Smart Cities:

Growth and Intelligent Transportation Systems

Kabir Kedia
Nolan Pitsenberger
Sri Bhamidipati
Vashishth Doshi

Digital Twins

and their application in Transportation Infrastructure.

Executive Summary

- Digital Twin - virtual representation of a physical entity or system
  - Enables real-time monitoring, analysis, and optimization.
- Bridges the physical and digital worlds
  - Uses data from sensors and simulations to create dynamic models
- Industries
  - Manufacturing
  - Healthcare
  - Transportation
    - Efficient planning, construction management, maintenance

Digital Twins are the power behind every smart factory.

- Microsoft Corporation

Digital twins are the key to operational excellence

- Oracle Corporation

One day, every human will have a digital twin at birth, which can be used to design bespoke treatments for that person when they become ill, as well as model the impact of lifestyle choices on his or her long-term health.

- General Electric

Origin

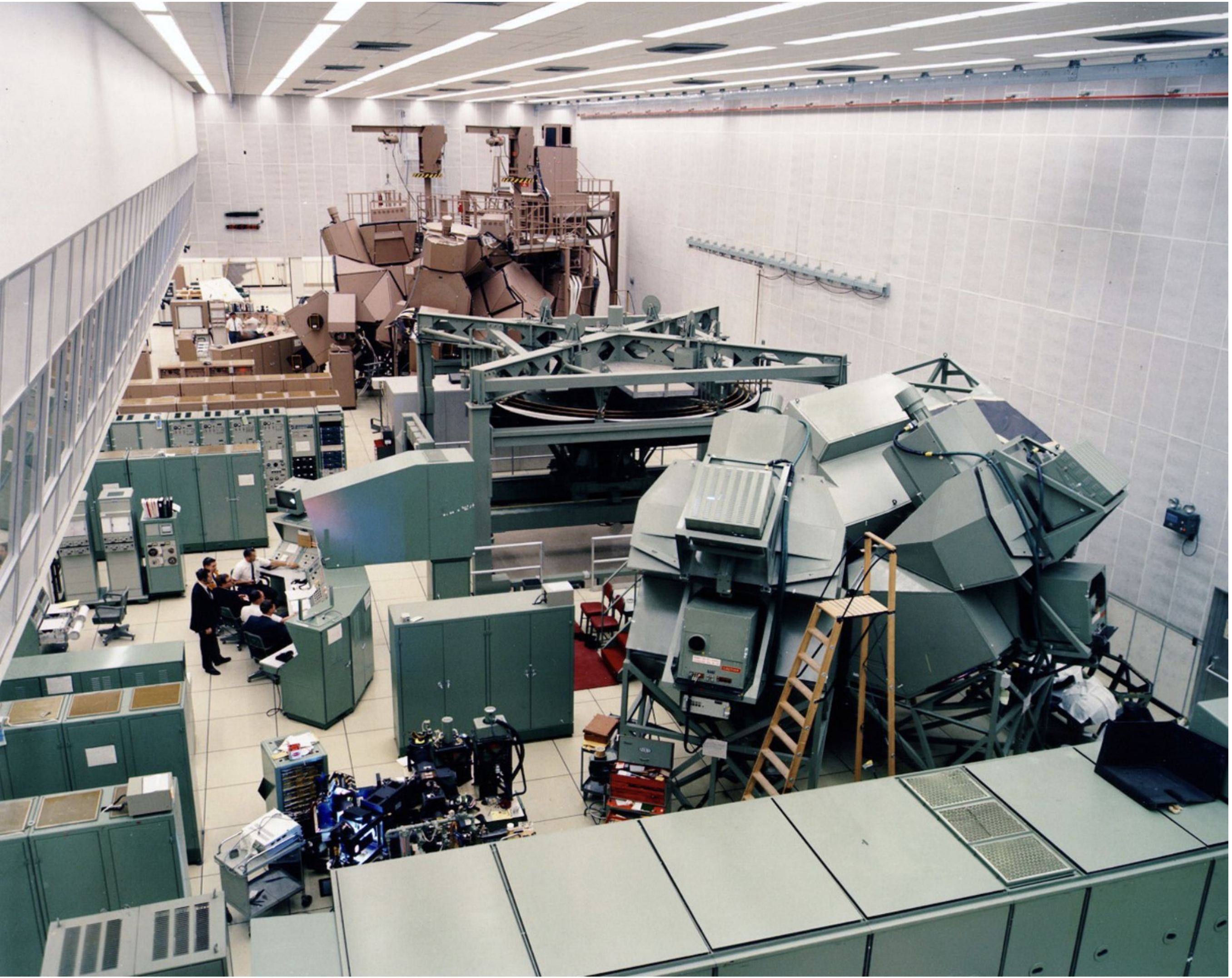
Digital Twins originated with NASA's space simulations of Apollo 13 in 1970s

