GLOBAL PRODUCT DATA INTEROPERABILITY SUMMIT 2022

Analysis Digital Twin

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Presenters Bio

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Marcus Richardson is an Interoperability Standards Analysis and Simulation engineer for The Boeing Company. In this role he develops and evaluates standards for physics modeling and scientific analysis. Prior to this role he was developing thermodynamic / fluid modeling libraries and pathfinders for the preliminary design of aircraft and developing lab test verification methods and fixtures.

Abstract

Digital twins require particularization to ensure their usefulness. One particularization, the analysis digital twin, offers access to digital knowledge of the behavior of a product or system. It answers questions that product developers have regarding the actual performance of their designs and has potential to aid customers and users with an advanced, simulator-like experience to enhance their learning and familiarity with the expected behavior of the product. Lack of maturity in the analysis standards may lead to a finicky analysis digital twins that cannot be debugged without the original authoring software and model developers. This presentation presents a mental model for an analysis digital twin that outlines the critical model interfaces for analysis standards, which standards would apply the best and what gaps exist relevant to the use case of the mental model. The mental model is based on an actual aircraft problem, which, due to the large time scales of the operational and maintenance problems, lends itself very well to simulation the aircraft data to tune that simulation – creating a digital twin. The presentation will propose concepts that need to be developed further into standards to make such a digital twin, a robust and trainable simulation model, a reality.

Presentation Objective

The concept of a digital twin has become commonplace in the aerospace industry. It offers the hope of creating value from seemingly insignificant data by enabling prediction and optimization of the performance of a product or process.

This presentation seeks to:

- **Spur interest in a more detailed discussion of DTws, getting it closer to an implementable level**
- **Connect DTw business problems with DTw architecture**

