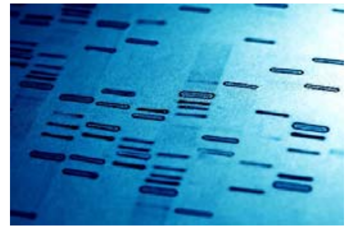
Digital Twins for Industrial IoT

[Presenter Name]

The growth of smart connected systems across many industries

Aerospace and Defense

Automotive



Biotech and Pharmaceutical

Communications

Electronics

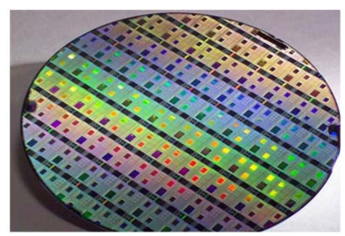
Energy Production

Industrial Machinery

Medical Devices

Process Manufacturing

Railway Systems



Semiconductors

Software and Internet

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

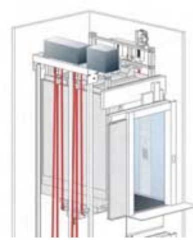
Do new things: **Transform with new business models and opportunities**

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
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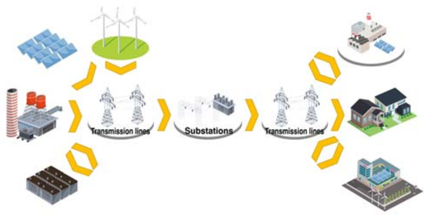
BuildingIQ provides predictive energy
optimization for buildings

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



Fuji Electric analyzes real-time behavior
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Lockheed predicts and optimizes
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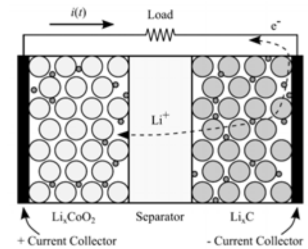
Newcrest Mining maximizes copper plant
efficiency and predicts onset of failures



NIO improves battery state-of-health
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Renoir Consulting predicts real-time
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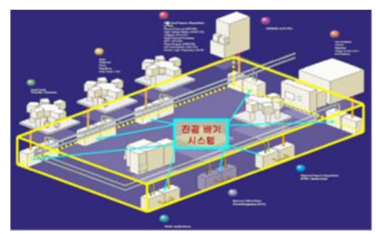


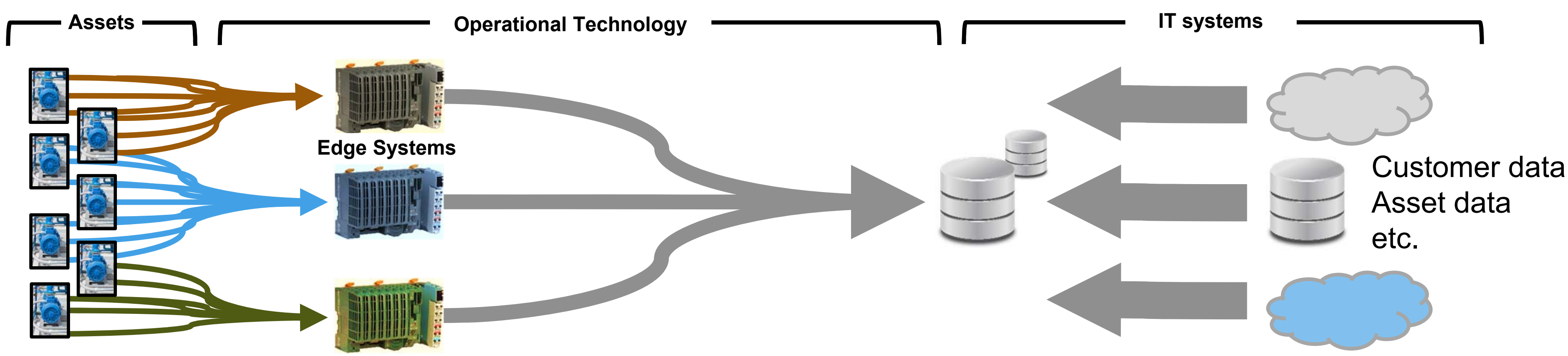
Korea institute creates self-diagnosing
chip manufacturing vacuum pumps

Data Volume, Movement, Latency, and Location

As more asset data is collected, and as IT/OT-centralized data becomes more accessible

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

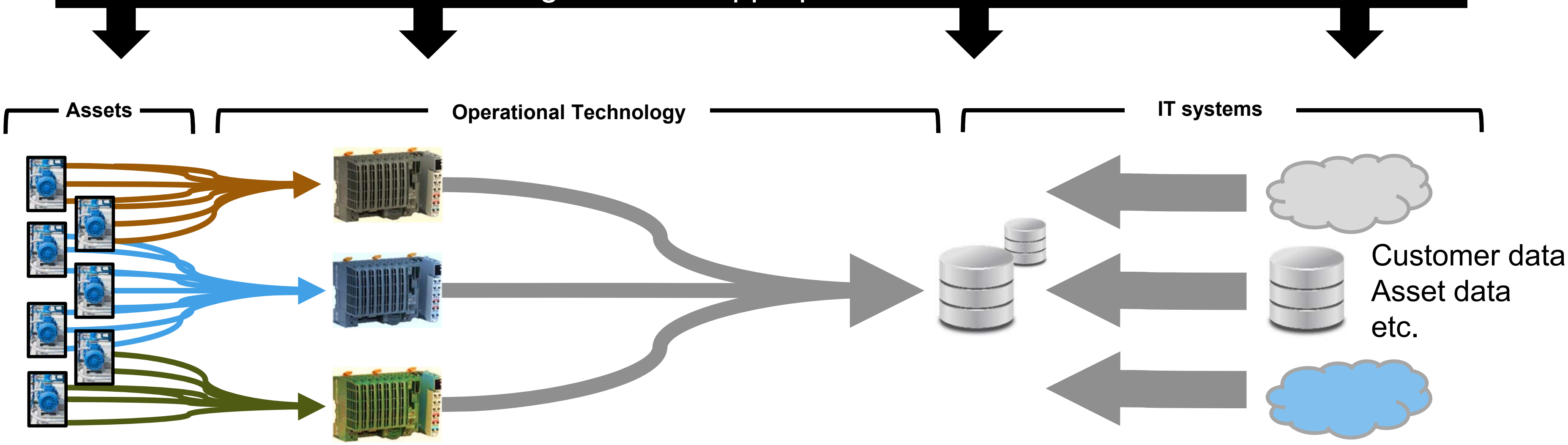
Challenges
- Time to transfer and access
- Costs of storage
- Data complexity



