DIGITAL TWIN FOR EDUCATION

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The Theory of the Digital Twin

Module 1

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What is a Digital Twin?

- Definition:

  Digital/virtual representation of a physical product, system, or process

- Three elements:
  - Physical Twin (Real Space)
  - Digital Twin (Virtual Space)
  - Digital Thread (Data link)

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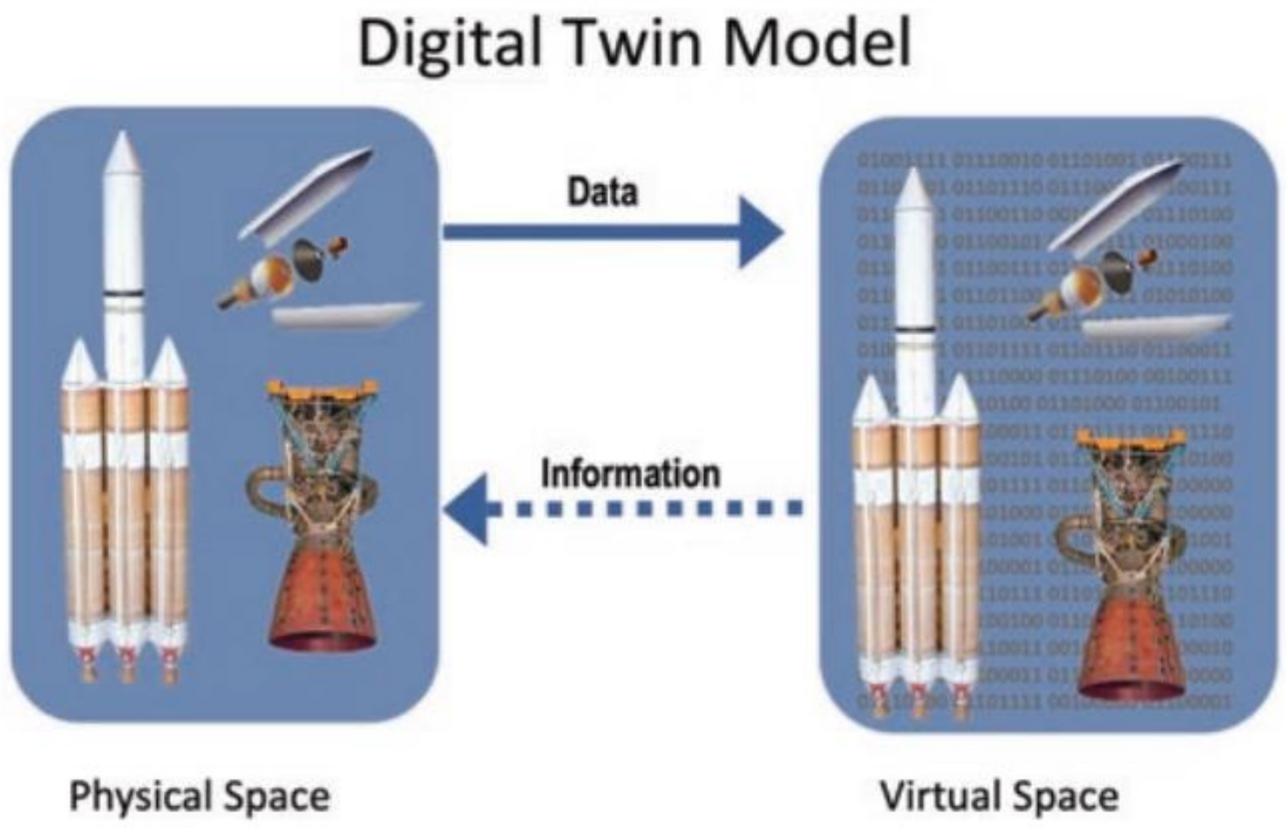
What is a Digital Twin?



Digital Twins: Past, Present, and Future (2023)
- Michael W. Grieves

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Digital Representations

- Digital Model (digital → physical)
- Digital Shadow (physical → digital)
- Digital Twin (two-way sync)

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Historical Background

- Apollo 13 – early “proto twin”
- Computer simulations (Von Neumann, Ulam, Shakey robot)
- First use of the term (1997)
- Defined in 2002, widely adopted by 2018

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Types of Digital Twins

- Prototype (DTP) – virtual design/testing
- Instance (DTI) – specific unit with data
- Aggregate (DTA) – collection of DTIs, predictive analytics

