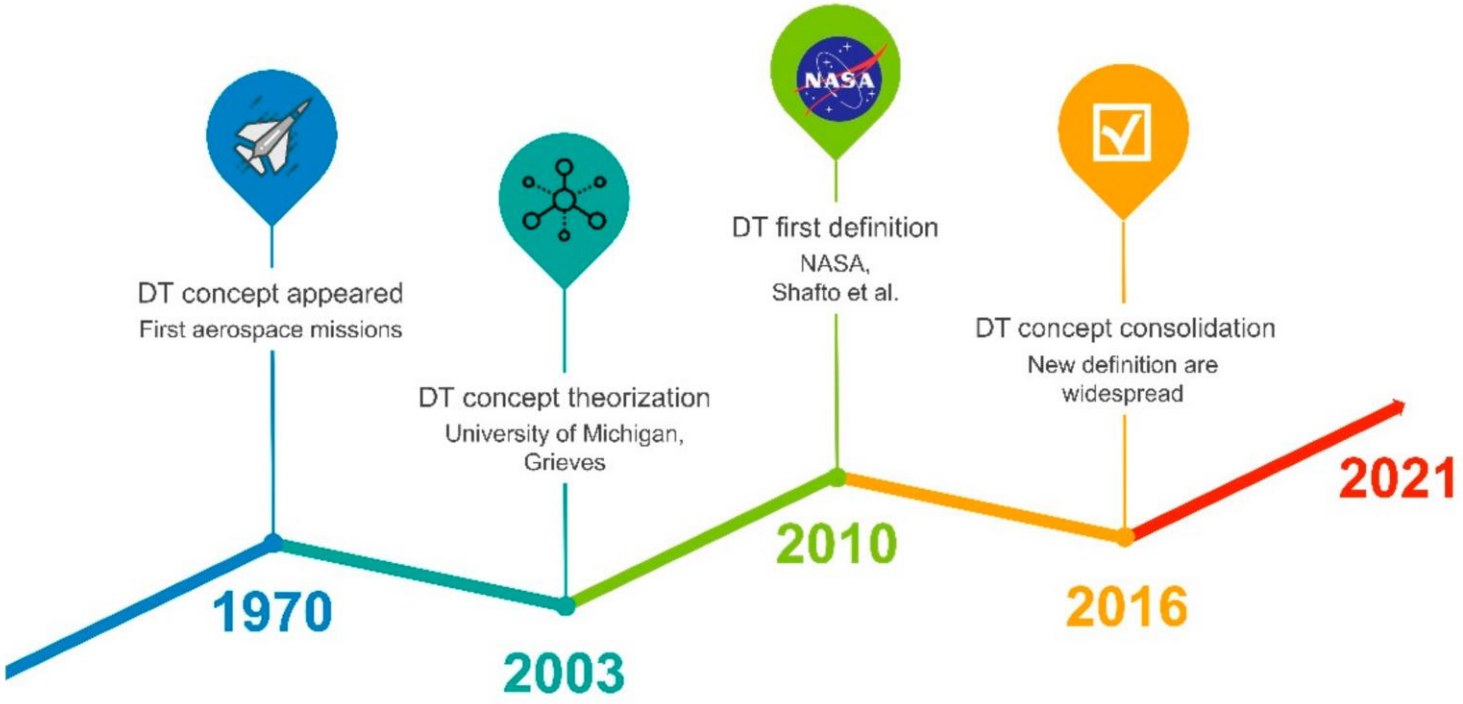
DIGITAL TWINS: BRIDGING PHYSICAL AND DIGITAL WORLDS

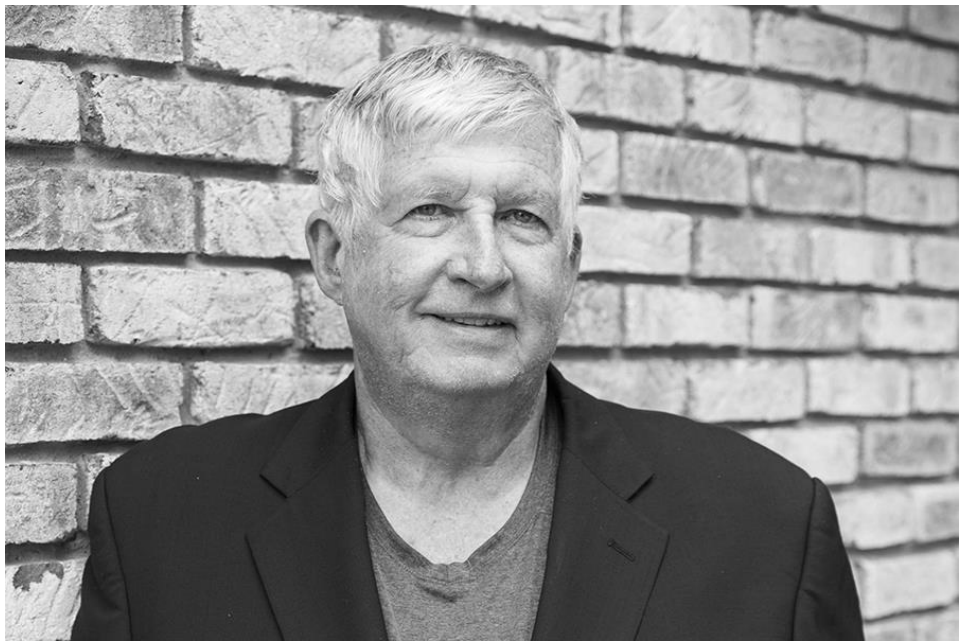
- **Mirror** the real world to unlock insight and innovation
- Fuse data, models, and real-time intelligence
- Continuously updated with real-time data

A digital twin is an integrated data-driven virtual representation of real-world entities and processes, with synchronized interaction at a specified frequency and fidelity


Data Collection
Physical twin
Digital twin
Objects
Processes
Systems
Representative models
Data management
Data analytics
Information & Decisions