The General Challenge – Design, Operations and Maintenance

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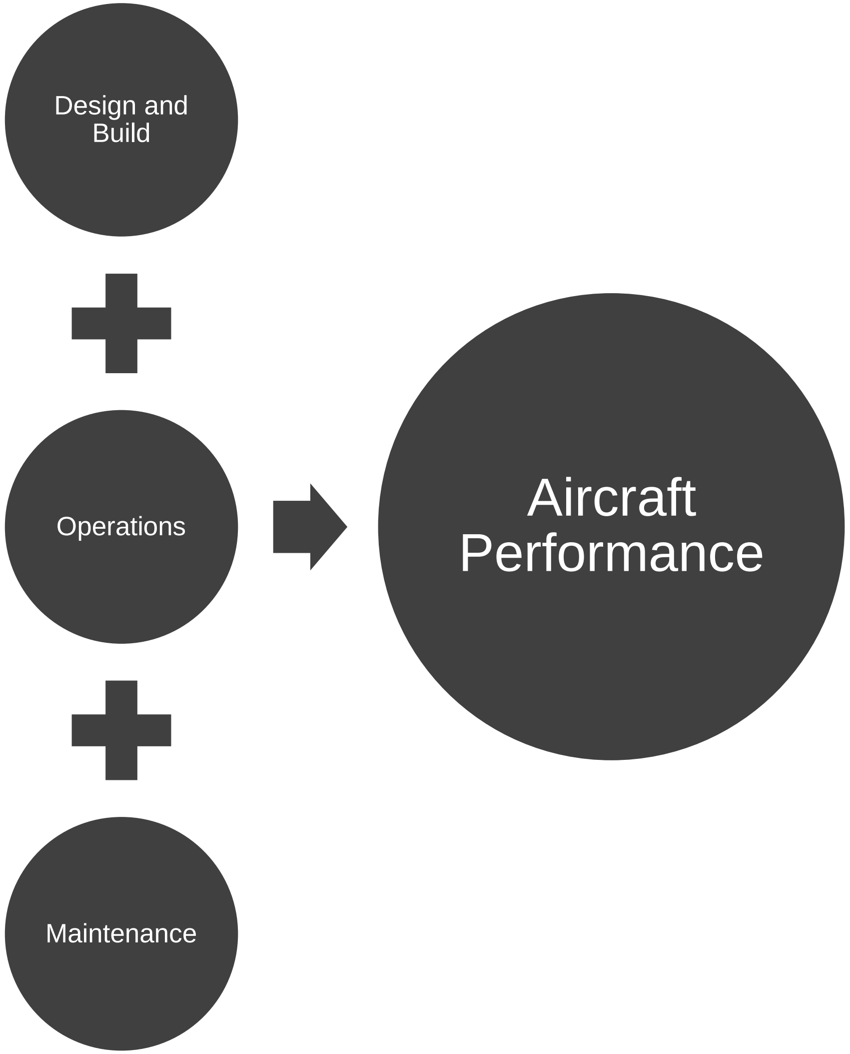
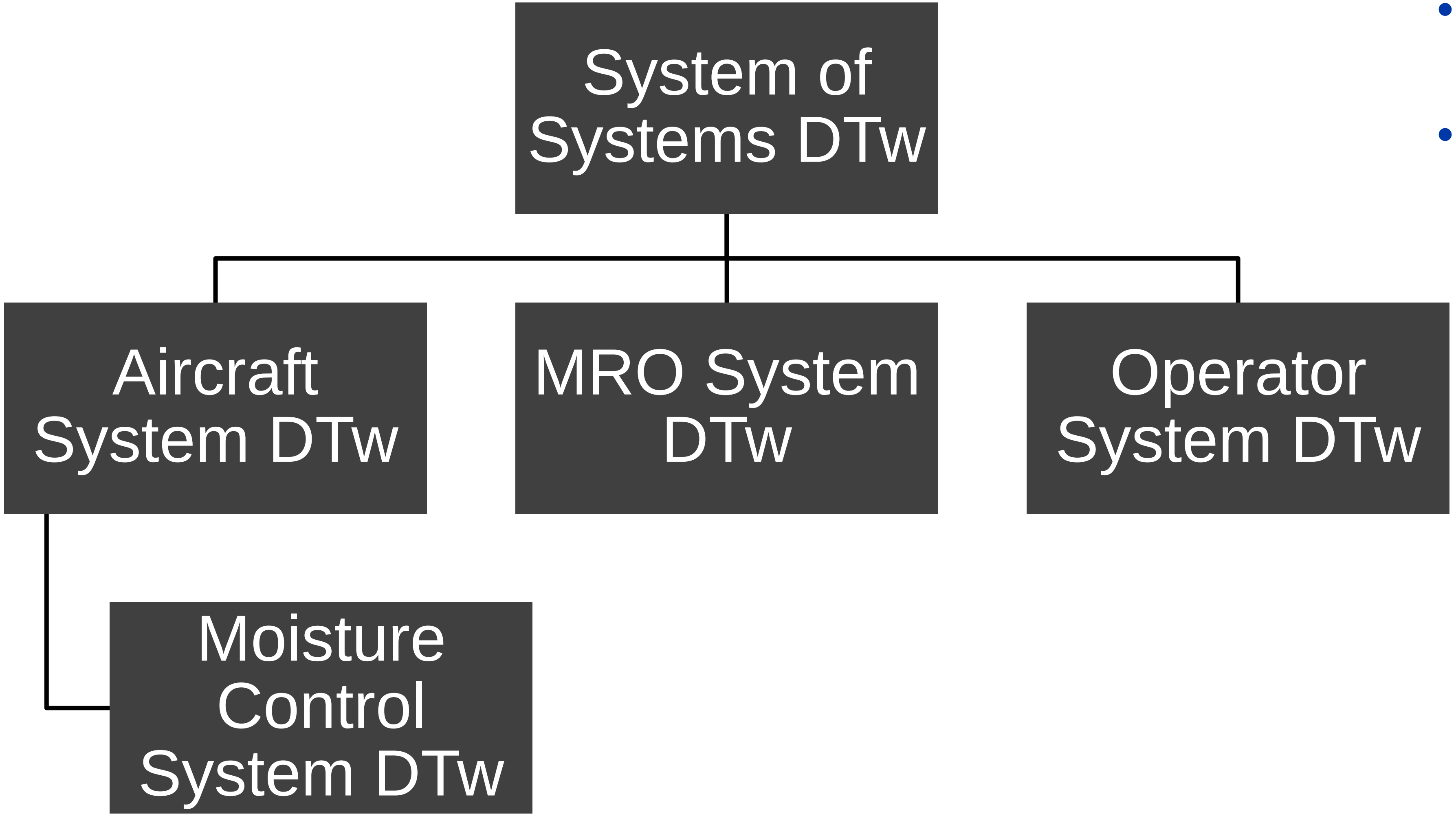


The ability of aircraft to perform according to specification depend on the alignment of its design with its operations and maintenance

Each activity is executed by a different entity, in this case the manufacturer, airline, and the maintenance, repair and overhaul (MRO) companies.

System of Systems Perspective



- **A DTw is part of a system**
- **A DTw of an airplane must**
  - **include systems and subsystems**
  - **address a problem of interest**

The Specific Challenge – Controlling Moisture in Commercial Airplanes

- **Aircraft passengers sometimes experience an issue known as "rain in the plane" where water drips from stowage bins onto the passenger during takeoff maneuvers**
- **This issue is caused by uncontrolled moisture that generates on cold structure during flight**
- **It is a particular problem for cold weather operators and long flights**
- **Controlling moisture is important for much more than just passenger comfort though**
- **Moisture builds up over long time scales (weeks and months)**