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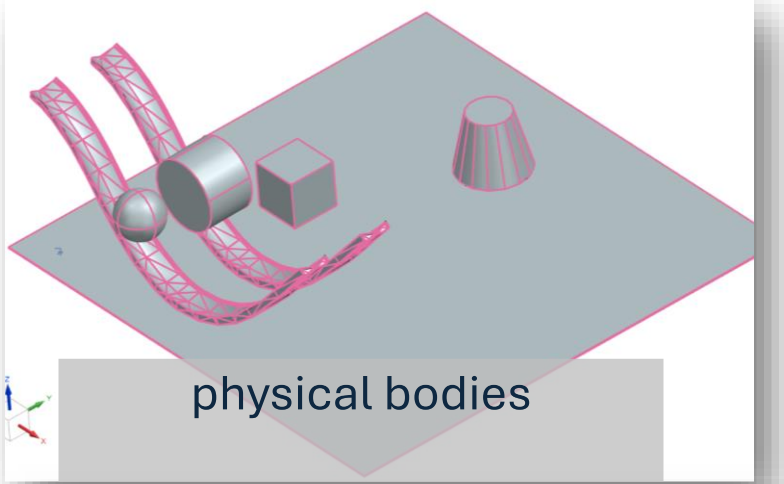
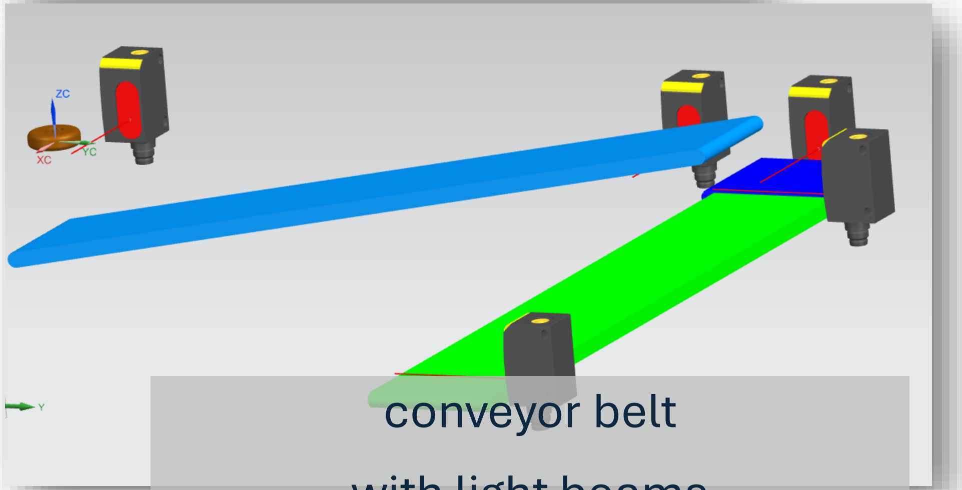
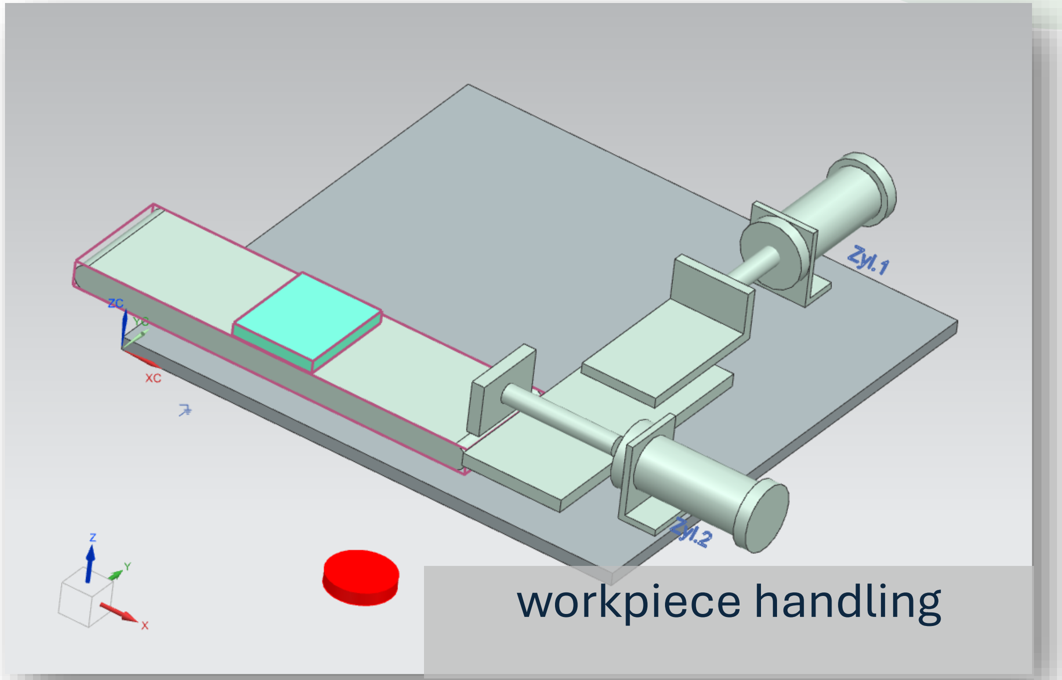
Examples of Digital Twins