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

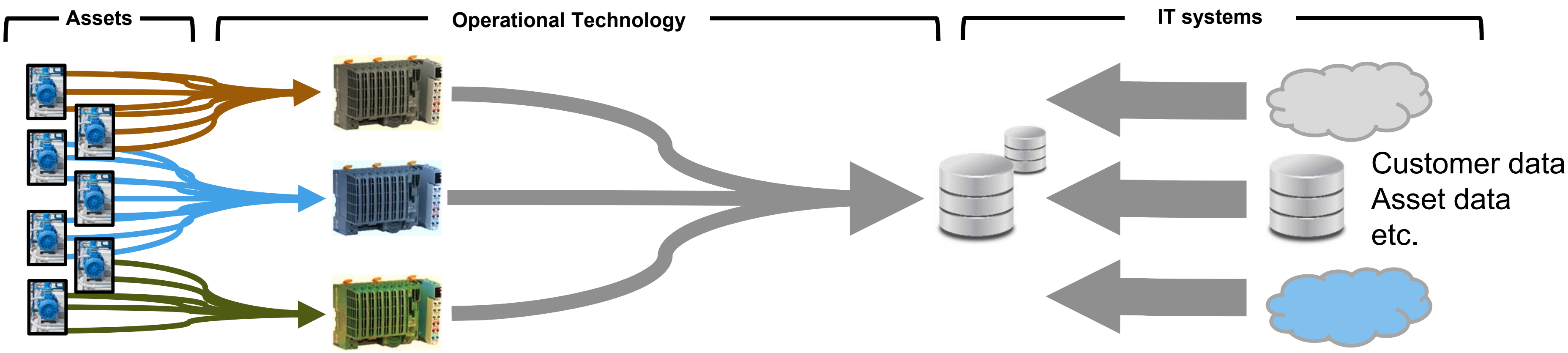
Controls System Engineer

Signal Processing Engineer

Computer Vision Engineer

Data Scientist

AI Engineer



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

INFRASTRUCTURE RESPONSIBILITY

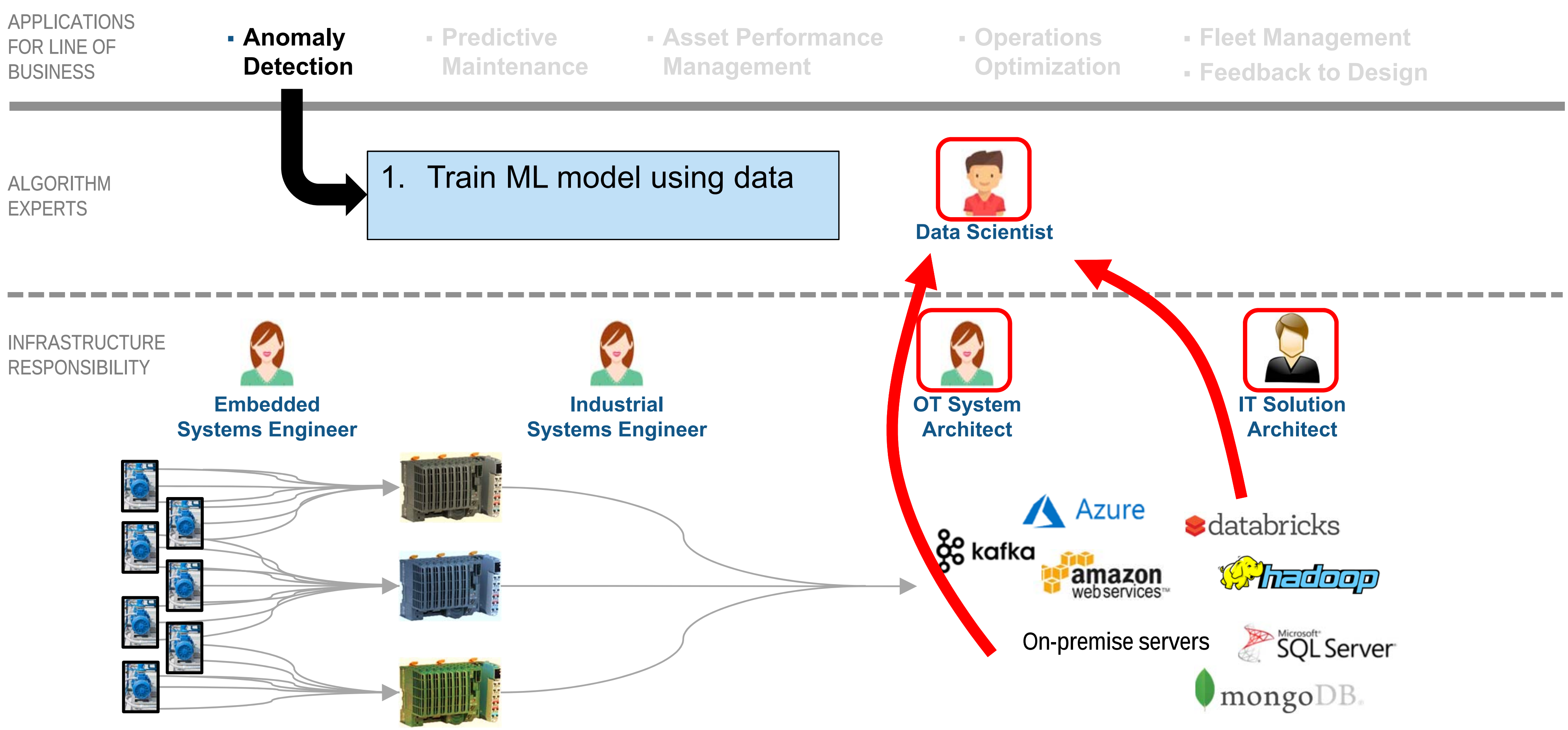
Embedded Systems Engineer | Industrial Systems Engineer | OT System Architect | IT Solution Architect

Assets | Operational Technology | IT systems

NXP, ARM, XILINX, NVIDIA, intel, ST life.augmented | TCP/IP, MQTT.ORG, Modbus, Rest APIs | SCADA, Windows | Azure IoT Hub, AWS IoT, thingworx, LUMADA | Azure Stream Analytics, kafka, Amazon Kinesis | Azure, amazon web services, docker | databricks, hadoop, CLOUDERA | TIBCO Spotfire, tableau, Power BI