THE BIRTH OF DIGITAL TWINS

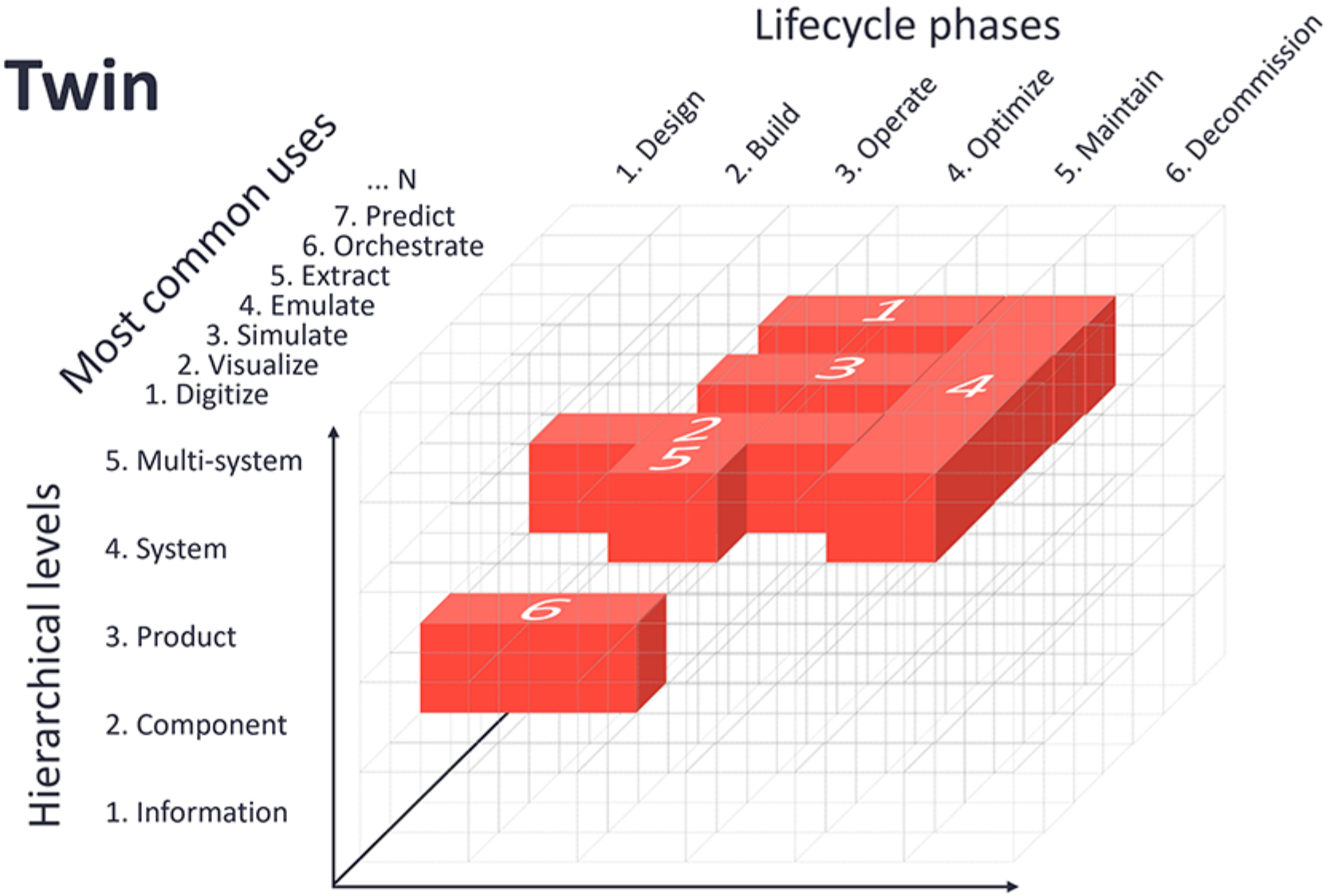




Dr. Michael Grieves
Father of the Digital Twins

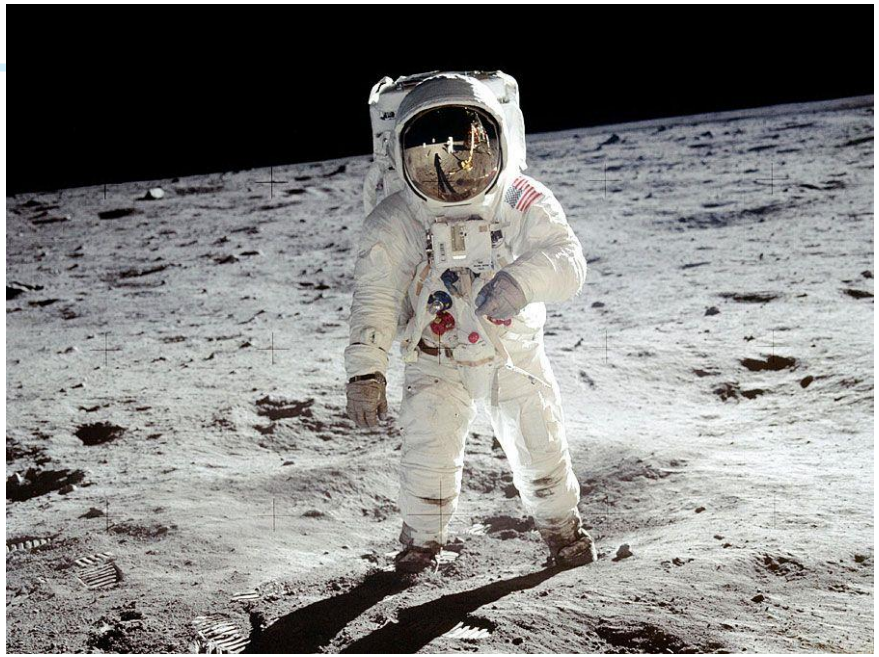
The 6 main Digital Twin applications

1. System prediction
2. System simulation
3. Asset interoperability
4. Maintenance
5. System visualization
6. Product simulation