physical bodies


conveyor belt

with light beams



workpiece handling

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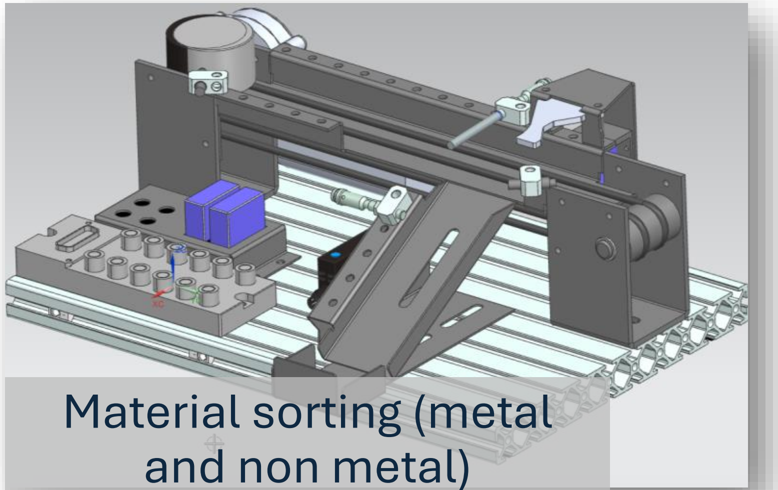
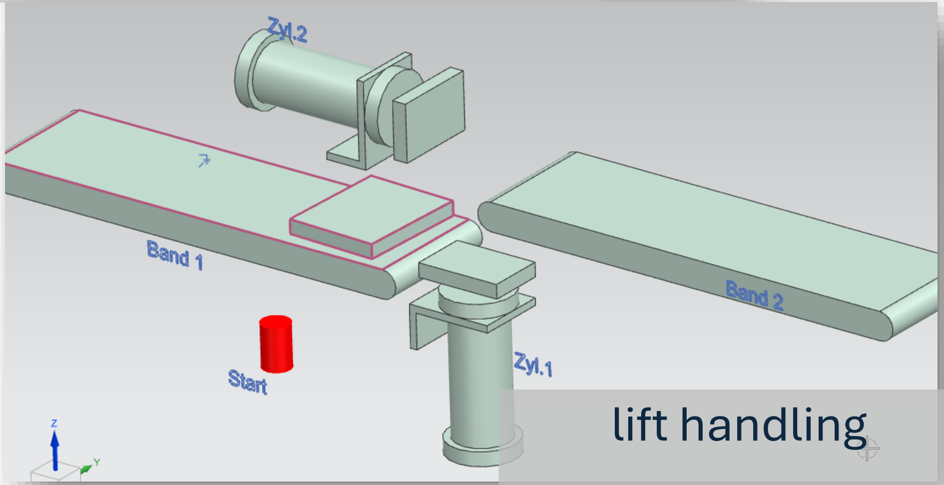
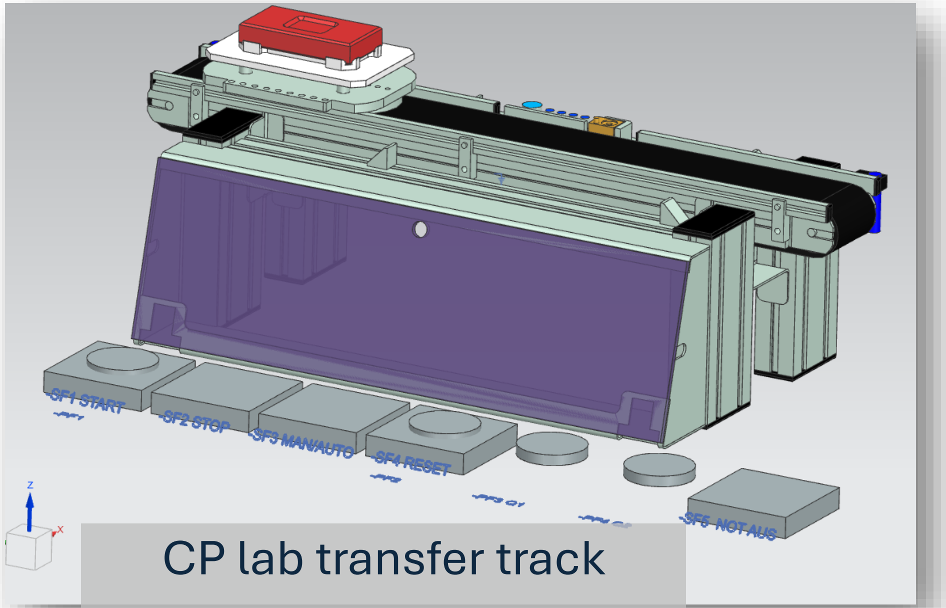
Examples of Digital Twins