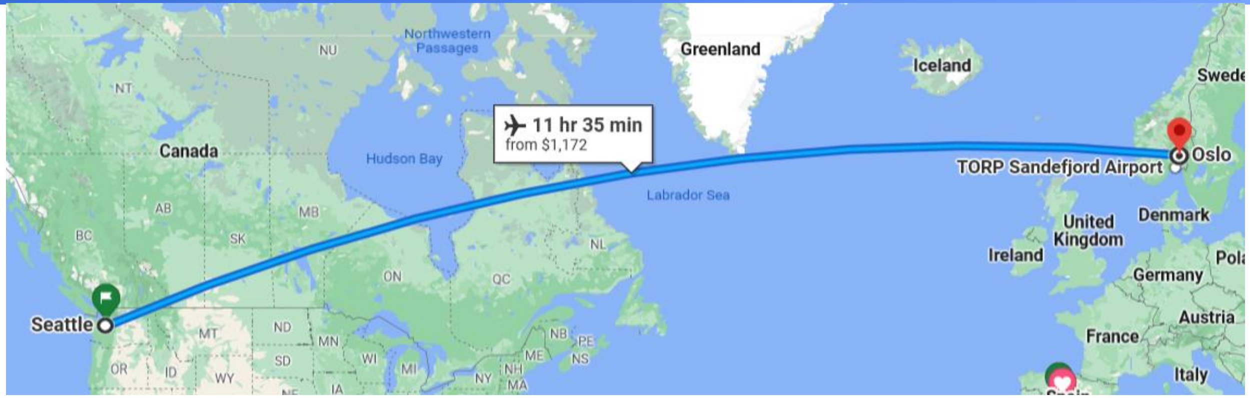
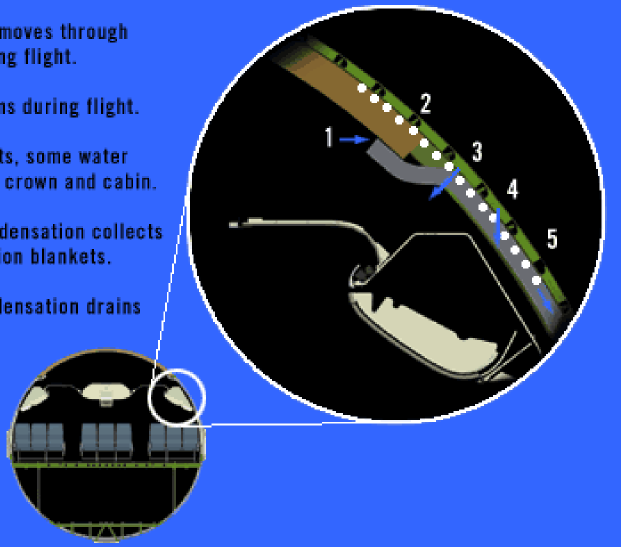


FIGURE 6. WET BLANKETS

FIGURE 2. MOISTURE CYCLE

1. Moist air moves through gaps during flight.
2. Frost forms during flight.
3. Frost melts, some water drips into crown and cabin.
4. Some condensation collects in insulation blankets.
5. Most condensation drains away.



Ref: https://www.boeing.com/commercial/aeromagazine/aero_05/textonly/m01txt.html

Moisture Control Factors

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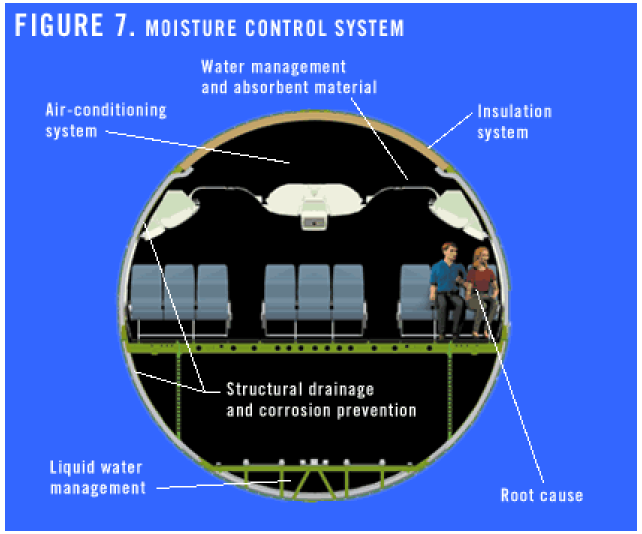
Category	Factor	Effect
Airplane Design /Configuration	Seating density	More people produce more moisture, causing higher cabin humidity levels and increased condensation rates.
	Insulation design	An insulation design that minimizes gaps will reduce condensation rates.
	Air-conditioning system design	The amount of outside air per occupant supplied to the airplane affects the in-flight humidity level. Increasing the outside air per occupant decreases the cabin humidity, which decreases the condensation rates.
Airplane Operations	Load factor	More people produce more moisture, causing higher cabin humidity levels and increased condensation rates.
	Utilization rate (hours per day the airplane is operating)	High airplane-utilization rates result in more time during which the structure is below the dew point and subject to greater accumulations of frost on a daily basis.
Environment	Air-conditioning system operation	For airplanes with overhead recirculation fans, operating these fans or air-conditioning packs on the ground will help dry out the crown space.
	Outside temperature	Colder structure temperatures cause higher condensation rates. Colder structure temperatures on the ground inhibit the evaporation of moisture from wet insulation.
	Outside Humidity	Dictates whether a ground cart or APU operations are recommended
Maintenance	Insulation blanket installation	Gaps in insulation coverage created during maintenance can increase condensation rates. Damage to insulation cover material can increase moisture problems with wet insulation.
	Use of ground-based forced-air systems	Ground-based forced-air systems can be useful for drying airplanes parked for extended periods.



