The growth of smart connected systems across many industries
Why make your systems connected and smart?

**Do things better:** Optimize your customer’s experience

- Anomaly detection
- Predictive maintenance
- Asset performance management
- Operations optimization
- Fleet management
- Feedback to design

**Do new things:** Transform with new business models and opportunities

From selling a system…
To selling the system’s operation, the capability as a service, etc.
MathWorks Customers Using Digital Twins and IIoT

Atlas Copco maintains Digital Thread for 120K air compressor systems

Schindler Elevator performs virtual commissioning with 20K system variants

BuildingIQ provides predictive energy optimization for buildings

Tata Steel optimizes operation to save 40% energy on cooling towers

Fuji Electric analyzes real-time behavior of distributed power systems

Lockheed predicts and optimizes aircraft fleet performance

Newcrest Mining maximizes copper plant efficiency and predicts onset of failures

NIO improves battery state-of-health for electric vehicle fleet

Renoir Consulting predicts real-time performance of drilling rig

Korea institute creates self-diagnosing chip manufacturing vacuum pumps

MATLAB EXPO
Data Volume, Movement, Latency, and Location

Challenges
- Storage capacity
- Ability to secure and manage
- More data is available

Benefits
- Time to transfer and access
- Costs of storage
- Data complexity

As more asset data is collected, and as IT/OT-centralized data becomes more accessible.
Infusing the “Smart” in your systems that are smart and connected...

Where is the best place to apply a particular algorithm? How can it be implemented there? What kind of digital twin is appropriate? How can it be built?
Multiple Roles Needed to Implement Algorithms for Applications

**Applications for Line of Business**

- Anomaly Detection
- Predictive Maintenance
- Asset Performance Management
- Operations Optimization
- Fleet Management
- Feedback to Design

**Algorithm Experts**

- Controls System Engineer
- Signal Processing Engineer
- Computer Vision Engineer
- Data Scientist
- AI Engineer

**Diagram**

- Assets
- Operational Technology
- IT systems

- Customer data
- Asset data etc.
Multiple Roles Needed to Implement Algorithms for Applications

APPLICATIONS FOR LINE OF BUSINESS

- Anomaly Detection
- Predictive Maintenance
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- Operations Optimization
- Fleet Management
- Feedback to Design

ALGORITHM EXPERTS

- Controls System Engineer
- Signal Processing Engineer
- Computer Vision Engineer
- Data Scientist
- AI Engineer

INFRASTRUCTURE RESPONSIBILITY

Embedded Systems Engineer
Industrial Systems Engineer
OT System Architect
IT Solution Architect

Embedded Chips
Industrial I/O
Edge Systems
IoT Platforms
Cloud Streaming
Cloud Platforms
Big Data
Dashboards

Assets
Operational Technology
IT systems

TCP/IP
SCADA
Azure IoT Hub
AWS IoT
Azure Stream Analytics
Azure Kinesis
Amazon Kinesis
Power BI
Power BI

Example: Machine learning model for anomaly detection of assets

1. Train ML model using data

Applications for Line of Business:
- Anomaly Detection
- Predictive Maintenance
- Asset Performance Management
- Operations Optimization
- Fleet Management
- Feedback to Design

Algorithm Experts:
- Data Scientist
- Embedded Systems Engineer
- Industrial Systems Engineer
- OT System Architect
- IT Solution Architect

Infrastructure Responsibility:
- Azure
- kafka
- databricks
- on-premise servers
- hadoop
- SQL Server
- MongoDB
- Amazon Web Services

On-premise servers
Example: Machine learning model for anomaly detection of assets

1. Train ML model using data
2. Deploy trained model

- Anomaly Detection
- Predictive Maintenance
- Asset Performance Management
- Operations Optimization
- Fleet Management
- Feedback to Design

APPLICATIONS FOR LINE OF BUSINESS

ALGORITHM EXPERTS

INFRASTRUCTURE RESPONSIBILITY

Embedded Systems Engineer
Industrial Systems Engineer
Data Scientist
OT System Architect
IT Solution Architect

On-premise servers
MongoDB
Kafka
AWS
Hadoop
Databricks
Azure
Digital Twins Present Different Challenges

- Anomaly Detection
- Predictive Maintenance
- Asset Performance Management
- Operations Optimization
- Fleet Management
- Feedback to Design

APPLICATIONS FOR LINE OF BUSINESS

- Machine Learning
- Deep Learning
- Kalman estimator
- System identification
- etc.