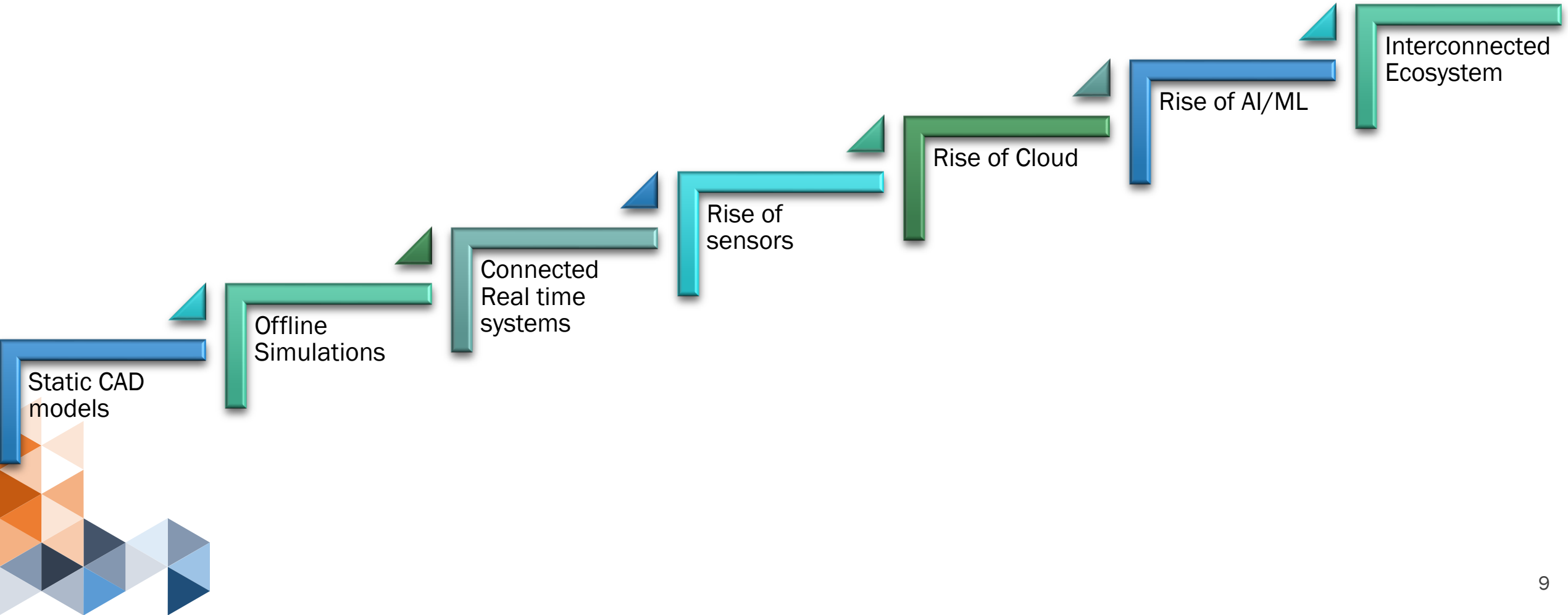


EARLY VISION: NASA'S MOON LANDING

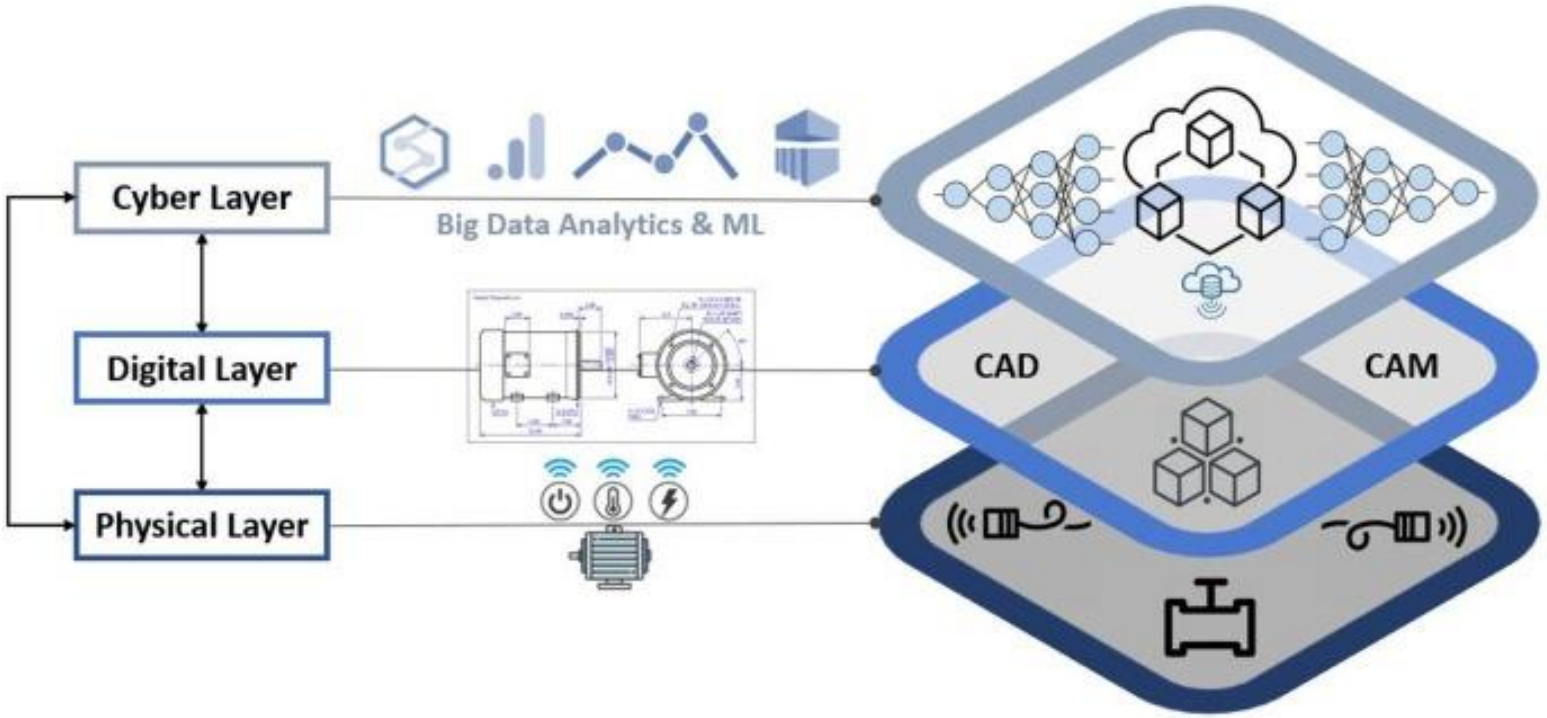
- Apollo missions had identical **spacecraft replicas** on Earth (1960s) (Physical Twins)
- Engineers mirrored conditions from space in real time
- Not digital, but **conceptually the first twins**



