Digitally Connected World

1995
Dawn of Information Society

2000
Development of Information Society

2015
4th Industrial Revolution IoT/Edge

2025...
Digitally Connected World
The Active Data Era

Hyper-connected
73.1 Zettabytes
of data will be generated from connected IoT devices by 2025.¹

Hyper-distributed
75% of data
will be created and processed outside a traditional centralized data center or cloud by 2025.²

Hyper-speed
1.8B 5G
worldwide connections, with top speeds up to 20 gigabits-per second, will be achieved by 2025.³

- 100x Lower power consumption by 2030.⁴
- 125x Higher Transmission Capacity by 2030⁴
- 200x Lower end-to-end latency by 2030⁴

¹. IDC, IoT Growth Demands Rethink of Long-Term Storage Strategies, 2020
². Gartner Predicts the Future of Cloud and Edge Infrastructure, 2021
³. GSMA, The Mobile Economy 2021, 2021
⁴. IOWN Global Forum 2020

Courtesy – Dell Technologies
Innovating with Digital Twins to Optimize Car Performance

>300 sensors

13,000 pieces of information

• Reduce F1 car build times from 48 months to less than 12
• Developed the P1 Hypercar in **half the time and half the cost** of industry standards (60 to 24 months; ~$1B to <$500M)
• Leverage data from the track for analysis to make in-race decisions on car setup and race strategy

The faster we get data, the faster we can design and engineer components. As a result, we can deliver changes trackside, optimize the cars and ensure we get the best racing results.

Edward Green
Principal Digital Architect, McLaren Racing
Emerging IoT Technologies Radar 2022

Digital Twin Adoption is Accelerating

- Aerospace
- Transportation
- Automotive
- Construction
- FinTech

- Energy
- Manufacturing
- Healthcare
- Pharmaceuticals
- Security
Foundation: Digital Twin Definition

A digital twin is a virtual representation of real-world entities and processes, synchronized at a specified frequency and fidelity.
Model and Simulate

The Tesla Model Y Digital Twins for benchmarking and cost reduction strategies. - Bing video
The digital twin is composed of three components i.e. physical entities in the real world, their virtual models and the connected data/view that tie the two worlds.
Advanced Digital Twins: Physics Simulation and Virtual Sensors

Source: Digital Twin 101 - digitalplaybook.org (aiotplaybook.org)
SMART FACTORY 4.0

Production Optimization in Harsh Environments with Low Latency, High Fidelity Use Cases
Digital Twin for Quality Control

Ability to detect product quality issues
- Understanding the process variables
- Understanding hardware and software interaction with process performance

Machine Learning application: Kernel Density Estimation (KDE)

Patented beam pattern generation

High speed thermography analysis. Process Max fault detection: 3s
“Only with a digital twin in place, can government agencies effectively analyze what can be done with the data and improve citizen living, create economic opportunity and revitalize a closer community,” Thomas Pramotedham, CEO of Esri Singapore
Digital Twin for Infrastructure Structural Integrity - Bridges

1. **DAQ**
   - Data is extracted from accelerometers and/or inclinometers located at the bridge beam.
   - The objective is to record impulses created by normal traffic over the bridge.

2. **Bridge Model Estimation**
   - Once impulses are detected a proprietary online model estimation algorithm is applied.
   - Natural frequency and damping factor values are estimated as the best dynamic description of the bridge.
   - This dynamic description is the first step of the bridge digital twin.

3. **Bridge Digital Twin**
   - Bridge Digital Twin is created using clustering techniques.
   - This digital twin should include the bridge normal behavior during specific time span, i.e., week, month, year.

4. **Bridge Health Monitoring**
   - Once digital twin is built, it can be compared to new data to see if the bridge has changed its response over time.
   - The comparison is done online producing a unique KPI that could be analyzed:
     - By its value.
     - By its trend.