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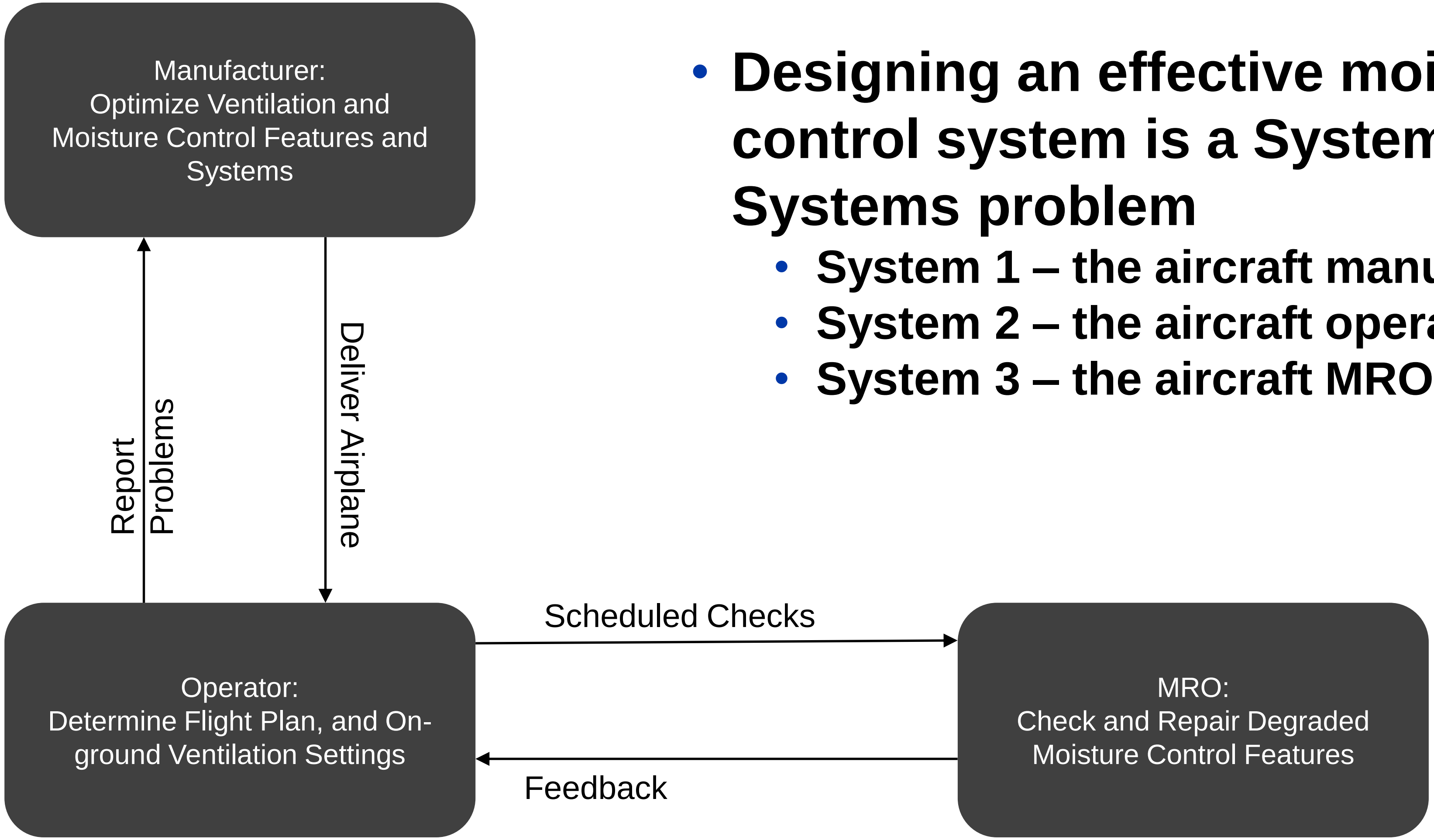
Controlling Moisture – Design, Operations and Maintenance



- **Designing an effective moisture control system is a System of Systems problem**
  - **System 1 – the aircraft manufacturer**
  - **System 2 – the aircraft operator**
  - **System 3 – the aircraft MRO**