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

Example: Machine learning model for anomaly detection of assets



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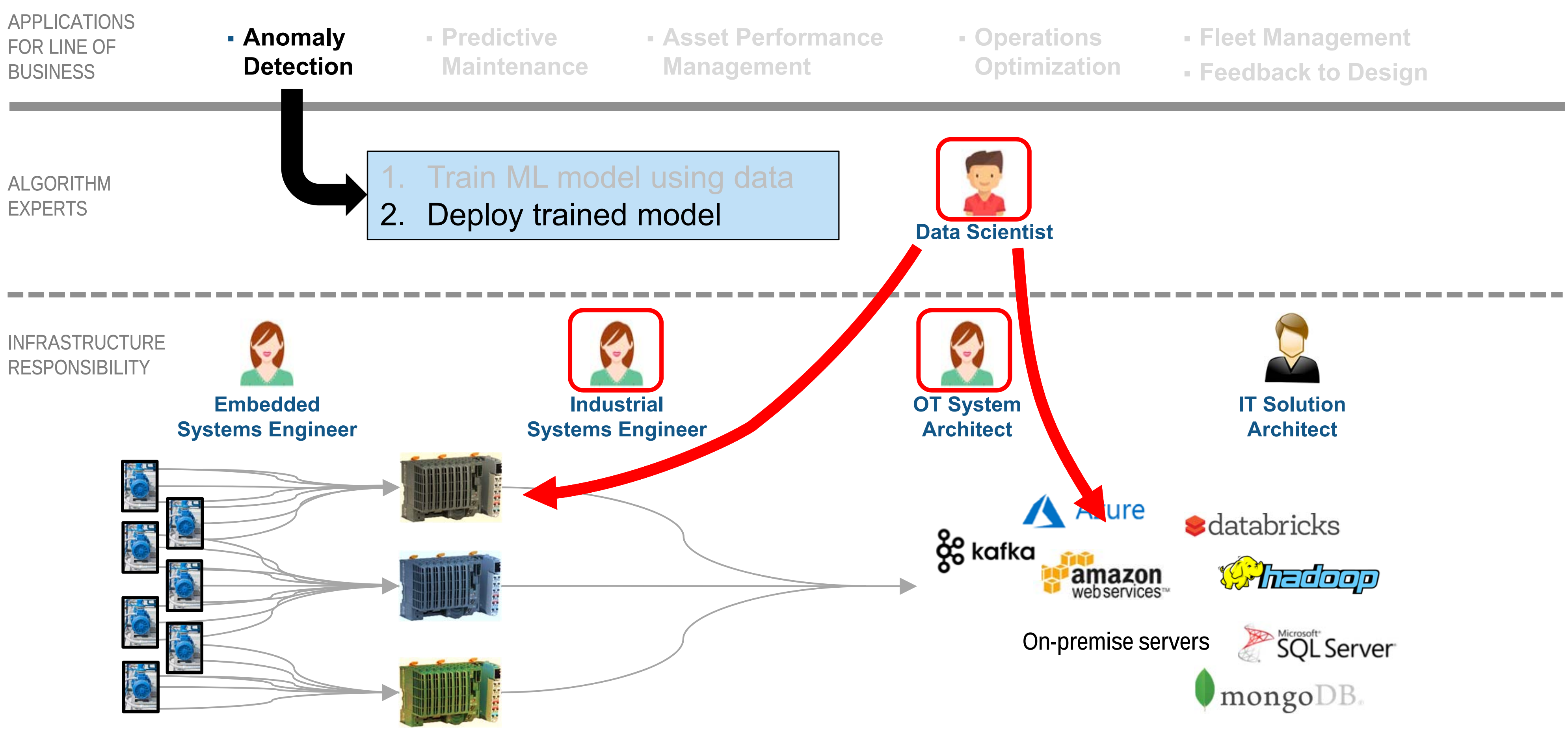

Digital Twins Present Different Challenges

APPLICATIONS FOR LINE OF BUSINESS

- **Anomaly Detection**
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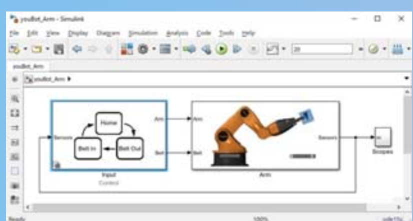
- **Feedback to Design**

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

Physics-Based



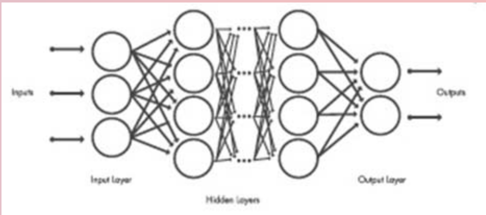
- Models of systems/components
- Electrical, mechanical, algorithms, etc.

Data-Driven

```
% Predicted state and covariance
x_prd = A * x_est;
p_prd = A * p_est * A' + Q;

% Estimation
S = H * p_prd' * H' + R;
B = H * p_prd';
klm_gain = (S \ B)';

% Estimated state and covariance
x_est = x_prd + klm_gain * (z - H * x_prd);
p_est = p_prd - klm_gain * H * p_prd;

% Compute the estimated measurements
y = H * x_est;
```

- Kalman estimator
- System identification
- etc.

AI-Based



- Machine Learning
- Deep Learning
- etc.

Digital Twins Present Different Challenges

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DIGITAL TWIN

Digital Twin Overview

1. Streaming data from asset is accessed

2. Algorithm updates digital twin to asset's current state

3. Updated digital twin available

Digital Twins Present Different Challenges

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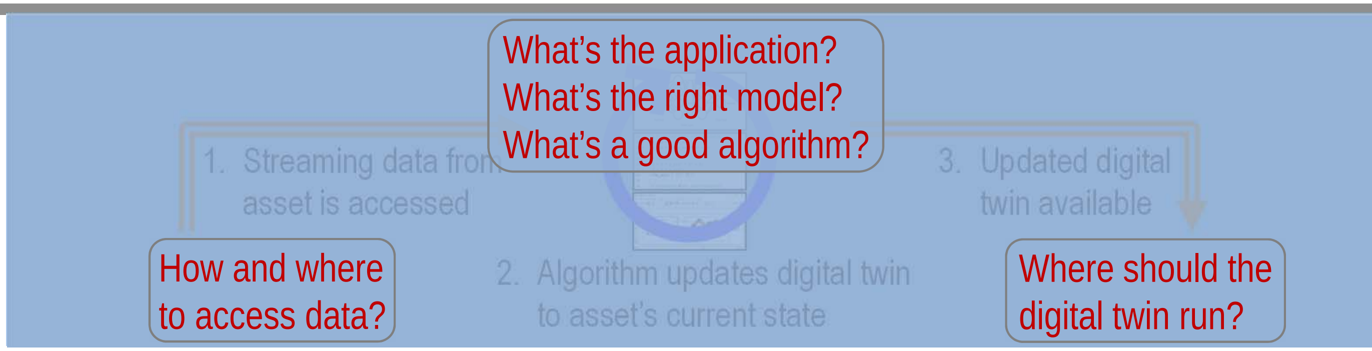
DIGITAL TWIN