5. **Bridge Health Analysis**
   - PoC done in three bridges located in the U.S.A.
   - Detection of outliers.
     - That could be correlated to abnormal traffic.
   - Trend analysis.
     - That could provide bridge degradation information.
     - High sensitivity: it can correlate weather effect on the structure.
Nov 2019 vs May 2020

~184hrs of preventable borer downtime identified worth ~44k product tonnes
$4m PdM - Underground Long Conveyor

**Challenge**
Reduce long conveyor (underground) downtime by 30%

**Solution**
XMPro monitor 52 (80+km) conveyors and predict fluid coupling and lagging failures

**Benefits**
~184hrs of preventable borer downtime identified worth ~44k product tonnes

---

**Measures of Success**

**Time to value** - 30 days to deploy initial release
- Integration with OSIsoft Historian and Oracle EAM
- Complex Engineering models
- Predictive analytics executed at 2 sec intervals
- 30% reduction in conveyor downtime due to fluid coupling failures add $+4m in revenue

**Always On, Situational Awareness**
- 52 long conveyors in series
- Monitored and analyzed every 2 seconds
- Real-time dashboards with notifications
- Drill-down for decision-support and automation

**Expert Knowledge Capture**
- XMPro Recommendations capture expert knowledge on maintenance best practices
- Replaced ad-hoc BI style Excel (.xls) analysis with continuous analysis and notifications for reliability engineers to prescribe appropriate actions
- Recommended actions incorporated into predictive/prescriptive maintenance processes

---

CUSTOMER STORY - Mining

Conveyors ➔ Borers ➔ Crushers ➔ Management OEE ➔ Pumps ➔ Fans
End to End Visibility and Control Over the Entire Supply Chain

**Source:** Can a supply chain digital twin make you twice as agile? | EY - US

---

**Characteristics**

- Functional E2E ecosystem visibility and synchronous collaboration
- Clear reporting and analytics
- Balance cost optimization, risk mitigation, and growth

**E2E Visibility & control tower**

- Integrated end-to-end visibility with cross-functional real-time dashboards
- Synchronized parameter setting and optimization
- Early warning system with clearly defined alerts
- Respond to global shocks and shifting customer demands

**End to end digital twin**

- Design flexible, cost effective, and resilient supply chain ecosystems
- Prescriptive recommendations based on AI
- Scenario capabilities spanning the entire supply chain
- Integrated optimization tools to optimize key supply chain parameters in real-time

**Digitally enabled & autonomous**

- Self healing master data and planning parameters
- Digital twin orchestration of supply chain with continuous planning
- Enterprise level digital twin

---

**Linear supply chain**

**Networked ecosystem**

---

Source: Can a supply chain digital twin make you twice as agile? | EY - US
Digital Twin for Efficiencies in Business Operations

Customer Experience

Information Systems

The internet of things (IoT)

Ecosystems

Data and Analytics

Digital Twin of Organization

© 2020 – Thynkli Enterprises Inc.
The market for digital twin software and services is expected to reach global revenue of $183 billion by 2031, up from $9 billion in 2021.

Source: Gartner Dec 2021, Digital Twin Revenue Opportunity Projection (adapted)
Our Family

- OMG
- digital twin
- AREA
- OMG Standards Development Organization
- Industry IoT Consortium
- Responsible Computing
- BPM+ Health
- CISQ
Digital Twin Consortium Steering Committee

[Logos of various companies]
## Consortium Focus

### Improving Interoperability
- We are ensuring digital twin models interoperate throughout your product lifecycle
- We are influencing the requirements for digital twin standards
- We are developing best practices for security, privacy and trustworthiness
- We are creating a library of reference implementations for digital twins
- We are providing frameworks to better work across the digital twin technology stack

### Accelerating the Market
- Our members are benefiting from a neutral ecosystem to drive industry collaboration
- We are helping our members to combine their resources, therefore reducing their risks
- We are learning from shared use cases
- We are reducing the skills gap and involving employees from various departments in the proper consortium group
- We are influencing the solution roadmaps for digital twin vendors
- We provide access to the world’s leading experts throughout your digital twin journey