Material sorting (metal and non metal)



lift handling



CP lab transfer track

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Types of Digital Twins

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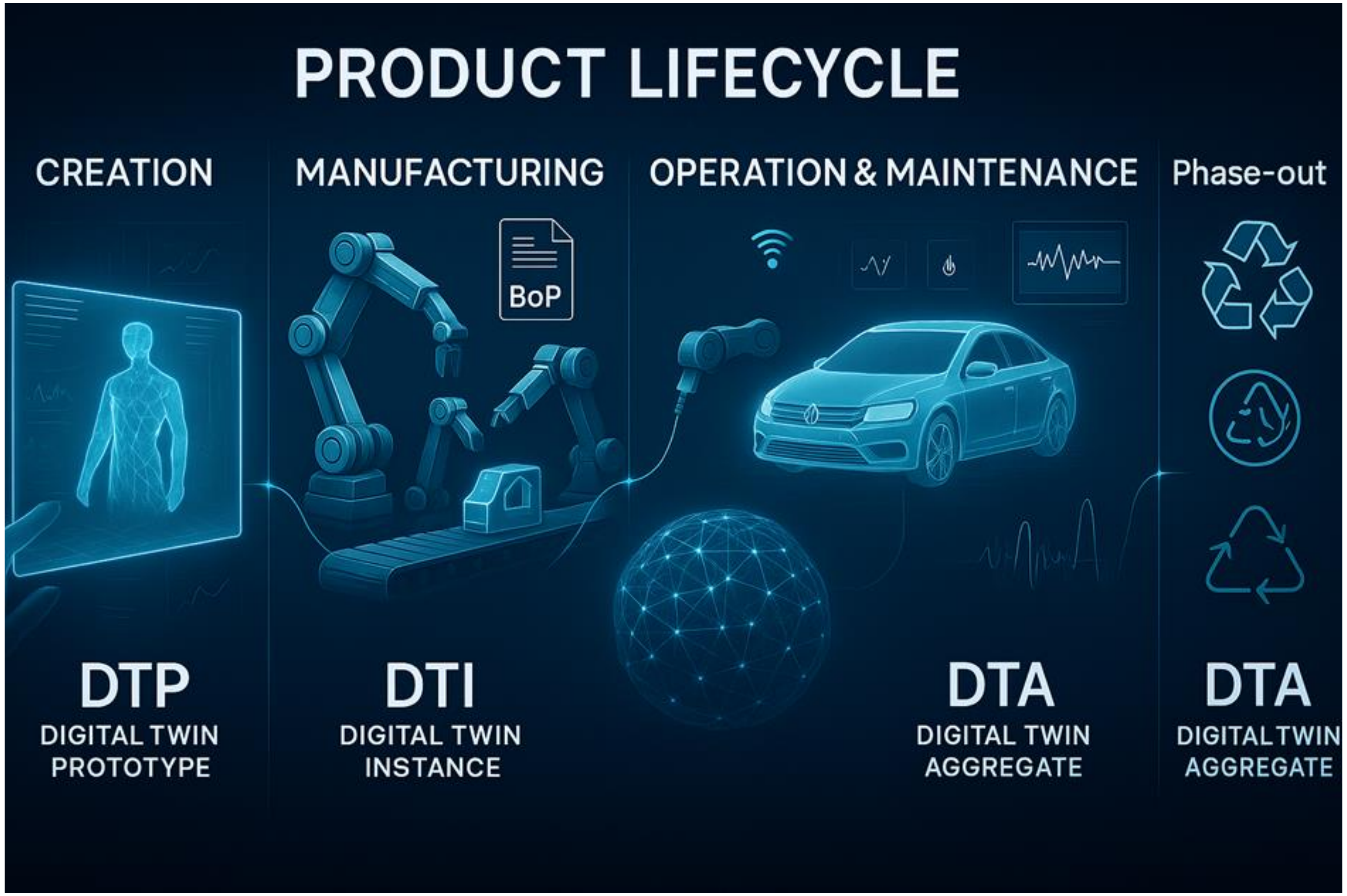

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Twins in the Product Lifecycle

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- Four phases: Create – Manufacture – Operate – Phase-out
- Twins applied across all stages

Evolution of Digital Twins

- Phase 0: Traditional (drawings, CAD)
- Phase 1: Transitional (3D models)
- Phase 2: Conceptual (data experiments)
- Phase 3: Replicative platforms (today)
- Phase 4: Intelligent Twins (AI-driven, predictive)