Moisture Control Digital Twin Goals

- **Inform ground operations with airplane specific historical data**
- **Enable automated maintenance predictions**
- **Collect data to drive product improvements recommendations**
- **Create feedback loop from maintenance records to the design and operations models**

Setting up the Digital Twin Solution

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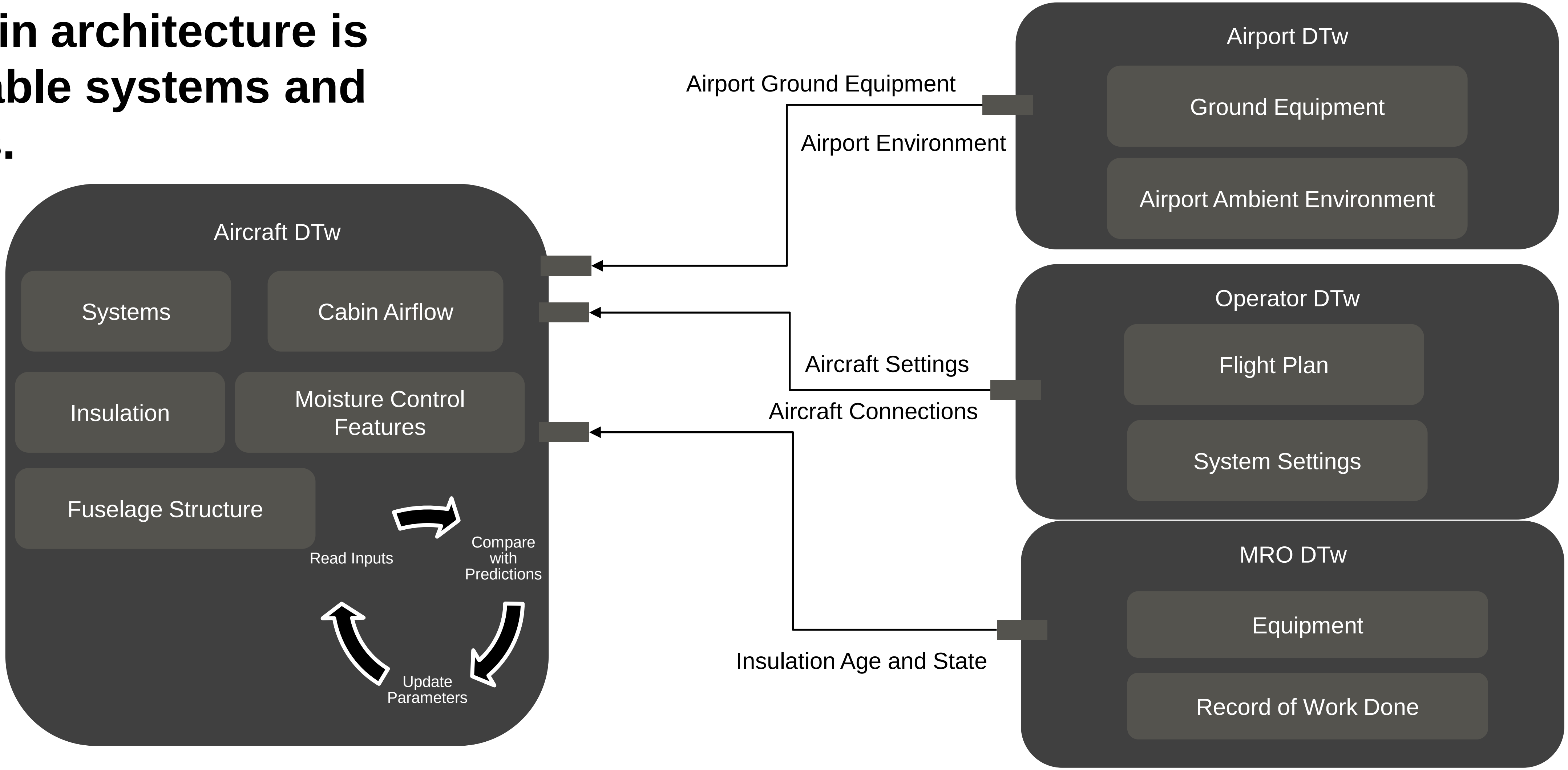
- **Moisture control system design**
  - **requires assuming a customer usage profile with many variables**
- **Moisture control system operation**
  - **May deviate from that profile, increasing or decreasing the maintenance**
- **Moisture control system maintenance records**
  - **Are currently not used to inform manufacturer simulations (no model feedback)**

Physical World	Digital World
Manufacturer: Delivers Aircraft	Manufacturer: Delivers Moisture Control DTw
Operator: Operates Aircraft	Operator: Updates the DTw with Operational Data
MRO: Repairs the airplane	MRO: Updates the DTw with Part State Information

The Moisture Control DTw System Architecture

A digital twin architecture is needed enable systems and other DTws.