### Demonstrating the Value
- We are fostering the development of a collaborative environment for open-source code
- We are enabling our members to learn from experts
- We developing use cases and applying them to your industry
- We are accelerating your project investment
- We are working to help you maximize quantifiable outcomes
- We are helping to influence the direction of the market and get your project online faster
Standards and best practices

• DTC is not a standards body, however we are part of the OMG umbrella
• We work to align with standards bodies to evolve existing standards
• These collaborations provide recommendations for interoperability and standards requirements
  • Joint DTC-IIC Interoperability Working Group
  • Open-Source, Standards Requirements, and Platform Stack
Structure
Working Groups

Academia & Research
- Develop digital twin program
- Accelerator program
- POC, Pilot Programs
- Educational collateral

Aerospace & Defense
- Assets – Land, Sea, Air
- Dev Sec Ops
- EOL Extension
- Logistics / Management
- Supply Chain and Value Chain

Architecture, Engineering, Construction & Operations (AECO)
- Smart buildings to Cities
- Greenfield to Brownfield
- Lifecycle - BIM to Twin
- Operations / Maintenance

Agriculture, Food & Beverage
- Agriculture (field to fork)
- Aquaculture (ocean to plate)
- Supply chains,
- Value chains
- Harvest to Process - Delivery

FinTech
- Transactions
- Governance
- Compliance
- Risk Tolerance
- Risk Management
- Access control

Healthcare & Life Sciences
- Predictive and Preventative
- Healthcare management
- Medical devices
- Patient journey
- Pharmaceuticals

Manufacturing
- Manufacturing equipment
- Industrial Automation
- Additive Manufacturing
- Product development
- Supply chain

Mobility & Transport
- Transport - Autonomous Vehicles / Systems
- Operation / Management Vehicles, People
- Infrastructure, Corridors
- Airports, seaports, Rail/Trucking
- Supply chain Operations

Natural Resources
- Oil & gas
- Mining
- Alternative Energy
- Renewables
- Waste Management
- Environmental Impact

Capabilities and Technology
- Terminology / Taxonomy
- Technology (Horizontal)
- Security & Trustworthiness
- Frameworks,
- Full Stack Platform
- Ref architecture

Initial Working Groups at DTC Launch
Cross-Collaboration

Member Directed

- Innovative
- Collaborative
- Demonstrative
# Capabilities & Technology Working Group

<table>
<thead>
<tr>
<th>Categories</th>
<th>Capabilities</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital Twin Maturity &amp; Assessment</td>
<td>Security &amp; Trustworthy</td>
<td>Environmental, Societal, Governance</td>
</tr>
<tr>
<td>Composable Framework</td>
<td>Reliability</td>
<td>Sustainability</td>
</tr>
<tr>
<td>Digital Twin System Reference Architecture &amp; Open Source</td>
<td>Safety</td>
<td>Circular Economy</td>
</tr>
<tr>
<td>Technology Spotlight</td>
<td>Resiliency</td>
<td>Reusable</td>
</tr>
<tr>
<td>Technology Showcase</td>
<td>Interoperability</td>
<td>Scalable</td>
</tr>
<tr>
<td>Value Innovation Platform</td>
<td>Privacy</td>
<td>Repeatable</td>
</tr>
</tbody>
</table>
Capabilities Periodic Table

An innovative framework for delivering digital twin projects based on use case capabilities

- Architecture and technology agnostic requirements definition framework.
- Aimed at organizations who want to design, develop, deploy and operate digital twins based on use case capability requirements (versus the features of technology solutions).