DIGITAL TWIN → DIGITAL REPRESENTATION OF AN ASSET, REGULARLY UPDATED TO REFLECT THE CURRENT STATE OF A SPECIFIC OPERATING ASSET

Physics-Based
- Models of systems/components
- Electrical, mechanical, algorithms, etc.

Data-Driven
- Kalman estimator
- System identification
- etc.

AI-Based
- Machine Learning
- Deep Learning
- etc.

MATLAB EXPO
Digital Twins Present Different Challenges

- Anomaly Detection
- Predictive Maintenance
- Asset Performance Management
- Operations Optimization
- Fleet Management
- Feedback to Design

**APPLICATIONS FOR LINE OF BUSINESS**

1. Streaming data from asset is accessed
2. Algorithm updates digital twin to asset's current state
3. Updated digital twin available

**DIGITAL TWIN**
Digital Twins Present Different Challenges

- Anomaly Detection
- Predictive Maintenance
- Asset Performance Management
- Operations Optimization
- Fleet Management
- Feedback to Design

APPLICATIONS FOR LINE OF BUSINESS

What’s the application?
What’s the right model?
What’s a good algorithm?

DIGITAL TWIN

1. Streaming data from asset is accessed
2. Algorithm updates digital twin to asset’s current state
3. Updated digital twin available

How and where to access data?

Where should the digital twin run?

MATLAB EXPO
Digital Twins Present Different Challenges

- Anomaly Detection
- Predictive Maintenance
- Asset Performance Management
- Operations Optimization
- Fleet Management
- Feedback to Design

APPLICATIONS FOR LINE OF BUSINESS

- Electrical Engineer
- System Engineer
- Mechanical Engineer
- Algorithm Specialist
- Data Scientist
- MBD Engineer

DIGITAL TWIN

What's the application?
What's the right model?
What's a good algorithm?

How and where to access data?

Where should the digital twin run?
Digital Twins Present Different Challenges

Digital Twin Applications for Line of Business
- Anomaly Detection
- Predictive Maintenance
- Asset Performance Management
- Operations Optimization
- Fleet Management
- Feedback to Design

Digital Twin
- Electrical Engineer
- System Engineer
- Mechanical Engineer
- Algorithm Specialist
- Data Scientist
- MBD Engineer

What's the application?
What's the right model?
What's a good algorithm?

How and where to access data?
- Embedded Systems Engineer
- Industrial Systems Engineer

Where should the digital twin run?
- OT System Architect
- IT Solution Architect

Infrastructure Responsibility

What's the application?
What's the right model?
What's a good algorithm?

How and where to access data?
- Embedded Systems Engineer
- Industrial Systems Engineer

Where should the digital twin run?
- OT System Architect
- IT Solution Architect

Applications for Line of Business
- Anomaly Detection
- Predictive Maintenance
- Asset Performance Management
- Operations Optimization
- Fleet Management
- Feedback to Design

On-premise servers
- Azure
- Databricks
- Kafka
- Amazon Web Services
- Hadoop
- MongoDB
- SQL Server
Key Puzzles and Challenges

- How to leverage asset data as it’s streamed, processed, and archived?
- How can algorithm experts and infrastructure experts collaborate better?
- How to leverage the IT/OT technologies, especially as they change?
- How to incrementally add functionality as needs and applications evolve?
- How to create and use digital twins?
- How to verify and validate?

A Demo Illustrates How to Address These Challenges

- Physics-based Digital Twins to Explore “What-if” Scenarios
Demo: Use Physics-based Digital Twins to Explore “What-if” Scenarios

**STEPS:**
1. Create operational digital twin, reusing system design knowledge and models
2. Tune digital twin realizations to match each operating asset, using recent data streamed from the deployed fleet
3. Explore possible future scenarios for each asset, using its digital twin
4. Use digital twins to assess the OT/IT capacity to support large numbers of assets
Digital Twin for “What if” Analysis of a Hydraulic Pump

1. Model the physical asset
Digital Twin for “What if” Analysis of a Hydraulic Pump

Detail: Range of modeling methods for Digital Twins

Factors in choosing:
- Do you have knowledge of system’s physics or only operational data?
- What does your application need?
- Who has the expertise needed to create it?
Our Approach for Digital Twins

- Enable you to create, modify, and operationalize your own physics-based, data-driven, and AI-based models, using MATLAB and Simulink
  - Foundation skills already exist in most organizations
  - Tools designed, documented, and supported so engineers can use on their own
  - Supports inclusion of models from other tools and languages

