KENT STATE UNIVERSITY

Digital Twins in Construction:
Bridging Physical and Virtual Worlds in AEC

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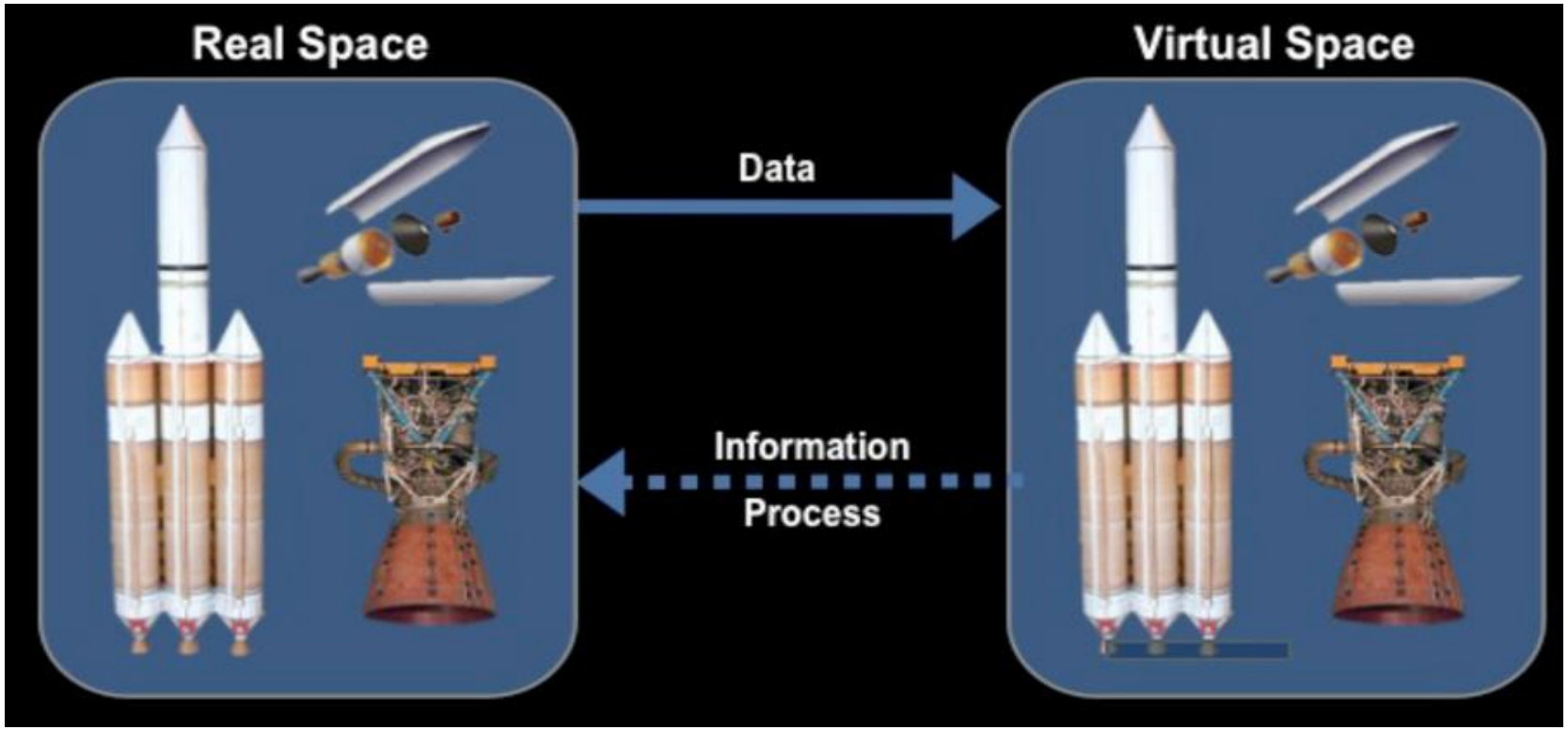
Learning Objectives

- Define Digital Twins
- Understand their applications in construction
- Analyze benefits, limitations, and future challenges

What is a Digital Twin?

- The first **digital twin**, although not labeled as such, came about at **NASA during the 1960s** as a means of modelling the **Apollo missions**
- NASA used simulators to evaluate the **failure of Apollo 13's oxygen tanks**



Apollo 13 Had a Digital Twin?

What is a Digital Twin?