Composable Framework:
- Provides a foundation for an emerging marketplace
- Enables development teams to collaborate, design, and build
- Accelerates digital twin adoption
Frameworks

Business Maturity Model

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategy &amp; Ambition</td>
<td>Strategic vision, digital ambition, strategic planning and alignment.</td>
</tr>
<tr>
<td>Leadership</td>
<td>Style and skills to lead the organizational transformation.</td>
</tr>
<tr>
<td>Culture, Change &amp; Capability</td>
<td>Openness, innovation, collaboration, change resistance and management and digital capabilities and skills.</td>
</tr>
<tr>
<td>Operating Model &amp; Process Standardization</td>
<td>Processes description, operating model agility and how decisions are made.</td>
</tr>
<tr>
<td>Digital Twin Technology</td>
<td>Models, external data sources, intelligent services and digital thread.</td>
</tr>
</tbody>
</table>

Composable Capability Table

Periodic Table  Excel Toolkit  User Guide

Technology

Technology Spotlight

The Digital Twin Consortium's Technology Spotlight Initiative provides members with the opportunity to present their thought leadership and work going on with Digital Twins to the rest of the Membership. Your presentation will be recorded and made available to all Members.

Reference Library – Use Cases and Case Studies

Technology Showcase – Initial Use Cases in Progress

- Healthcare & Life Sciences
- Manufacturing
- Mobility
- Natural Resources
- Financial Technology
- Infrastructure
- Business Process
- Smart City
- Emergency Services
- Information Security
Opportunities for Collaboration

Working Group Deliverables include but are not limited to:

- White Papers
- Tech Briefs
- Webinars
- Frameworks
- Industry Round Tables
- Use Cases / Case Studies
Welcome to the digital twin industry's definitive use case reference library

The Technology Showcase is a living journal that chronicles the evolution of digital twins. Here, you
Technology Showcase – Use Cases in Progress

**Healthcare & Life Science**
- Long-haul COVID Management
- Bio-mimicry in Life Science
- Senior Living / Nursing Facilitation

**Infrastructure**
- Buildings as Batteries
- Health assurance Buildings
- Emergency Services

**Natural Resources**
- Water Management
- Carbon Sequestration
- Windfarm Operations

**Manufacturing**
- Industrial Automation
- AI Realtime Quality Control
- Supply Chain Composability

**Mobility**
- Intelligent Transport
- Smart Corridors
- Fleet Charging Stations

**Financial Technology**
- Financial transactions
- Operational Resiliency
- Carbon Credit Futures
OBJECTIVE

To develop and provide an energy infrastructure to enable rural and campus communities to achieve energy security and meet renewable energy goals.

VALUE

- Operational Resiliency
- Optimized Energy Consumption
- Economic Opportunity

DIGITAL TWIN ROLE

- Performs autonomous monitoring and analysis
- Enables efficient load balancing and storage
- Provides prioritized real-time optimization of energy consumption

An innovative approach to digital twins that enables decentralization of power grids at unprecedented speed and scale.

This use case provides optimization of the power, thermal, and related aspects for campuses and buildings. Through decentralization, the distribution of energy can be performed at scale. This allows unparalleled energy redistribution speeds and enables the solution to scale up to cities and states.

DOWNLOAD THE TECHNICAL SUMMARY

The solution provides templates for enabling mass customization at scale, allowing for continuous improvement based
Ecosystem Expansion
Accelerator Program

Companies Involved

- GeoPlasma Research Institute
  - Bruce Leyborne MSc, Senior Geophysics Technician
  - David Johnson BSEE, Applied Geomagnetic Methodology
  - GeoPlasma Research Institute
  - DTC 2022

Objectives & Values

- Objective: Integral step for interdisciplinary space weather & geophysics-based environmental impact predictive methodology
- Value:
  - Bottom-up approach to develop planetary weather and related environmental impact predictive forecasting
  - Digital Twin Role
    - Support development of real-world monitoring, simulation, and for improved forecasting of existing deployed solutions