Digital Twins Present Different Challenges

APPLICATIONS FOR LINE OF BUSINESS

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DIGITAL TWIN

Electrical Engineer

System Engineer

Mechanical Engineer

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

Algorithm Specialist

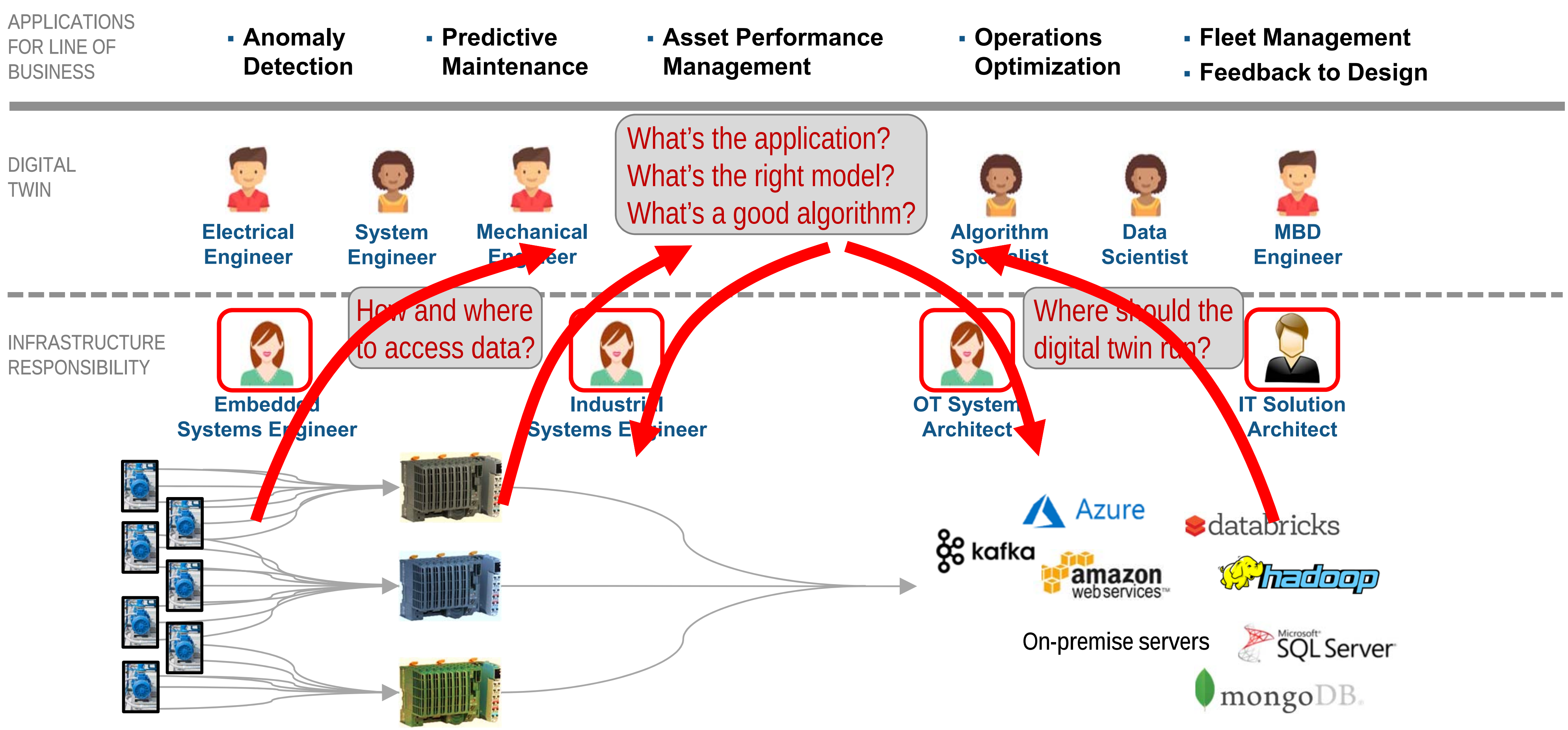
Data Scientist

MBD Engineer

How and where to access data?

Where should the digital twin run?

Digital Twins Present Different Challenges



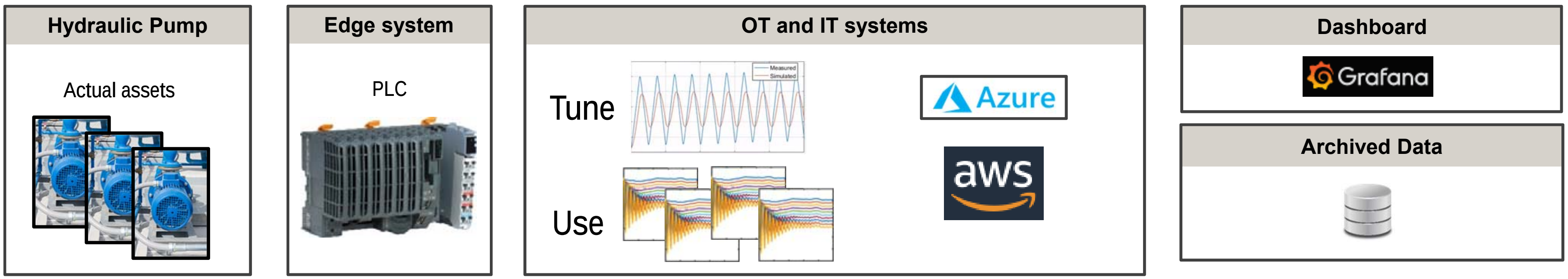
Key Puzzles and Challenges

- 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

Hydraulic Pump

Actual assets

Model and Algorithm Creation

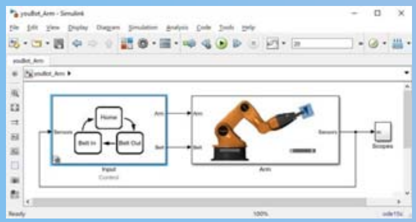
Physical models

Algorithm/Model Data

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

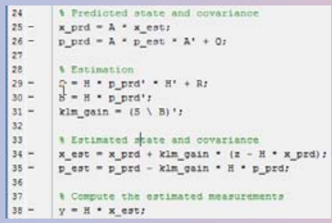
Detail: Range of modeling methods for Digital Twins

Physics-Based



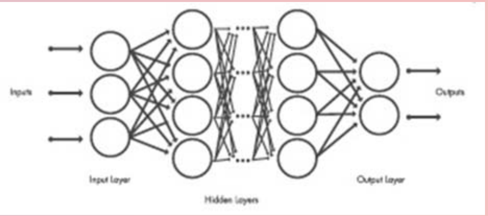
- Dynamical models of systems/components
- Electrical, mechanical, algorithms, etc.
- Include third-party models, e.g., FE models via FMI

Data-Driven



- Kalman estimator
- System identification
- etc.

AI-Based



- Machine Learning
- Deep Learning
- etc.