Aircraft DTw Models

Aircraft DTw

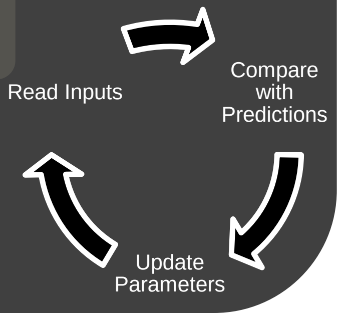
Systems

Cabin Airflow

Insulation

Moisture Control Features

Fuselage Structure



Systems:
Cooling, Heating and Ventilation System Behavioral Models

Tracks airflow and heat

Standards:
Modelica® Language

Insulation:
Finite Element Analysis Heat and Mass Transfer Models

Tracks water absorption and distribution

Standards:
ISO10303-209
Modelica® Language

Fuselage Structure:
Structural Thermal Response

Predicts structure temperatures

Standards:
Modelica® Language

Cabin Airflow:
Airflow distribution Behavioral Model

Tracks ventilation flow paths within the pressurized volume, humidity, and condensation rates

Standards:
Modelica® Language

Moisture Control Features:
Drainage Control Paths Behavioral Models

Track water drainage

Standards:
Modelica® Language

The Moisture Control DTw Sourcing Architecture

- **A collaboratively developed architecture creates a modeling infrastructure for service and product owners to connect their own models**
- **Following our example:**
  - **The airport produces a local weather and ground services model**
  - **The operator creates a route and ground operations model**
  - **The MRO supplies a detailed record of part serial numbers, findings and repairs**