Challenges

- Geophysical Monitoring New Madrid Seismic Zone
  - Objective: New interdisciplinary space weather forecasting technology
  - From multiple satellite solar/earth monitoring systems using Geophysical Intelligence
  - Combines monitoring e.m. activity in the: i. ionosphere ii. earth iii. power grids
  - Applies "Stellar Transformer" an innovative e.m. tectonic model accounting for internal induction effects from space weather interaction
  - Built on an innovative electro-dynamic model of the solar system

Use Case Overview

- GeoPlasma Research Institute
  - Digital Twins provides a pathway to Forecast Extreme Events

Solution Proposal

- Stellar Transformer Electro-Magnetic Monitoring
  - Requested Material Support
  - Hardware
    - Real time Synchronizers
    - Routers, Collectors, Conditioners
    - Connectors and cables
    - Compute data analytics interface w/ VR labs
  - Software
    - On-premise – data capture on site
      - A/D converter for data synchronization and conversion (physical to digital)
    - Virtualization and visualization equipment

Request

- Project Overview:
  - Geophysical monitoring station – GeoPlasma Research Institute
  - Business Development - Stellar Transformer Technologies

- Challenges to the Project:
  - Create a new interdisciplinary space weather forecasting technology
  - From multiple satellite solar/earth monitoring systems using Geophysical Intelligence
  - Combines monitoring e.m. activity in the: i. ionosphere ii. earth iii. power grids
  - Applies "Stellar Transformer" an innovative e.m. tectonic model accounting for internal induction effects from space weather interaction
  - Built on an innovative electro-dynamic model of the solar system

- Project Highlights: Challenges & Solutions
  - Geophysical monitoring - integral step
  - Combine digital data stream analytics
  - Synthesize with public domain data
  - Apply innovative e.m. tectonic model
  - Develop forecasting algorithms
Open-source Collaboration Community

GitHub projects and contribution:

Accelerates the adoption of enabling technology and techniques

- Contributions may include:
  - Open-source code implementations,
  - Collaborative documents for guidance and training,
  - Open-source models,
  - Other assets that are of value to the digital twin community.

- Initial entries include high-profile and high-impact projects.
Global Coverage with Regional Branch Organizers

Active:

- Canada
- Chile
- UK
- Spain
- France
- Netherlands
- Italy
- Germany
- Korea
- Australia/New Zealand
• Establish Digital Twin program(s) for Academia and Universities
  • Initial focus: Intro level - University coursework
  • Spans Introductory to advanced levels
  • Future potential for developing an entire curriculum

• Develop Digital Twin educational programs through global outreach
  • Work with founders and members to identify existing areas of interest and related opportunities
  • Partner with DTC Regional Branch Organizers and Liaison organizations
  • Establish an Educational Accelerator program

• Develop Digital Twin Research & Proof of Concept / Pilot Programs
  • Utilize Educational Accelerator program contributions/contributors related resources for project joint development
  • Publish promote results - thought leadership papers, blogs, webinars, articles, ...
  • Future - establish a “Digital Twin Solution Architect” training and certification program
Liaisons – global collaboration

American Institute of Aeronautics & Astronautics
AloT User Group
Augmented Reality for Enterprise Alliance
buildingSMART International
The Smart Manufacturing Institute

Centre for Spatial Data Infrastructures and Land Administration
Continental Automated Buildings Association
Coalition for Smarter Buildings
The FIWARE Foundation
Global Mining Guidelines Group
Global Transaction Center

International Building Performance & Data Initiative
Industry IoT Consortium
Industrial Digital Twin Association
LINUX Foundation – LF Edge/EdgeX Foundry
LINUX Foundation – Public Health

Manufacturing x Digital
National Institute of Building Sciences BIM Council
Project Haystack
Royal Institution of Chartered Surveyors
Smart Cities Council
Smart Water Networks Forum
Evolution
Digital Twin Evolution

Information Evolution

Physical to Virtual Maturity

0 Traditional
1 Transitional
2 Ad Hoc
3 DT Platform
4 IDT Platform

Front Running Simulation FRS

© Michael W. Grieves, LLC 2003-2022
Thank You!