- **Definition: A digital replica of physical assets, processes, or systems**
  - Digital Twin = Physical Asset + Digital Representation + Real-time Connection
- **Key elements: real-time data, integration, feedback loop**
- **Digital Twin ≠ 3D Model**
  - Must involve data flow, sensing, and actuation or insight generation

Digital Twins vs BIM

Feature	BIM	Digital Twin
Focus	Design & documentation	Lifecycle performance
Data	Static or updated manually	Real-time & dynamic
Use Cases	Coordination	Monitoring, simulation, control

Why We Need Digital Twins?

Why We Need Digital Twins? Bridge the Physical and Digital

✅ Enables real-time monitoring

✅ Simulates behavior under different scenarios

✅ Tracks wear, usage, and performance

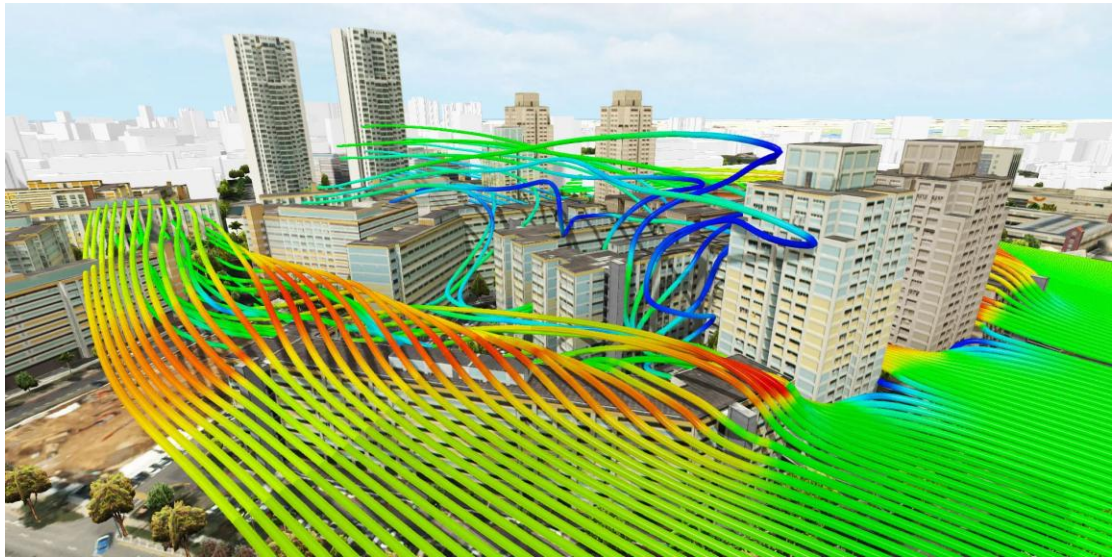
✅ Run "what-if" simulations without disrupting real systems

✅ A shared digital twin allows owners, architects, engineers, and contractors to see the same live model

Virtual Singapore – Singapore Digital Twin

- A 3D digital twin of the city-state, a dynamic model **incorporating real-time data** and enabling users to visualize and **simulate urban planning, infrastructure management, and disaster preparedness**

- Integrated with traffic, utilities, and planning



Virtual Singapore – Singapore Digital Twin

Digital Twin Use Cases in Construction

- Construction monitoring
- Progress tracking
- Predictive maintenance
- Safety simulations

How to Build A Digital Twin?

Step	Purpose	Tools/Tech	Example
1. **Capture Physical Reality**	Create geometry & spatial context	Laser Scanning, Drones, Photogrammetry	Point cloud of a bridge
2. **Develop a Semantic Model**	Translate to structured, editable format	BIM (Revit, ArchiCAD), GIS	IFC model of HVAC system
3. **Integrate Sensors & Data Streams**	Enable real-time data	IoT, PLCs, RFID, SCADA	Temperature, vibration, humidity
4. **Connect to a Central Platform**	Synchronize model & data	Unity Reflect, Azure Digital Twins, Autodesk Tandem	Unity scene with real-time updates
5. **Analyze, Simulate, Predict**	Extract insights, test scenarios	Machine Learning, FEA, CFD, Agent-based modeling	Predictive maintenance alerts

How to Build A Digital Twin?