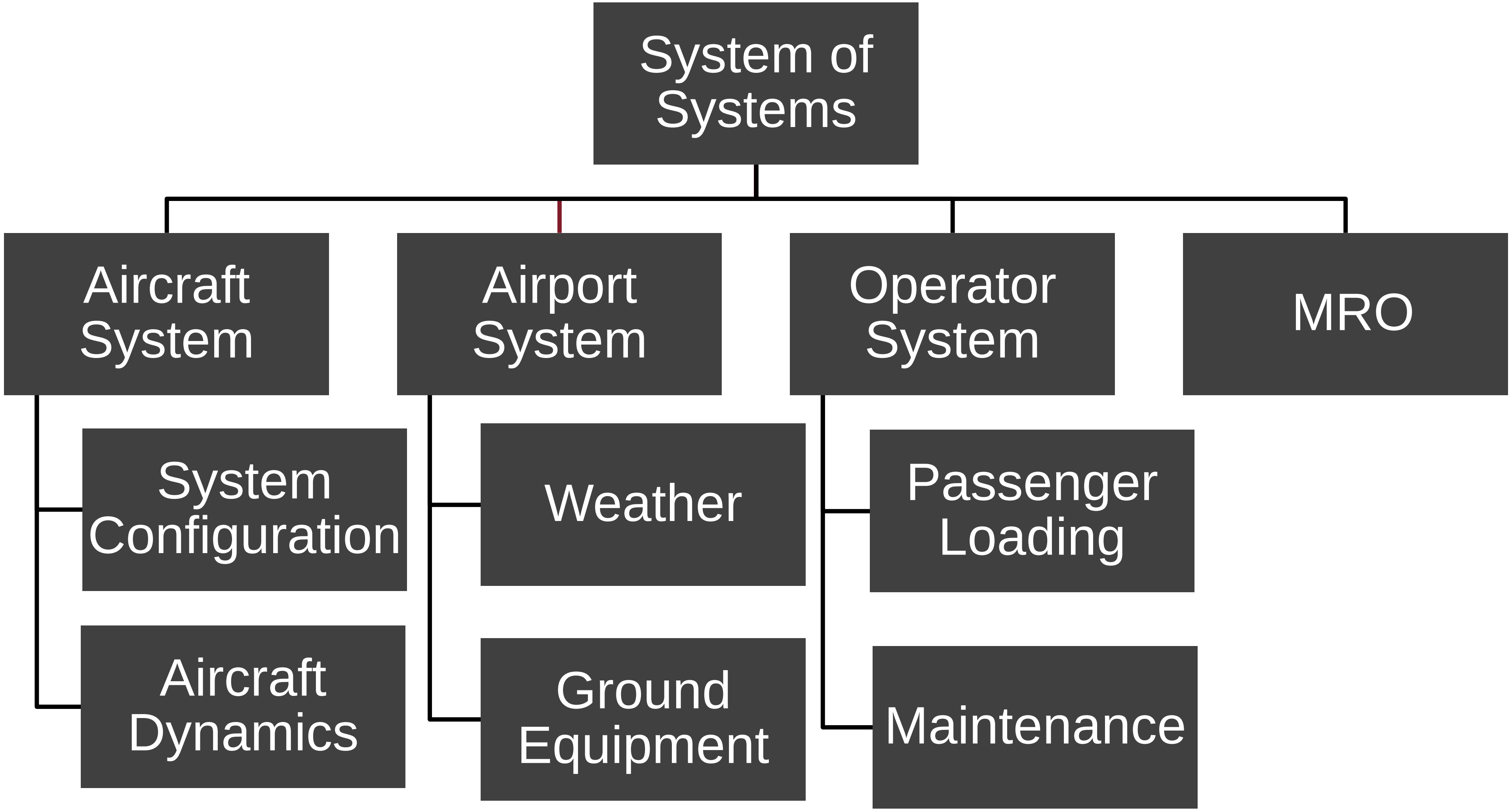
Effects of the Digital on the Physical

- **As the twin gets developed, it may drive the addition of sensing hardware on the physical platform (i.e. humidity sensors)**
- **What else can I do with that data?**
- **Will the digital data drive customers to change their operational procedures or manufacturers to alter their designs?**
- **Does access to a digital twin by manufacturers and operators lead to enhanced airplane requirements?**

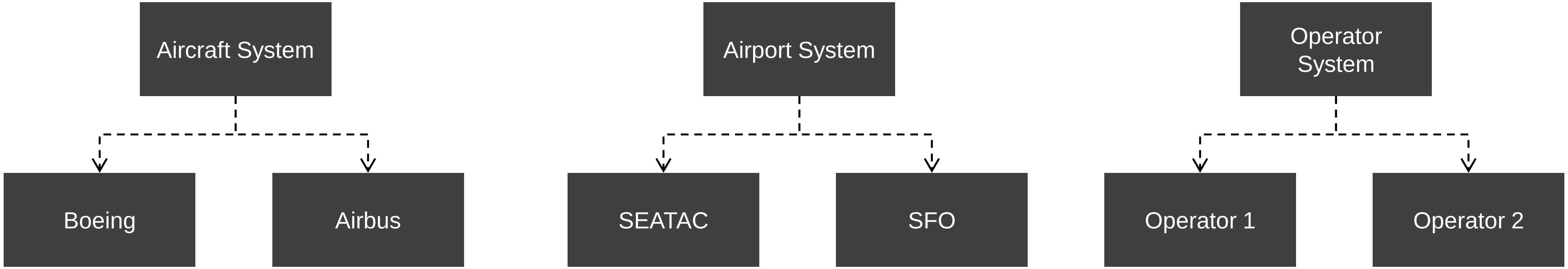
The Moisture Control DTw Standards Architecture

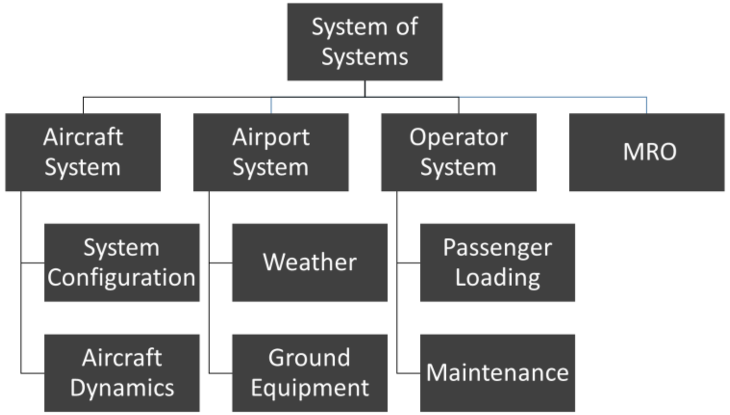
- **At a minimum**
  - **the standards at the data interfaces must be defined**
  - **the interface data must be controlled by an interface control spec**
- **Optimally**
  - **the model language, inputs and outputs within each model of the digital twin would comply with available standards like Modelica® and ISO10303-209**
  - **The framework of the system of systems would comply with context and framework standards like MoSSEC (ISO 10303-243), OMG's Product Knowledge Framework, and OMG's Ontology**
  - **Each DTw would comply with the same fundamental standards as the system of systems**