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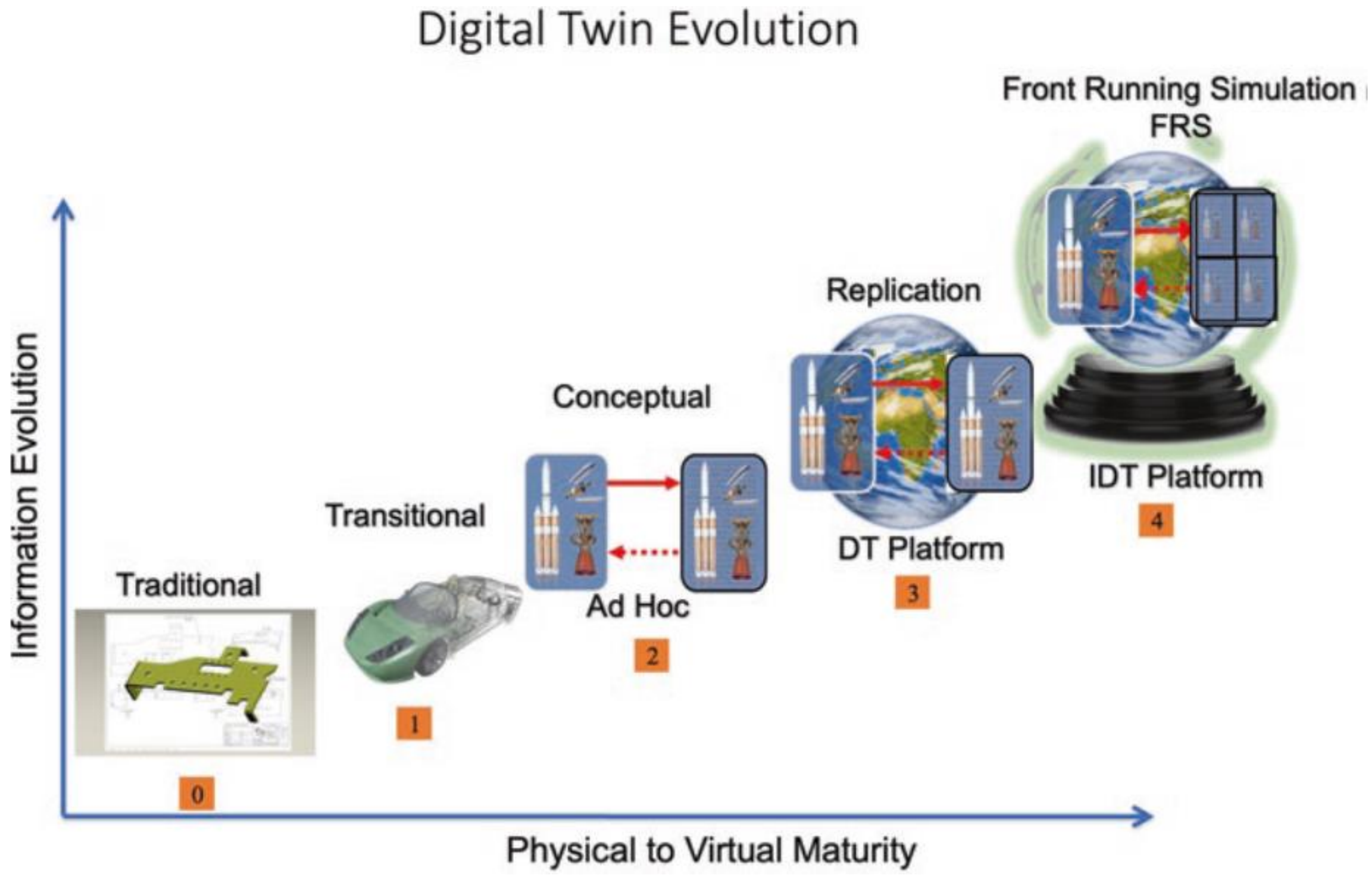
Evolution of Digital Twins



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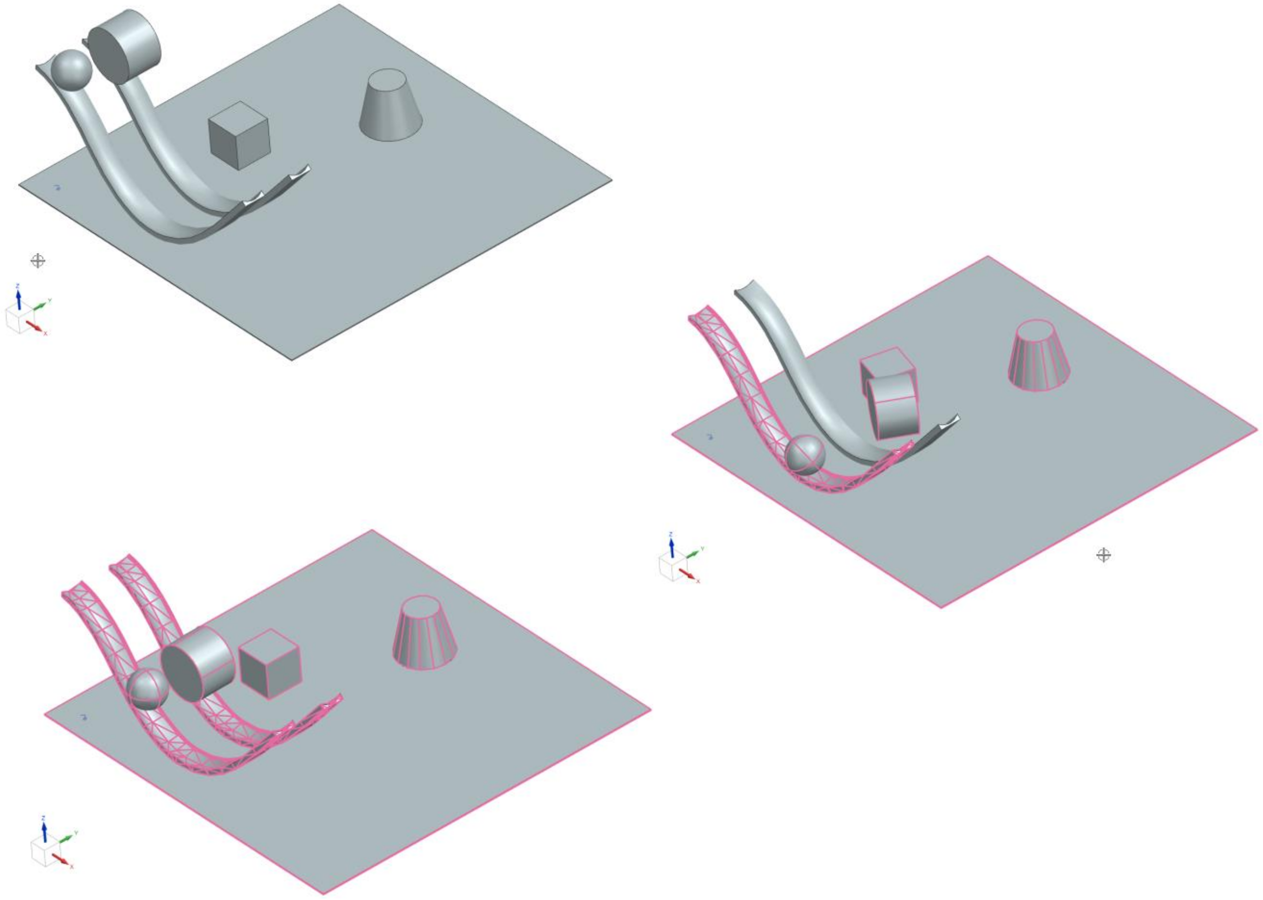
Simulation & Testing