Digital Twins and Apollo 13

- First digital twin brought to life by NASA in the 1960s
    - Simulators used to model the spacecraft and analyze potential failures

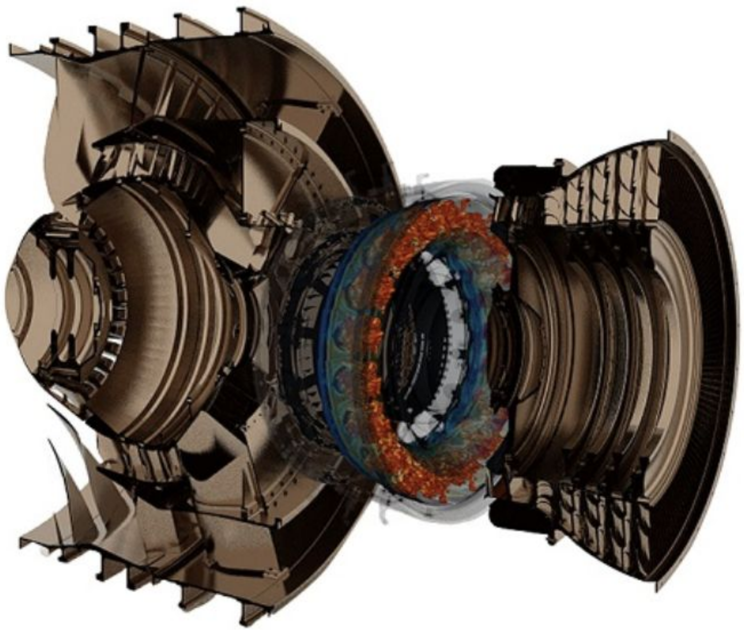
"The simulators were some of the most complex technology of the entire space program: the only real things in the simulation training were the crew, cockpit, and the mission control consoles, everything else was make-believe created by a bunch of computers, lots of formulas, and skilled technicians"

- Gene Kranz,
  NASA Chief Flight Director,
  Apollo 13



Apollo Simulators at Mission Control in Houston. The Lunar Module Simulator is in the foreground in green The Command Module Simulator is at the rear of the photo in brown

Evolution and Impact of Digital Twins



- **Aerospace:** General Electric monitors over 1.2 million jet engines, enhancing maintenance efficiency and extending engine lifespan.

- **Healthcare:** Siemens Healthcare creates digital organ twins to assist in surgical planning.

- **Urban Planning:** The Virtual Singapore project leverages a city-wide 3D model for optimized urban development.

- **Manufacturing:** Siemens reduces downtime by 30% with digital twin technology.

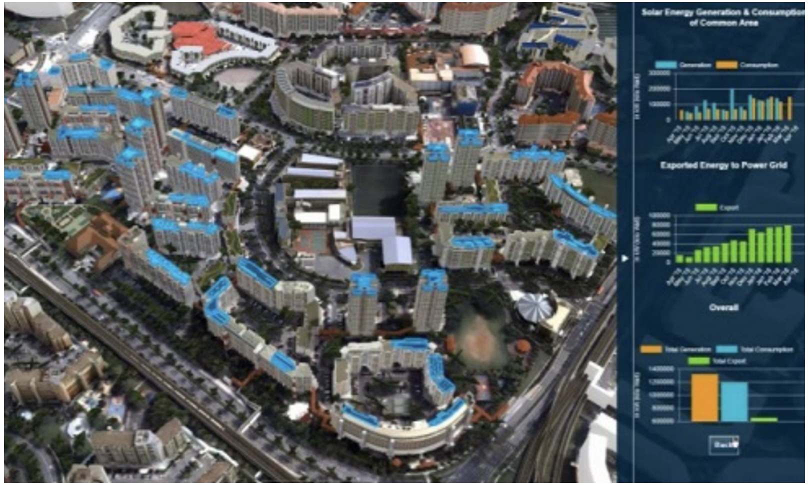
- **Automotive:** Tesla uses digital twins for vehicle diagnostics and software updates.

- **Shipping and Logistics:** The Port of Rotterdam employs digital twins to optimize shipping processes and minimize vessel waiting times.