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

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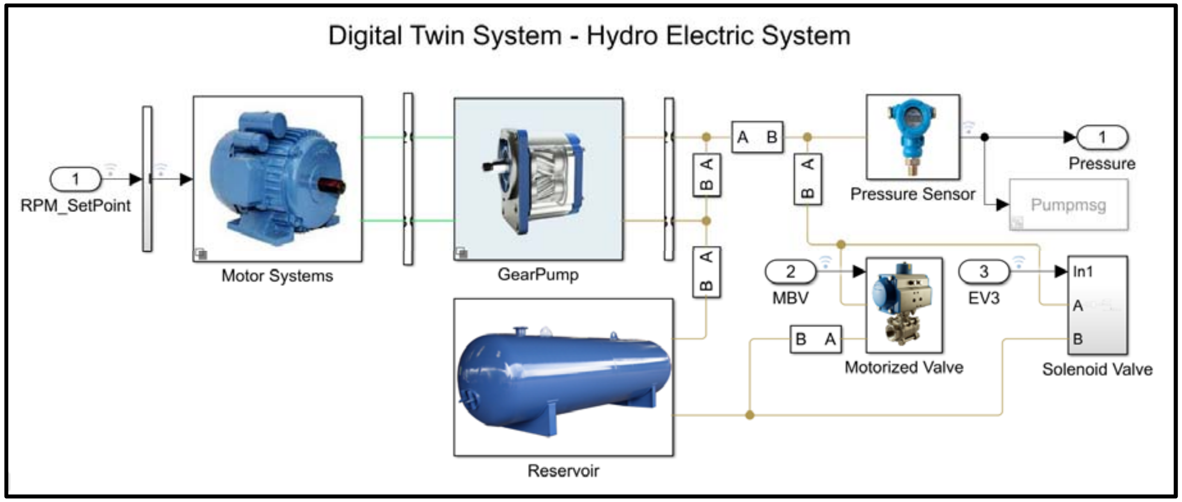


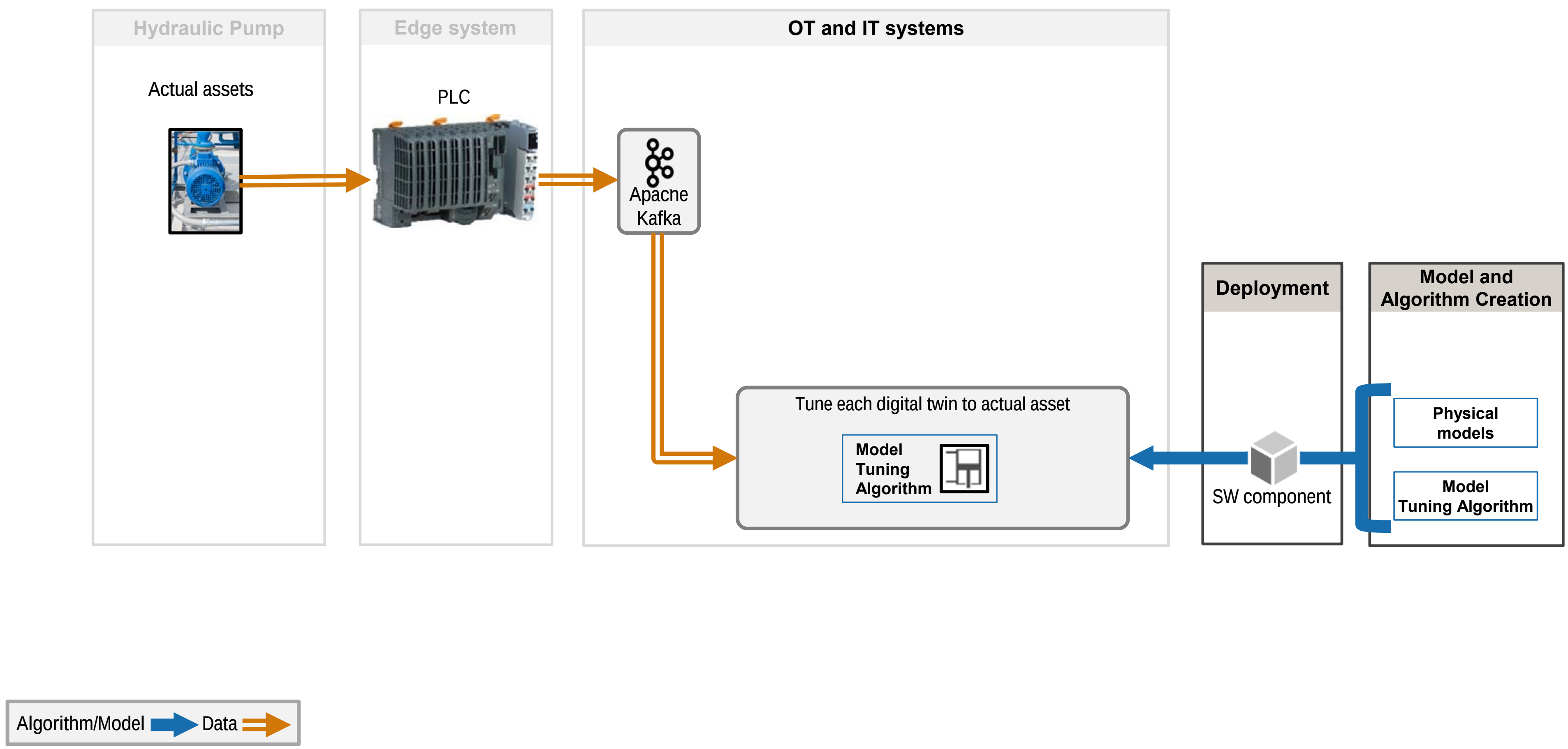
Model and Algorithm Creation

Physical models

Algorithm/Model → Data →

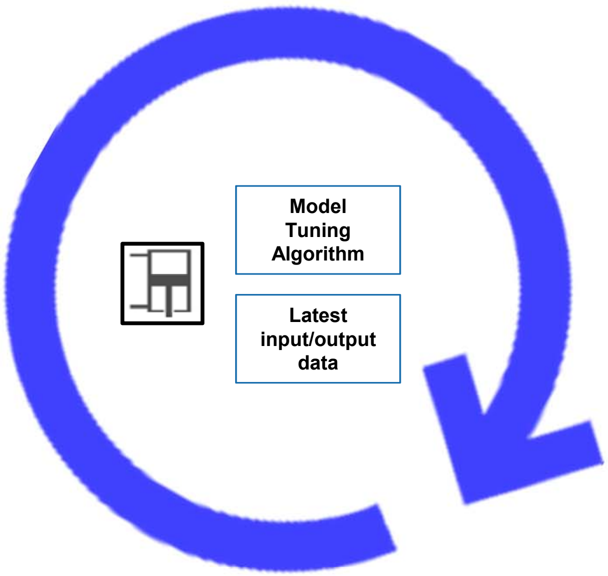
Digital Twin for “What if” Analysis of a Hydraulic Pump