The digital models can be given physical properties (e.g. density, friction, ...). Thus, the model behavior corresponds to the real behavior. The bodies roll down the ramp at different speeds. Also bodies can leave the ramp.

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Simulation & Testing

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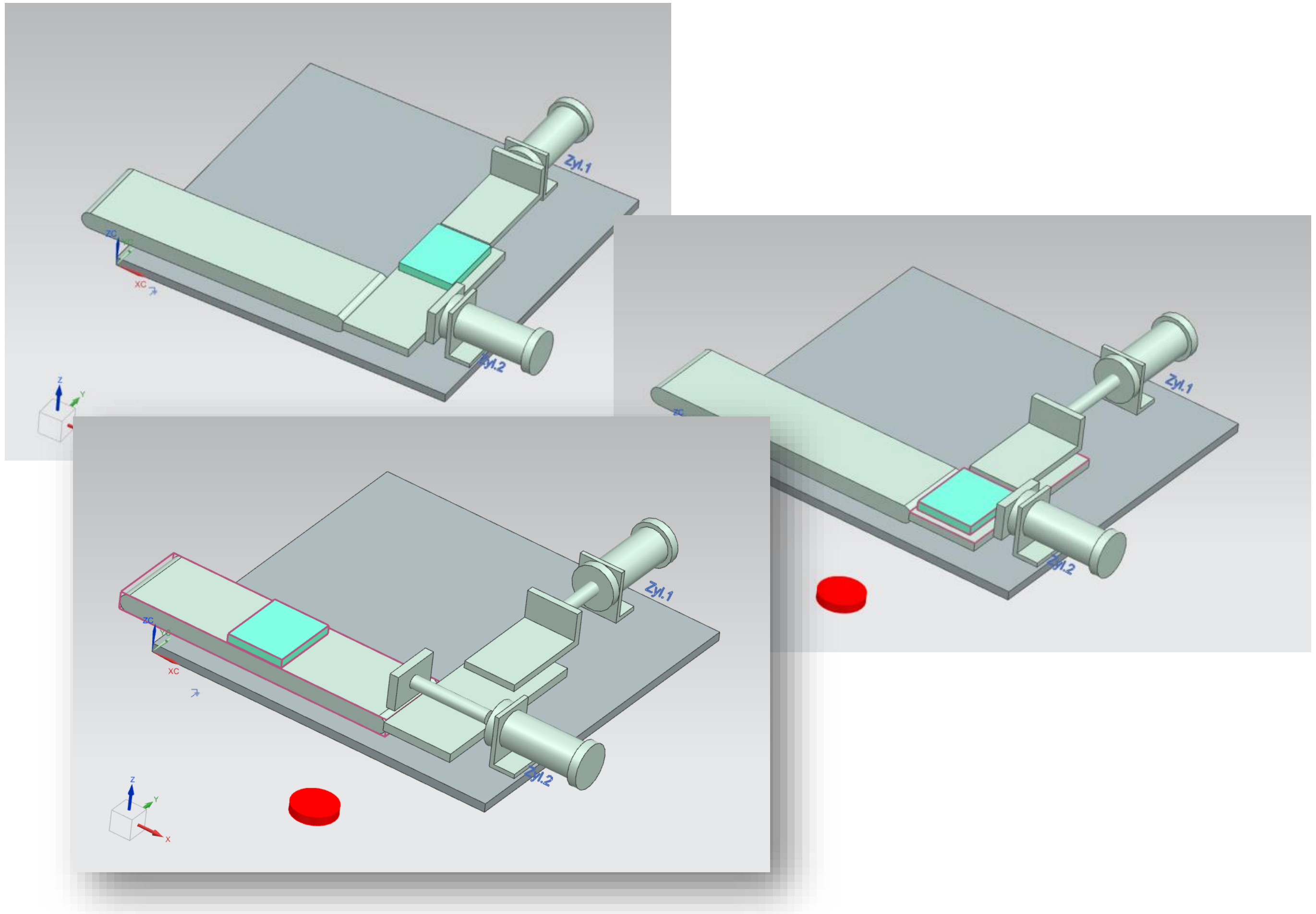

Digital pneumatic cylinders extend and transmit a force to the workpieces so that they reach the next conveyor belt. The cylinders can be integrated into PLC programming and controlled.