Systems [Building/Machines/Infrastructure…]

↳ **LiDAR scan** → [Point Cloud]

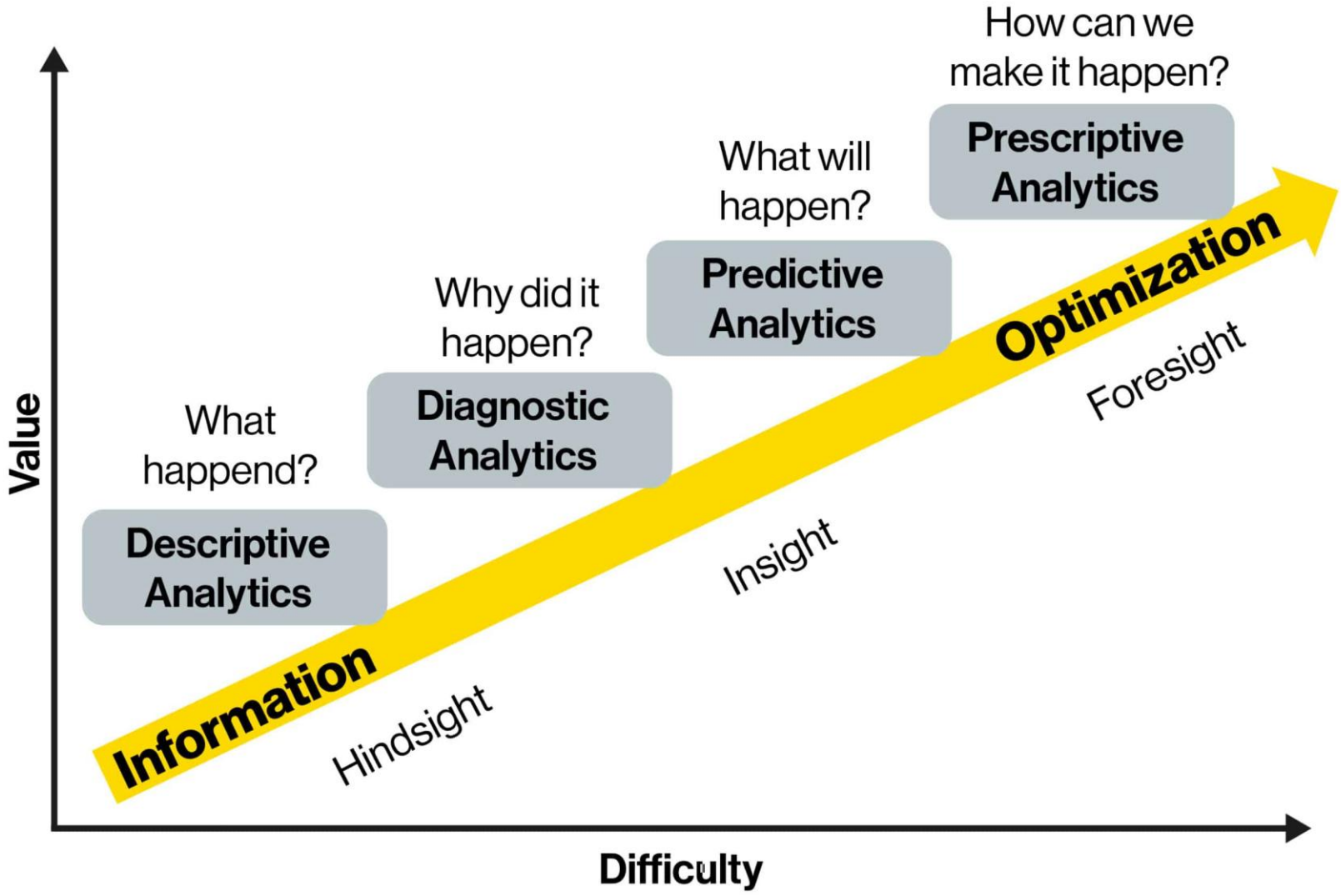
↳ **Revit/IFC BIM** → [Semantic 3D Model]

↳ **Raspberry Pi/IoT Sensors** → [Real-Time Data Stream]

↳ **Unity or Unreal Engine** → [Visualization & Interaction]

↳ **Python/MATLAB** → [Analytics & Simulation]

Common Data Analytical Types



Maturity Levels of Digital Twins in AEC

- **Descriptive** – 3D Model + Static Metadata
- **Informative** – Real-time sensor integration
- **Predictive** – Simulation & forecasting
- **Prescriptive** – Automated recommendations
- **Autonomous** – Self-optimizing, learning systems

Challenges and Ethical Implications

- Interoperability and data standards
- High cost of implementation
- Cybersecurity and data privacy

The Future Landscape

- **AI + Digital Twins = Smart decision-making**
- **Potential to revolutionize education, collaboration, sustainability**

Demo: Build Your First Digital Twin Prototype

- **Using Unity + sample BIM model + a CSV file simulating sensor data, visualize and update component states**
  - Add 2 clickable elements
  - Display data overlay
  - Trigger visual change (e.g., turn red if temperature > 80°F)
  - Export a walk-through video

Group Activity

- Design a Digital Twin for a University Building (CAED building)
- What data would you need? What insights could be generated?

Thank You!