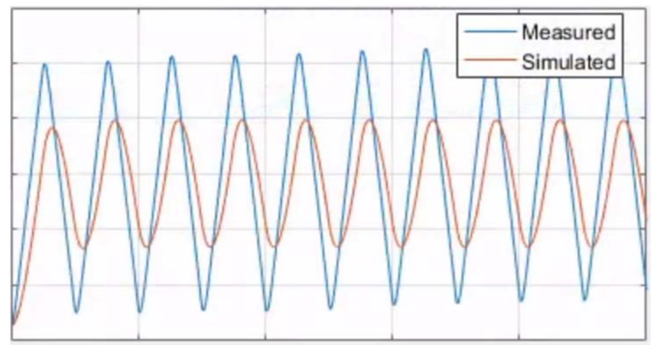
2. On OT system, tune model using streaming data so model matches asset



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



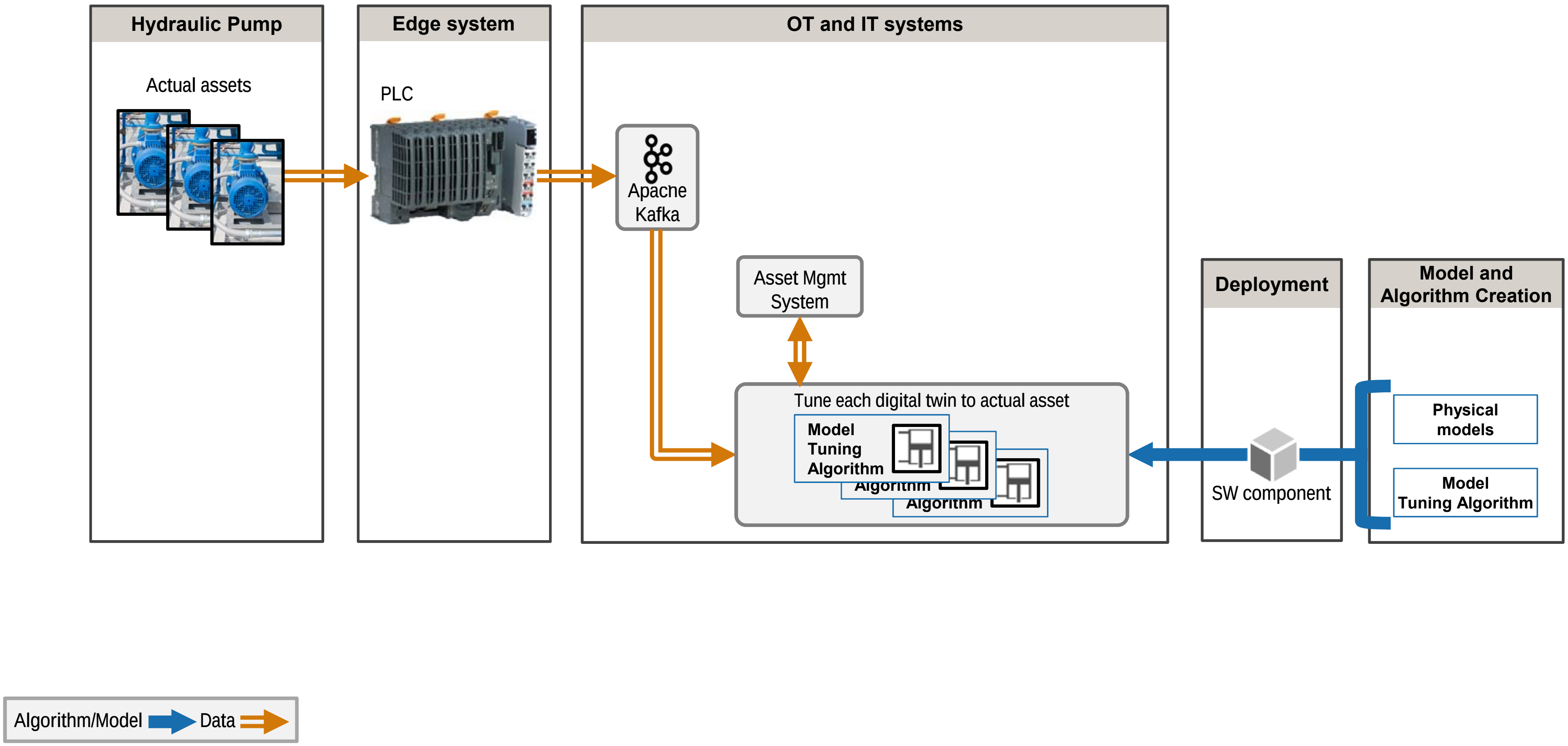


Start with latest available digital twin, and tune to next version.

- 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.

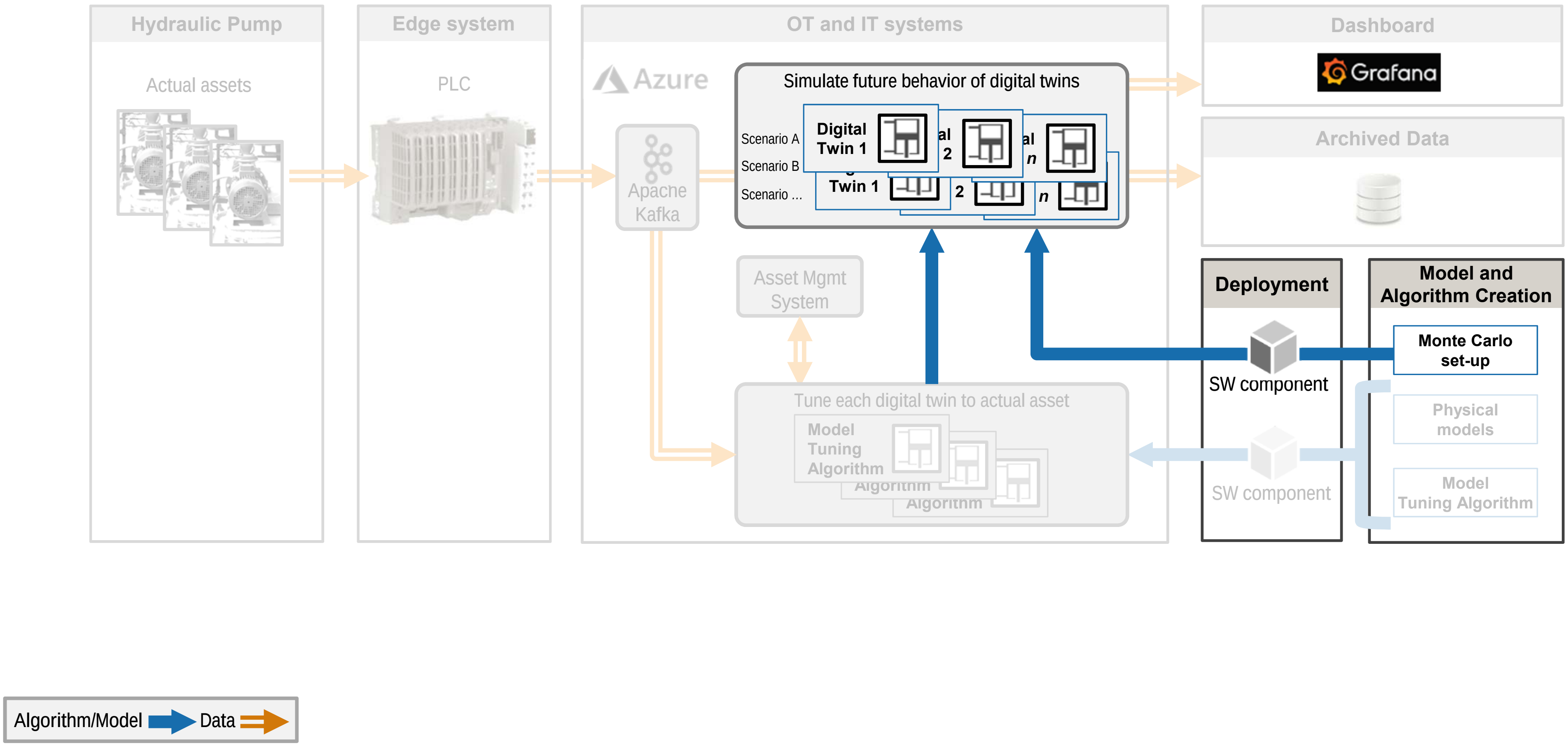
Digital Twin for "What if" Analysis of a Hydraulic Pump