Case Study: Virtual Singapore

Project Overview

- Virtual Singapore, launched in 2014 as a **$73 million collaboration** between **Singapore's National Research Foundation** and **Dassault Systèmes.**
- Cutting-edge digital twin platform - integrates **3D modeling, sensor data**, and LiDAR Data to form a real-time twin of the city.
- **Applications**
    - Urban planning
    - Resource management
    - Disaster response
    - Smart City initiatives



Energy analysis using Virtual Singapore's Digital Twin

Key Features

- **High-Fidelity 3D City Model:** Detailed, photo-realistic representation of buildings, terrain, and infrastructure, created using LiDAR and aerial photography.
- **Integration of Geospatial and IoT Data:** Geospatial, real-time sensor, and IoT data to enable big data analytics, and visualization.
- **Collaboration and Urban Development:** Collaboration among stakeholders to test urban development scenarios.
- **Advanced Simulation Capabilities:** Models urban phenomenon like heat distribution and flooding.

Impacts

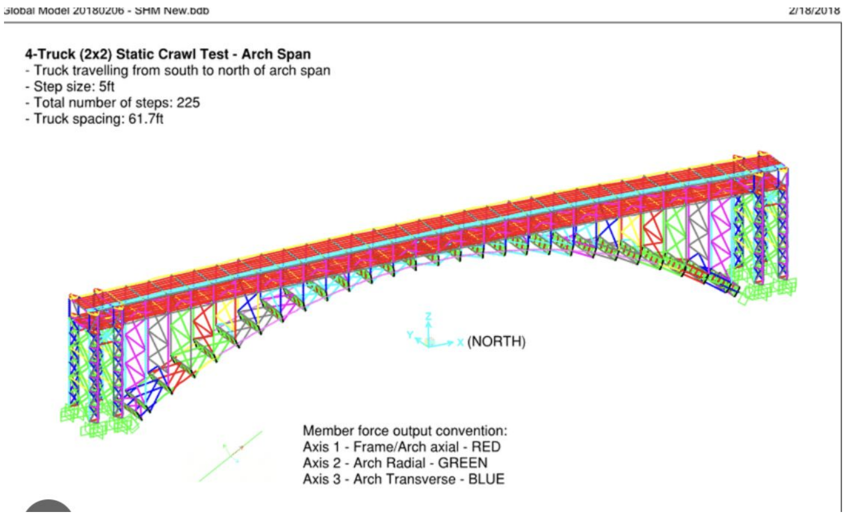
- **Urban Planning:** Optimizes city layouts, assessing development impacts, and improving transport planning
- **Sustainability and Environment:** Monitors environmental conditions and supporting climate resilience
- **Disaster Management:** Simulations and real-time risk monitoring
- **Economic Innovation:** Positions Singapore as a leader in smart city technology
- **Citizen Engagement:** Provides interactive urban data
- **Enhanced Decision-Making:** Detailed simulations and real-time data capabilities

Singapore's 3D Model open to the public for research

Case Study: The digital twin of bridges in Minnesota

Project Overview

- The **2007 failure** of the I-35W bridge – 14 deaths, 145 casualties prompting DOTs to rethink bridge inspection.
- The Minnesota Department of Transportation (MnDOT) started using **autonomous drones** equipped with **omnidirectional cameras** for GPS-independent bridge inspections.
- These drones produce **high-quality images** and **detailed 3D Digital Twins**, improving the accuracy of inspections.
- Digital replicas have the benefit of
  - Streamlining maintenance
  - Reducing timelines
  - Reducing monitoring costs



Digital twin of the arch of a bridge

Key Features

- **Comprehensive Bridge Inspections**: UAVs capture high-resolution images and videos along precise flight paths, ensuring consistent coverage.

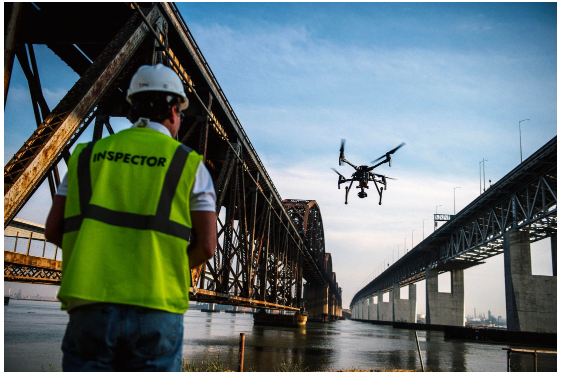
- **3D Digital Twin Creation**: Advanced photogrammetry technology (Acute 3Ds 2015) and ContextCapture software stitch images in real-time into a realistic 3D mesh.

- **Enhanced Data Integration**: Augmented LiDAR provides additional depth, supporting life cycle analysis and proactive maintenance planning.