- Enable model reuse from your Model-Based Design workflows
  - Physics-based and data-driven models already created by your subject matter experts
  - Support a Digital Thread from development to deployment to operationalization

- Enable your equipment provider to share their models with you
  - Especially powerful when they use Model-Based Design themselves
  - Proven capabilities for sharing models (e.g., used between automotive OEMs and suppliers), including protection of IP in models
Digital Twin for “What if” Analysis of a Hydraulic Pump

1. Model the physical asset
Digital Twin for “What if” Analysis of a Hydraulic Pump

2. On OT system, tune model using streaming data so model matches asset
Digital Twin for “What if” Analysis of a Hydraulic Pump

Detail: Model-tuning approach, and how to preprocess data and confirm resulting model, may vary from application to application

- The tuning data could be batched or recent history, not only streaming
- Tuning options include optimization-based parameter tuning, model following, machine learning retraining, and supervised online learning, etc.
Digital Twin for “What if” Analysis of a Hydraulic Pump

3. Tune models for all assets, to generate a set of Digital Twins
Digital Twin for “What if” Analysis of a Hydraulic Pump

4. Simulate many possible future scenarios using Digital Twins

Hydraulic Pump
- Actual assets

Edge system
- PLC

OT and IT systems
- Azure
- Apache Kafka

Simulate future behavior of digital twins
- Digital Twin 1
- Digital Twin 2
- Digital Twin n

Tune each digital twin to actual asset
- Model Tuning Algorithm

Deployment
- SW component

Model and Algorithm Creation
- Monte Carlo set-up
- Physical models
- Model Tuning Algorithm

Dashboard
- Grafana

 Archived Data
Digital Twin for “What if” Analysis of a Hydraulic Pump

Example: Use Digital Twins to assess future operating envelopes of pumps

- For each pump, use parallel simulations to generate the pressure map for many different load configurations.

- This surface plot shows lines of constant pressure. Within the range of available RPM values (1000-1440), there are regions where certain load requests could not be maintained (e.g., you can’t spin the pump fast enough).
4. Simulate many possible future scenarios using Digital Twins

Digital Twin for “What if” Analysis of a Hydraulic Pump

<table>
<thead>
<tr>
<th>Hydraulic Pump</th>
<th>Edge system</th>
<th>OT and IT systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual assets</td>
<td>PLC</td>
<td>Apache Kafka</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Azure</td>
</tr>
</tbody>
</table>

- **Simulation**
  - Simulate future behavior of digital twins
  - Scenario A
  - Scenario B
  - Scenario...

- **Data Management**
  - Asset Mgmt System
  - Tune each digital twin to actual asset

- **Deployment**
  - Monte Carlo set-up
  - Physical models
  - Model Tuning Algorithm

- **Dashboard**
  - Grafana

- **Archived Data**

Diagram:

- Algorithm/Model → Data → OT and IT systems
  - Digital Twin 1
  - Digital Twin 2
  - Digital Twin n

Legend:

- Apache Kafka
- Azure
- Grafana
Digital Twin for “What if” Analysis of a Hydraulic Pump

5. Simulating a lot of assets to exercise the IT/OT infrastructure

Use simulations to generate realistic load of asset data streams, to test key aspects of OT/IT system (e.g., throughput, compute, algorithmic performance, data storage, etc.)
BuildingIQ provides predictive energy optimization for buildings

Atlas Copco maintains Digital Thread for 120K air compressor systems

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NIO improves battery state-of-health for electric vehicle fleet

Korea institute creates self-diagnosing chip manufacturing vacuum pumps
MathWorks Industrial IoT and Digital Twin Advisory Service

- Digital Twin creation and implementation
- Application business value explorations and evaluation
- Maximize reuse of MathWorks Artifacts
  - Design-to-Operation across Application stages
  - Leverage other workflows (e.g. MBD, Virtual Commissioning, etc.)
- Infrastructure and Architecture
- Software Development processes for MATLAB or Simulink-based algorithms/models
- Focus Industries
  - Industrial, Aerospace, Automotive, Medical, Manufacturing, Oil and Gas

MathWorks consulting can partner with you to identify one or more focus areas in your company's Digital Transformation, and work through a specific plan so you are in control of your improved processes, tools, and design work.
With MATLAB and Simulink create algorithms and models that allow you to…

Do things better: Optimize your customer’s experience

Do new things: Transform with new business models and opportunities

- [www.mathworks.com/iot](http://www.mathworks.com/iot)
- [visit booth/demo station](http://www.mathworks.com/iot)
- Contact us to for further discussions