3. Tune models for all assets, to generate a set of Digital Twins



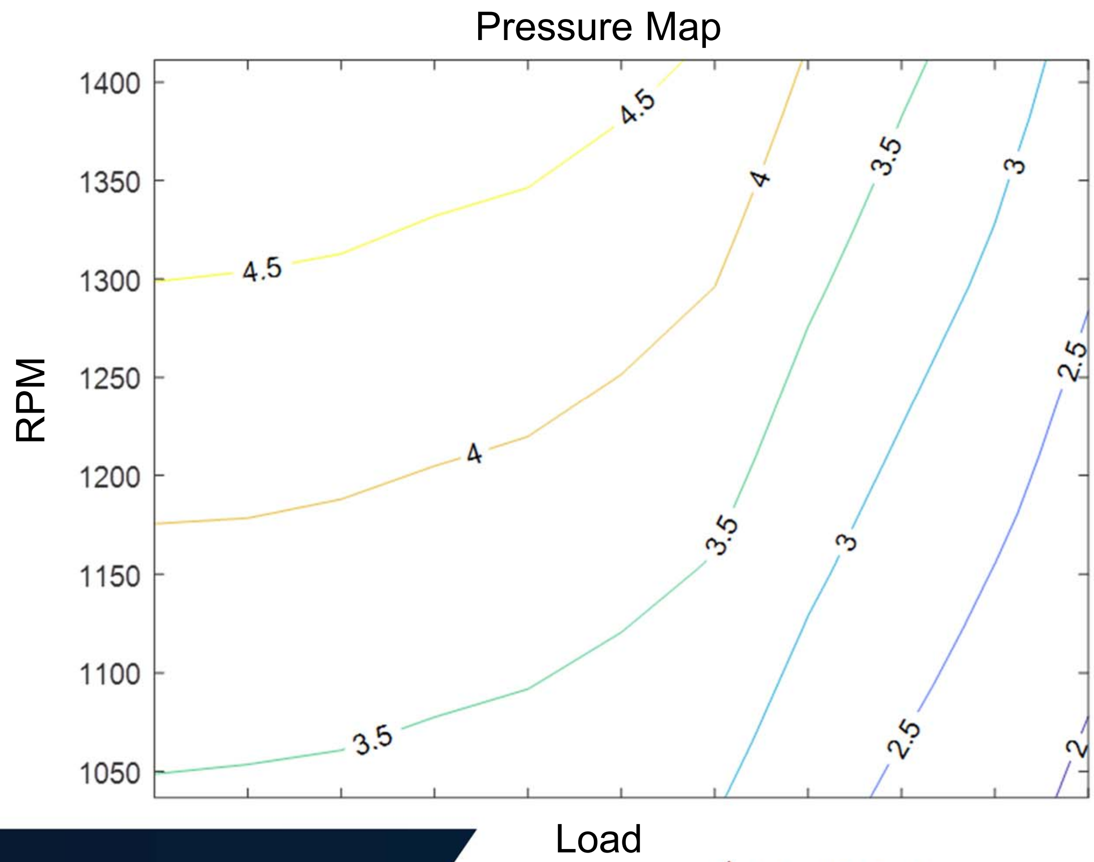
Digital Twin for “What if” Analysis of a Hydraulic Pump

4. Simulate many possible future scenarios using Digital Twins



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).