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Simulation & Testing

- Model = Static
- Simulation = Dynamic
- Grieves' Tests of Virtuality:
  - Visual, Performance, Reflectivity, Prediction

Advantages of Digital Twins

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- Real-time monitoring
- Predictive maintenance
- Fewer physical prototypes
- Better documentation & traceability

Challenges / Disadvantages

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- High costs
- Data integration complexity
- Cybersecurity risks
- Skills & training required

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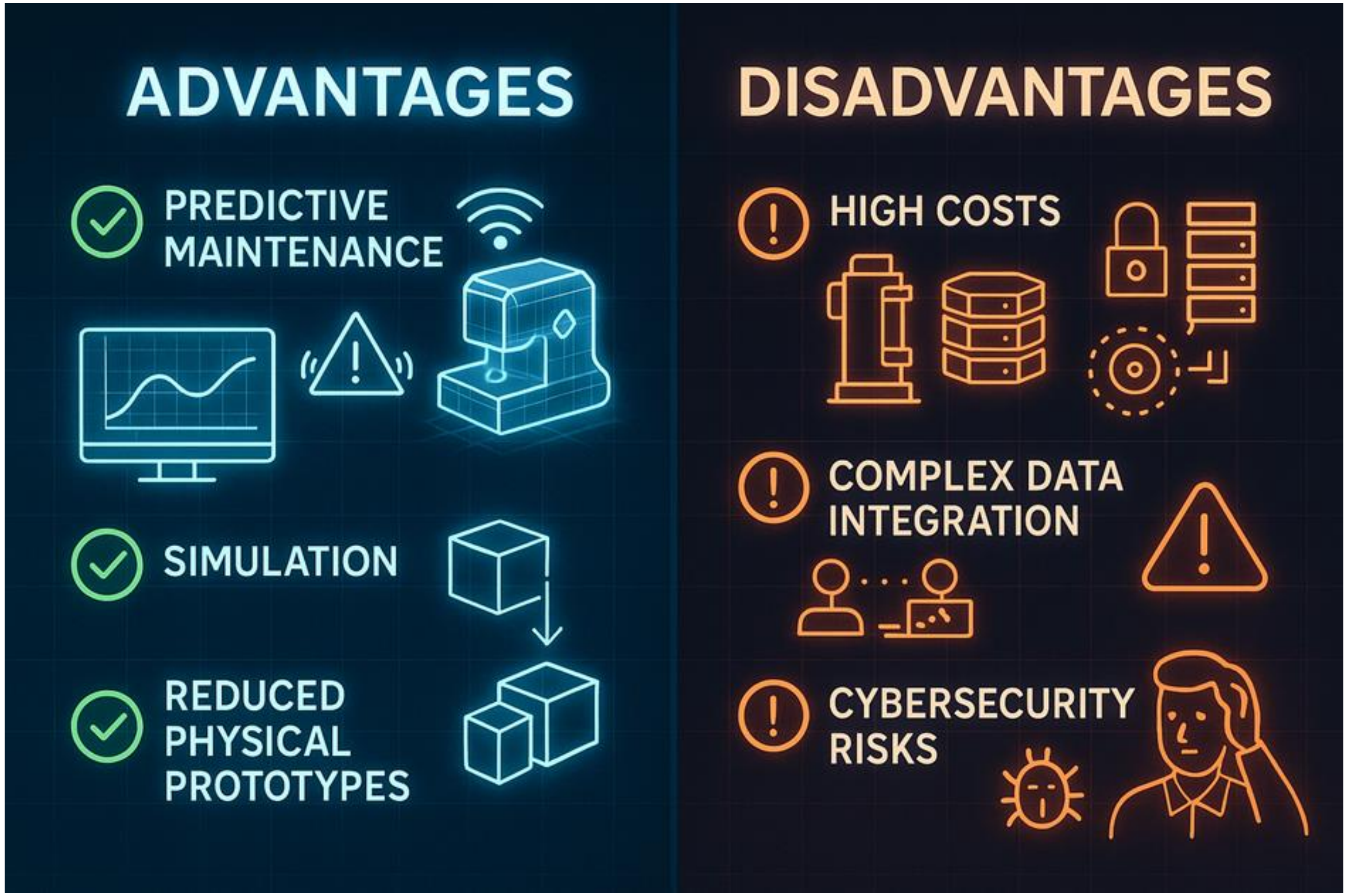
Challenges / Disadvantages