EVOLUTION OF THE FIELD

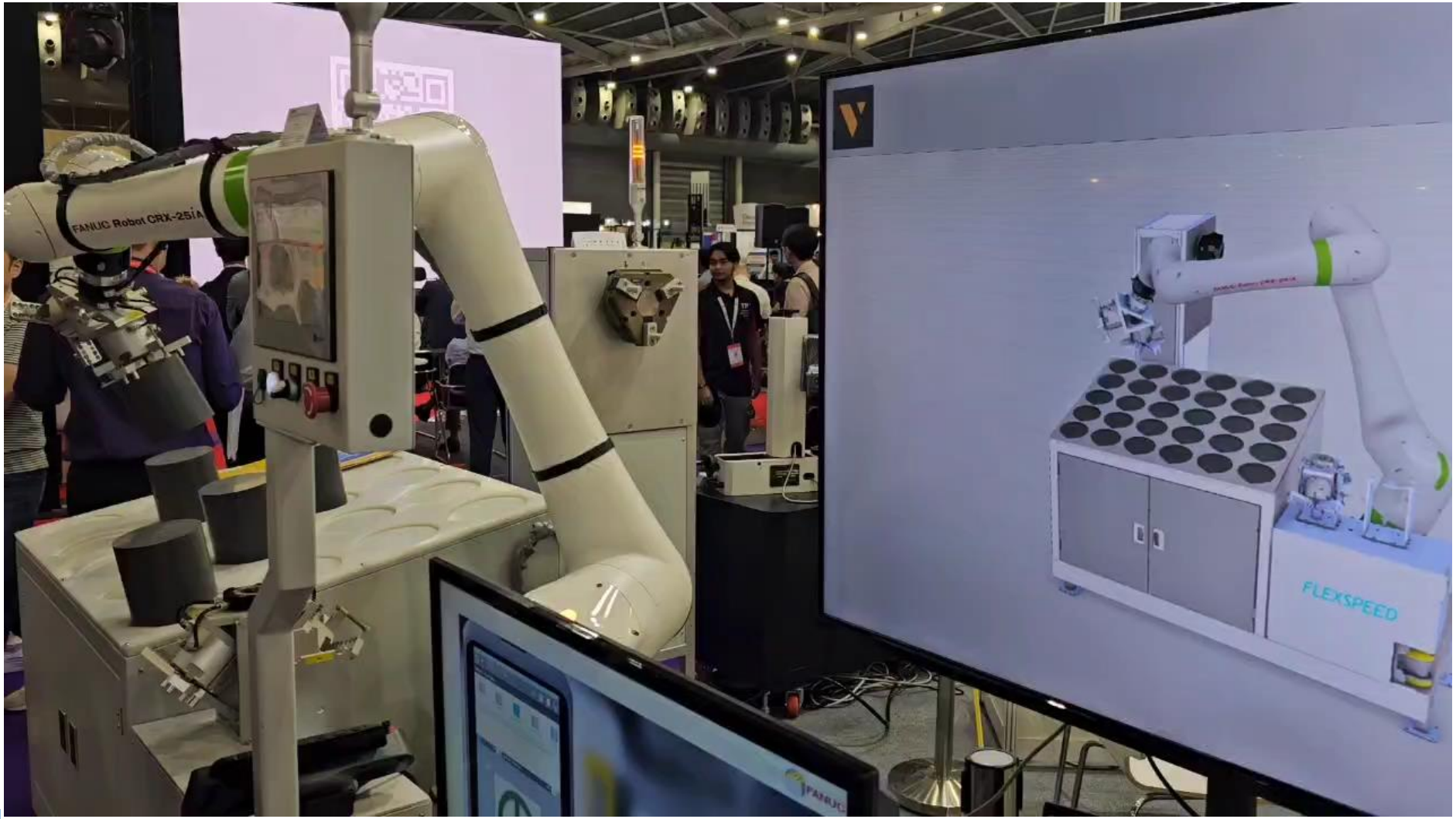


THE CORE ARCHITECTURE

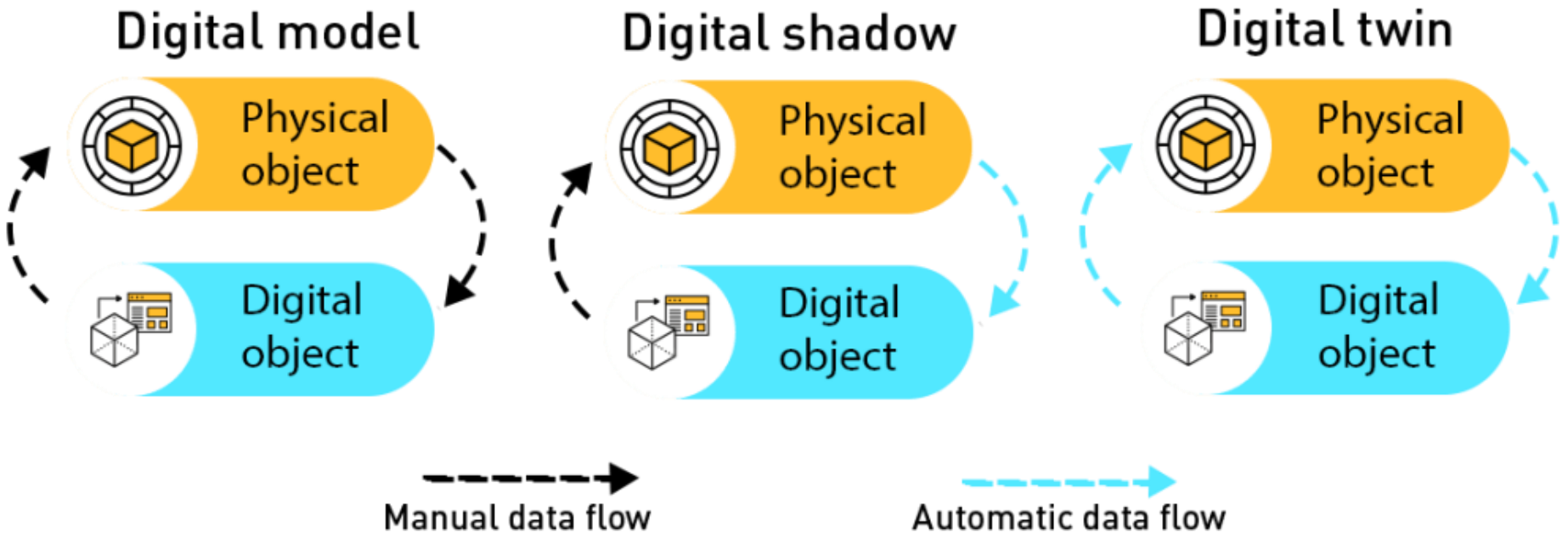


- **Physical layer:** Sensors, machines, environments
- **Digital layer:** Models, simulations, AI/analytics
- **Connection layer:** Data pipelines & real-time feedback