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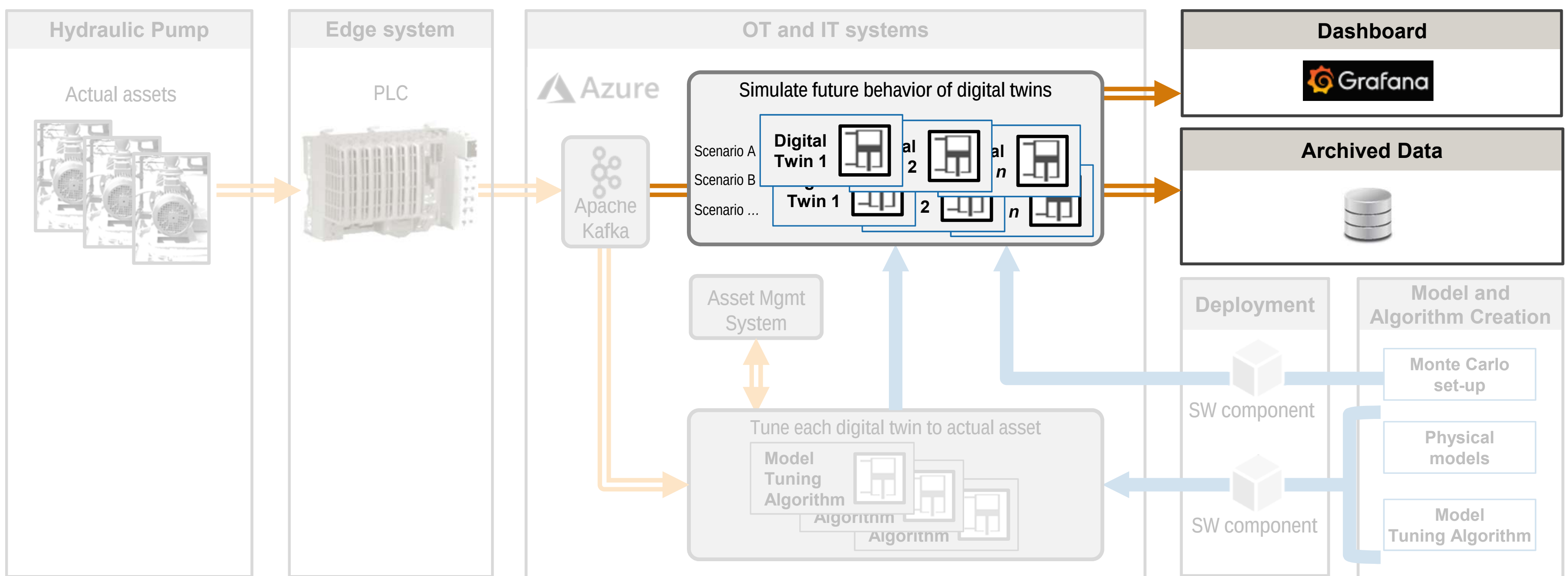
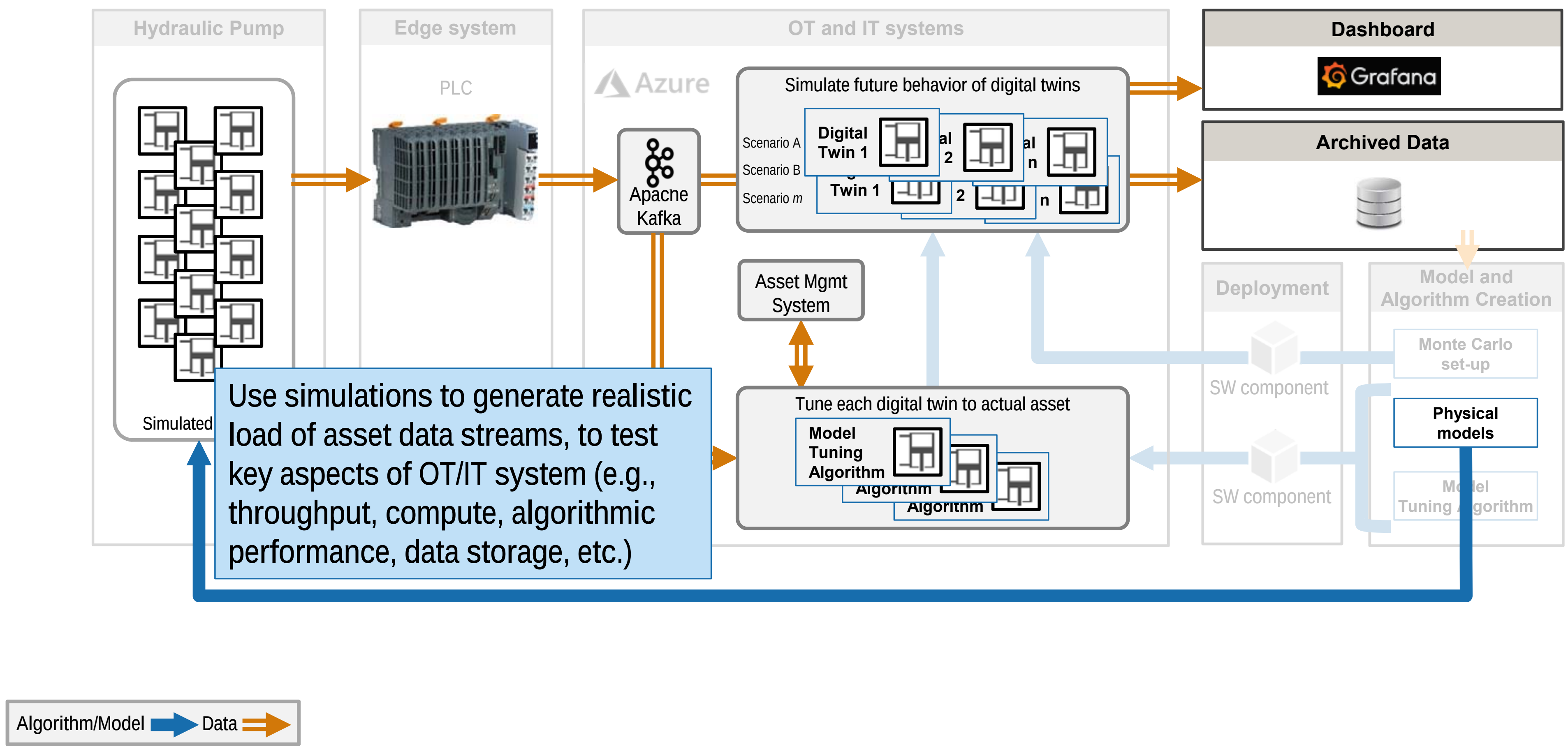


Algorithm/Model → Data →

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

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



MathWorks®

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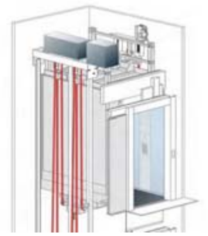

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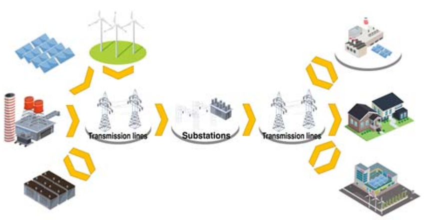

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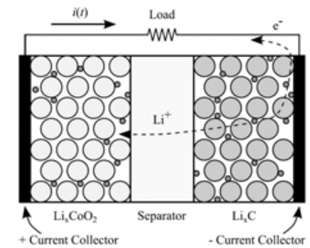

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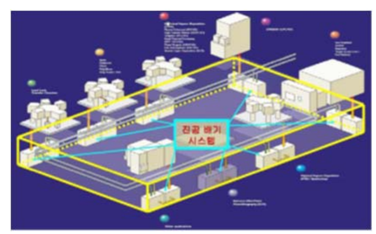
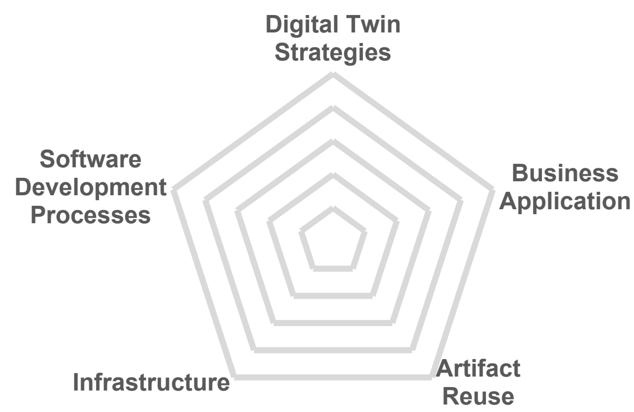


Korea institute creates self-diagnosing chip manufacturing vacuum pumps

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/digital-twin
- www.mathworks.com/iot
- *[visit booth/demo station]*
- Contact us to for further discussions