Digital Twins in Education

- Safe, repeatable learning environments
- Flipped & blended learning support
- Risk-free practice for students
- Challenges: cost, time, training

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Hardware & Software for Digital Twins

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- Hardware (Education):
  - Powerful PC (CPU, GPU, RAM, SSD)
  - VR/AR devices (Oculus Quest, HTC Vive, HoloLens)
- Hardware (Industry):
  - IoT sensors & edge computers
  - Servers & cloud platforms (Azure, AWS, MindSphere)
- Software:
  - **3D modeling:** Autodesk Inventor, Fusion 360, SolidWorks
  - **Simulation:** Ansys, COMSOL
  - **Data analysis & visualization:** Power BI, Python, MATLAB
  - **Interactivity & VR:** Unity, Unreal Engine

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The Future of Digital Twins

- Intelligent Twins (AI + simulation)
- Predictive “crystal ball” systems
- From reflection → proactivity
- Decision-making partner

Conclusion

- Digital Twins = bridge between concept & reality
- Useful across entire lifecycle
- Relevant for both industry & education
- From digital mirror → intelligent collaborator

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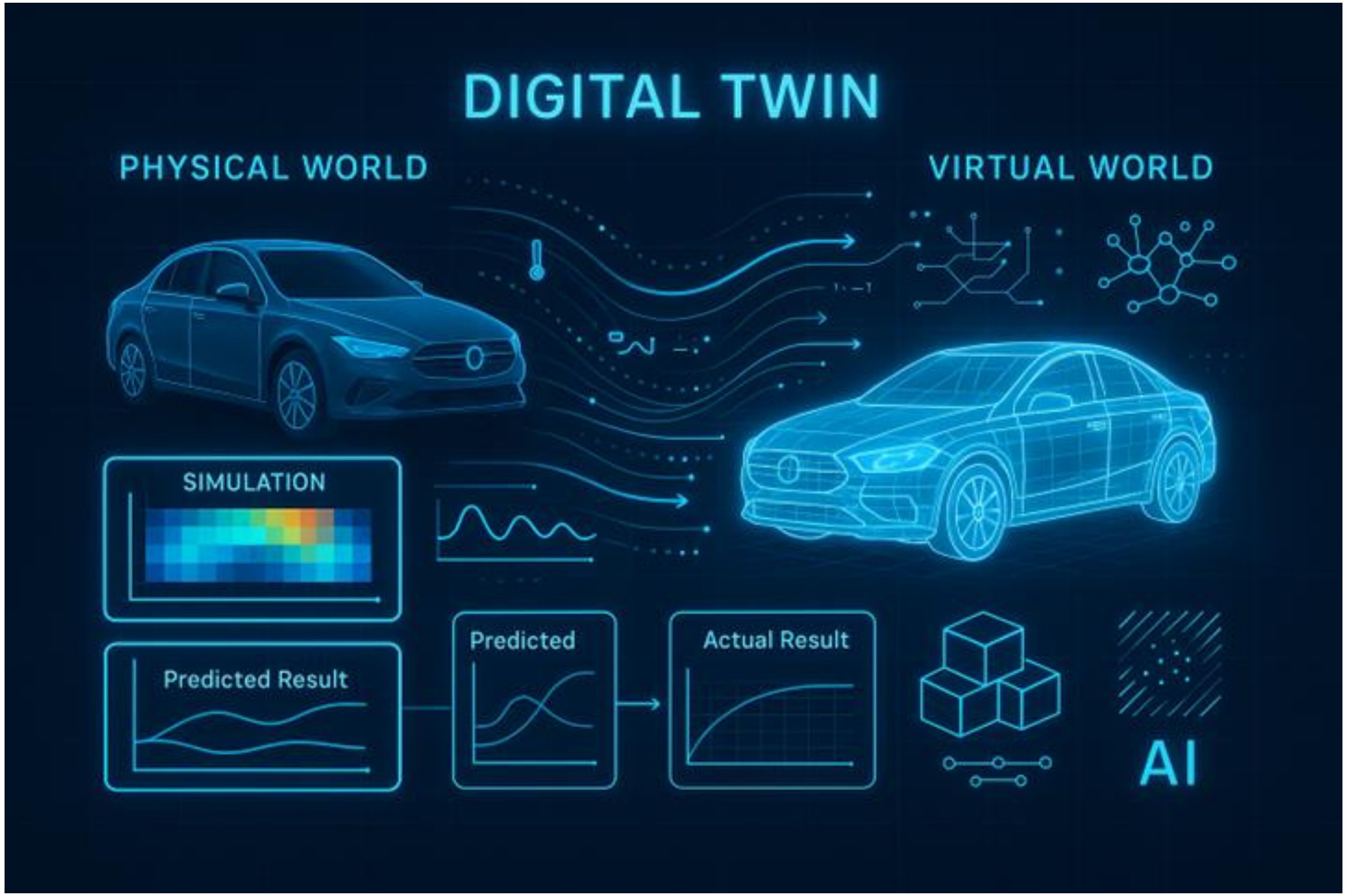
Conclusion



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