DIGITAL TWIN VS DIGITAL SHADOW VS DIGITAL MODEL

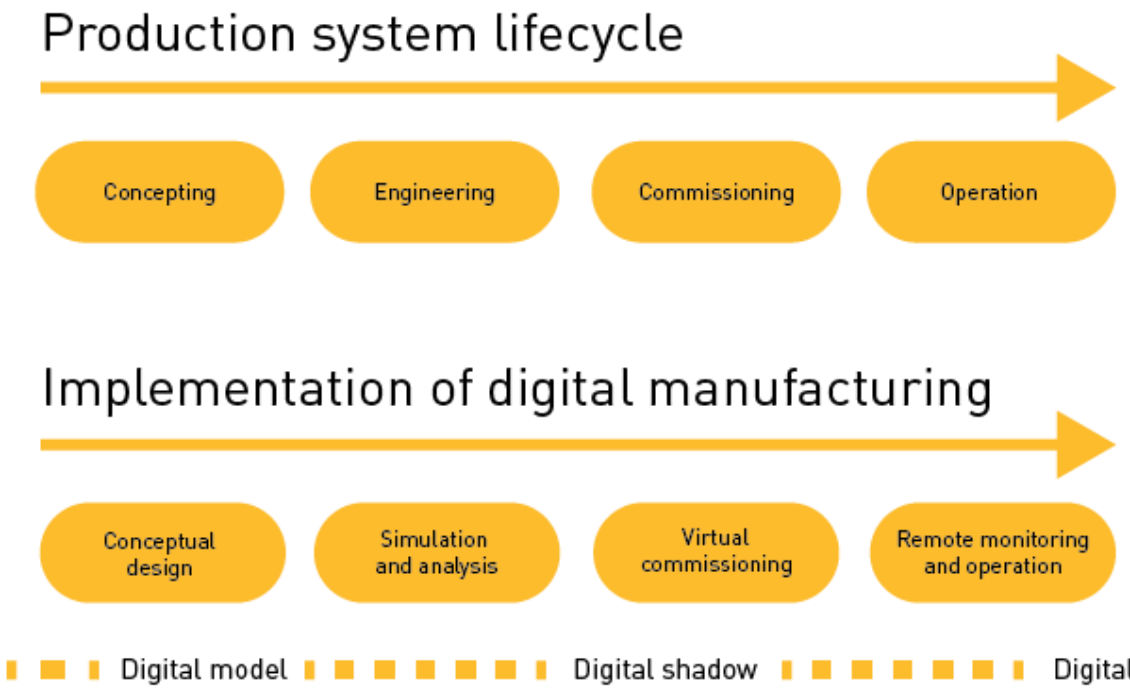


DIGITAL TWIN VS DIGITAL SHADOW VS DIGITAL MODEL



- A **digital shadow** is a **virtual representation that automatically receives real-time data** from its physical counterpart. However, this is a **one-way data flow**—it **monitors** the system but **cannot control or optimize it**.
- A **digital twin** is a **real-time, bidirectional digital counterpart** of a physical system. Unlike a **digital shadow**, it **not only receives real-time data but also influences the physical system**. This enables **live process optimization, predictive analytics, and AI-driven automation**.

DIGITAL TWIN VS DIGITAL SHADOW VS DIGITAL MODEL



Feature	Digital Model	Digital Shadow	Digital Twin
Data connection	✗ None	✓ One-way	✓ Two-way
Real-time updates	✗ No	✓ Yes	✓ Yes
Can influence physical system?	✗ No	✗ No	✓ Yes
Use cases	Conceptual design	Monitoring & reporting	Optimization & automation

CORE CAPABILITIES

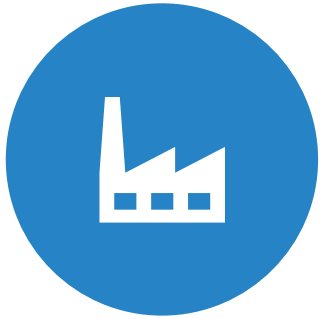
MONITOR AND DIAGNOSE SYSTEMS IN REAL TIME