Generalized Model Structure



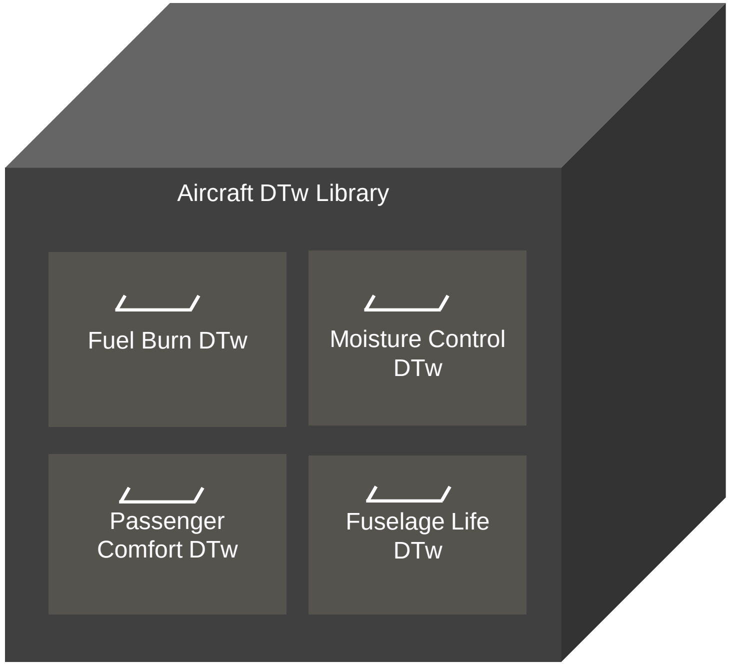
Model Instantiation Examples





Expanding the Vision

- **Moisture Control is one small opportunity for analysis DTws to**
  - **make operators more efficient**
  - **improve manufacturer design requirements**
  - **increase the value of the each individual aircraft**



Digital Twin Capabilities (OMG DTC)

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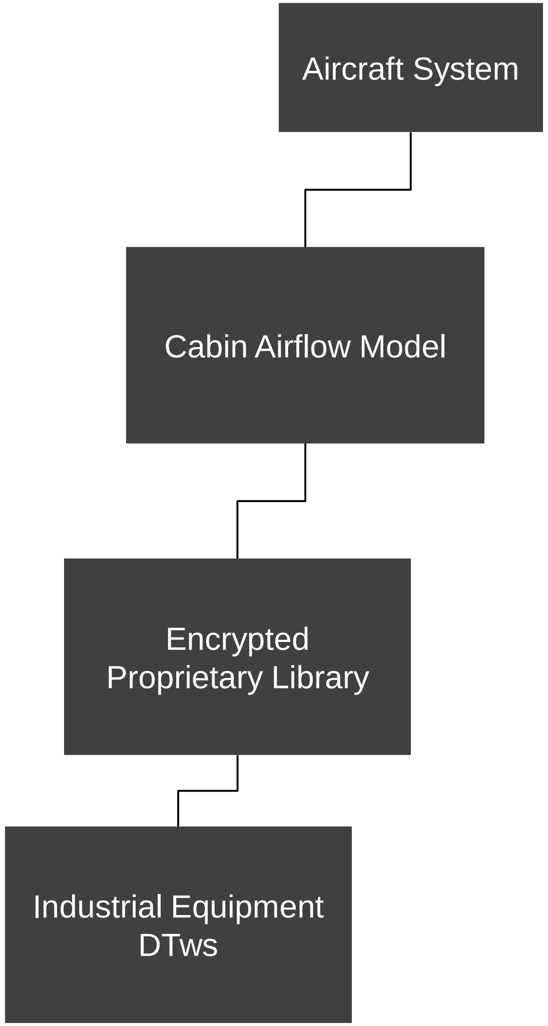
1 Data Acquisition & Ingestion	9 Synthetic Data Generation	17 Enterprise System Integration	23 Edge AI & Intelligence	29 Prediction		39 Basic Visualization	45 Dashboards
2 Data Streaming	10 Ontology Management	18 Eng. System Integration	24 Command & Control	30 Machine Learning ML		40 Advanced Visualization	46 Continuous Intelligence
3 Data Transformation	11 Digital Twin (DT) Model Repository	19 OT/IoT System Integration	25 Orchestration	31 Artificial Intelligence AI	35 Prescriptive Recommendations	41 Real-time Monitoring	47 Business Intelligence
4 Data Contextualization	12 DT Instance Repository	20 Digital Twin Integration	26 Alerts & Notifications	32 Federated Learning	36 Business Rules	42 Entity Relationship Visualization	48 BPM & Workflow
5 Batch Processing	13 Temporal Data Store	21 Collab Platform Integration	27 Reporting	33 Simulation	37 Distributed Ledger & Smart Contracts	43 Augmented Reality AR	49 Gaming Engine Visualization
6 Real-time Processing	14 Data Storage & Archive Services	22 API Services	28 Data Analysis & Analytics	34 Mathematical Analytics	38 Composition	44 Virtual Reality VR	50 3D Rendering
7 Data PubSub Push	15 Simulation Model Repository	52 Device Management	54 Event Logging	56 Data Encryption	58 Security	60 Safety	51 Gamification
8 Data Aggregation	16 AI Model Repository	53 System Monitoring	54 Data Governance	57 Device Security	59 Privacy	61 Reliability	62 Resilience

Data Services · Integration · Intelligence · UX · Management · Trustworthiness

OMG Digital Twin Consortium Capabilities Periodic Table

Open Model Architecture

- **Architecture reveals as much as maintenance documents**
- **System performance descriptions are replaced with models**
- **Models that encrypt critical data**



Open Architecture Challenges

- **Contracts**
- **IP**
- **Loss of Data control**

Thank you for listening!

- **Questions / Feedback**

- **Contact me if you would like to chat or collaborate**
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