Impacts

MnDOT Bridge Office reports benefits from incorporating drone inspections. Allows them to cultivate realistic digital twins of their different infrastructures, including:

- **Cost Efficiency**: Due to reduced labor and equipment needs
- **Improved Data Quality**: Superior imaging and analysis enable more precise asset management and decision-making
- **Enhanced Safety**: Minimizes on-site disruptions & protects inspectors by eliminating hazardous manual inspections and improves road safety for travelers
- **Taxpayer Savings**: Optimized processes result in significant cost savings for taxpayers
- **Reduced Traffic Disruptions**: Faster inspections and fewer lane closures minimize traffic delays, enhancing the experience for road users



Drone-based bridge inspection

Policy Applications

https://pollev.com/vd021

How would you use Pittsburgh's digital twin?

Policy Implementation Example with Cost/Benefit Analysis

- A cost-benefit analysis of digital twins - especially the case with UK's Department of Transportation - shows substantial long-term benefits.
- High initial costs for data collection, software, and training posed challenges, but they can be alleviated:
  - Phased implementation
  - Public-private partnerships or grants
  - Open-source solutions
- Long-term savings are estimated to be around Euro 850 million over 10 years.

A flyer for promoting digital twin by Middlesex University

So, why use digital twins in policy?

Policy Sandboxing

- You can **rehearse policy flows, timelines, constraints** before finalizing them
- **Tweak them according to learnings** from how these worked in the twin

Infrastructure Monitoring

- Saves public expenditure in monitoring infrastructure
- Multiple datasets – traffic, floods, thermodynamics of the bitumen together examined to **predict maintenance**

Policy Communications

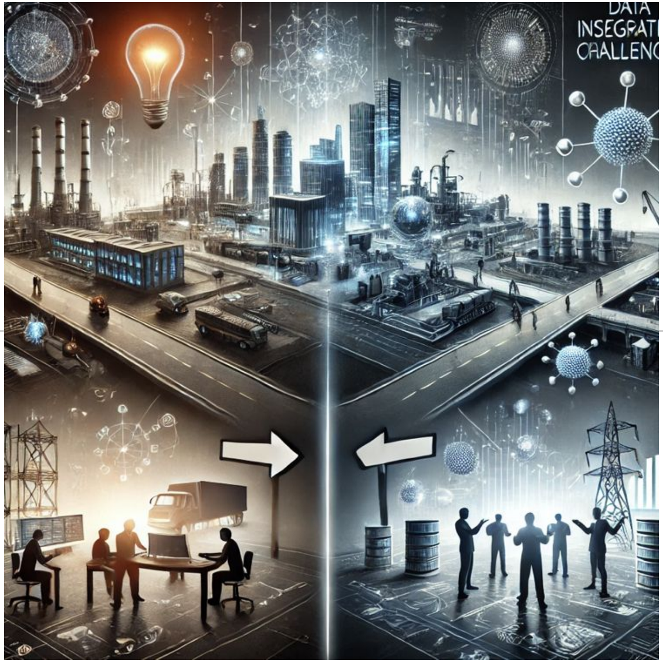
- As a policy leader or politician, I **can sell my policy better if I can show how my proposed changes work**
- Visualization of processes makes it explainable

Technical Replication

- The skeletons of the twins – their **design, data interactions is replicable** to most urban contexts

Democratization

- Digital twins can be **participative platforms** and accommodate the laymen's curiosity about their city
- **Understand and interact with your city** visually without the expertise



Limitations

Some challenges to be dealt with

Data Accuracy

Ensuring consistent and up-to-date data from various sources is crucial but challenging. This includes regulatory compliance issues, particularly regarding data usage and drone operations.

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Privacy and Security

Protecting sensitive infrastructure data is a significant concern.

High Initial Cost

The upfront investment in technology and training can be substantial, particularly for smaller organizations.

Technical Expertise

Operating and maintaining digital twin systems requires specialized skills, which may not be readily available within organizations

Scalability

As organizations grow and supply chains become more complex, ensuring the scalability of digital twin solutions can be challenging

Integration Challenges

Aligning new digital solutions with existing IT infrastructure and operational workflows can be complex and may lead to operational disruptions

Future directions, food for thought

Data Related Challenges

- Data **availability**
- Data **standardization** for simultaneous functionality
- Data **privacy and safety**

➔ **Improve data standards, quality** and availability
➔ **Comprehensive cybersecurity –** already happening

How do we address these issues?

Technical Challenges

- **Interoperability** of different data systems
- High **initial cost**
- **Computational limitations**

➔ **Enhance computational power –** already happening for AI

General Limitations

- **No regulatory framework**
- Maintenance and Updating
- **Stakeholder collaborations**

➔ **Stakeholder driven frameworks** for data, policy and technology – always useful

Thankyou!

Any questions ?

"I will now open the floor to questions. Bye bye!"