SIMULATE WHAT-IF SCENARIOS BEFORE ACTING

PREDICT FAILURES AND OPTIMIZE PERFORMANCE

MANAGE ENTIRE LIFECYCLE FROM DESIGN TO RETIREMENT

INDUSTRY USE CASES



MANUFACTURING: SMART FACTORIES, PREDICTIVE MAINTENANCE, PRODUCT LIFECYCLE

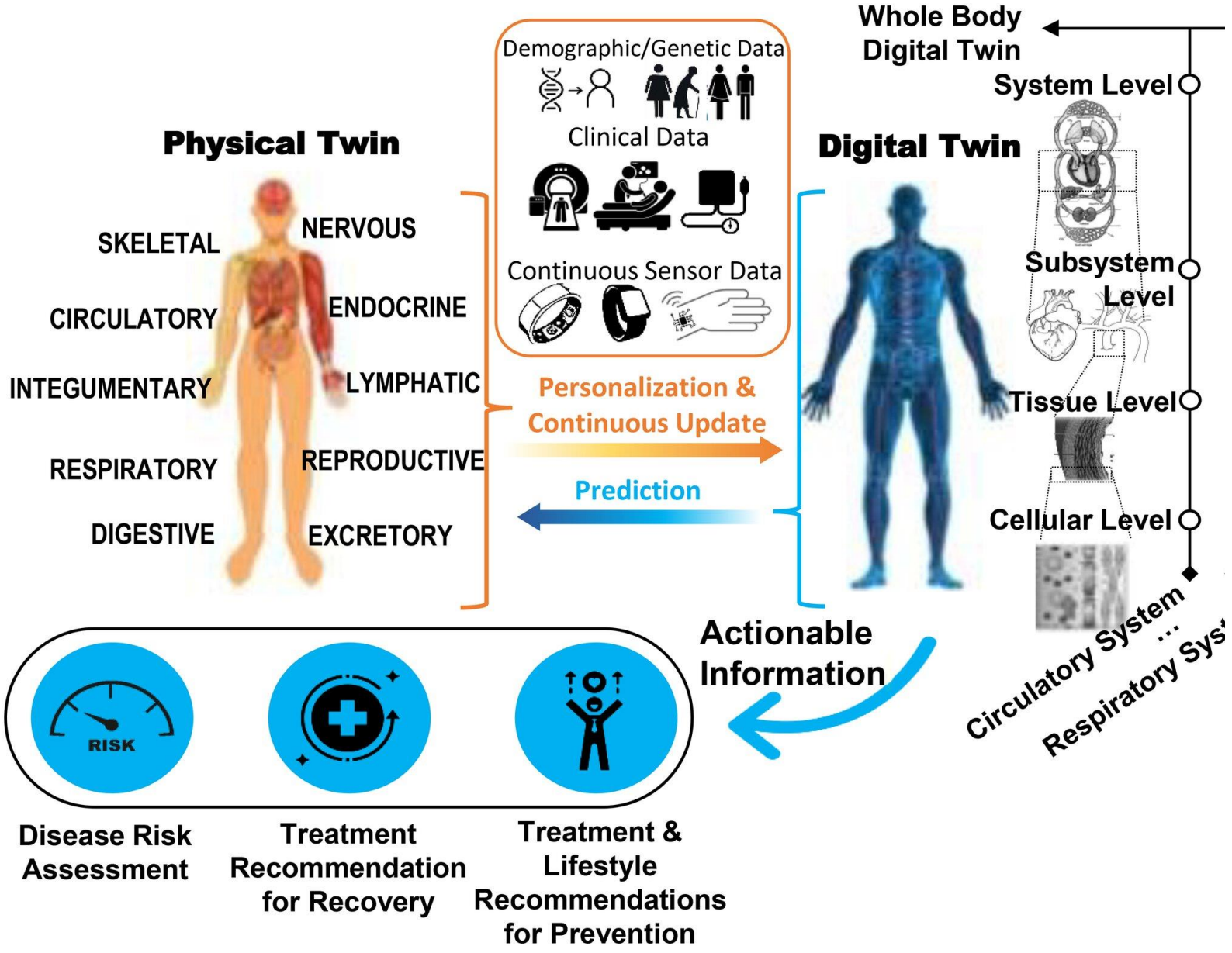
HEALTHCARE: PATIENT TWINS, SURGICAL PLANNING, HEALTH MONITORING

ENERGY & CITY: TRAFFIC, ENERGY, UTILITIES, SMART GRID

AEROSPACE/AUTO: JET ENGINES, VEHICLES, LOGISTICS OPTIMIZATION

BEYOND INDUSTRY: EMERGING FRONTIERS

- Personalized human digital twins
- Climate and planetary twins



DESTINATION EARTH

A DIGITAL REPLICA OF OUR PLANET

Destination Earth (DestinE) aims to develop a highly accurate digital model of Earth to monitor the effects of natural and human activity on our planet, anticipate extreme events and adapt policies to climate-related challenges.

ECMWF esa EUMETSAT

VALUE & IMPACT

Improve efficiency and reduce costs

Cut downtime and reduce risks

Accelerate innovation cycles

Drive sustainability and better decisions

CHALLENGES & OPEN QUESTIONS

- **Data quality,** standards, and interoperability
- Privacy, security, and trust concerns
- **High costs**, scalability, and
- Skill gaps (Technical Complexity)
- Ethical and regulatory frameworks still evolving

THE VISION AHEAD

- From twins of things → systems → societies
- Co-evolving living digital ecosystems
- The nervous system of our future world
- **Call to action:** “This is where imagination meets reality.”

Thank you

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