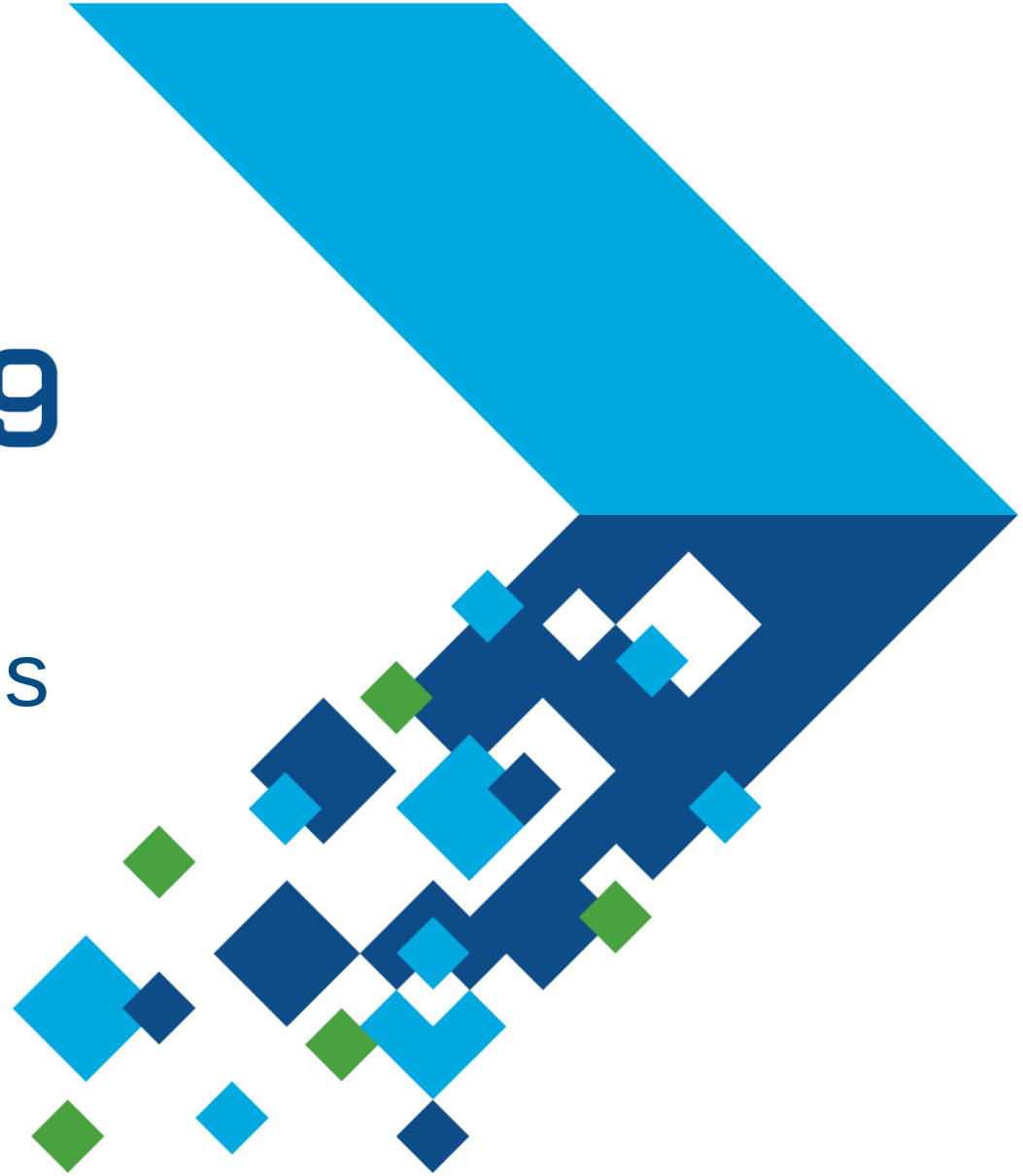
MATLAB EXPO 2019

Industrial IoT and Digital Twins

Coorous Mohtadi



Key Takeaways

- You can use MATLAB and Simulink for IIoT and Digital Twin applications, leveraging their strong Modelling, system simulation, and data analytics capabilities

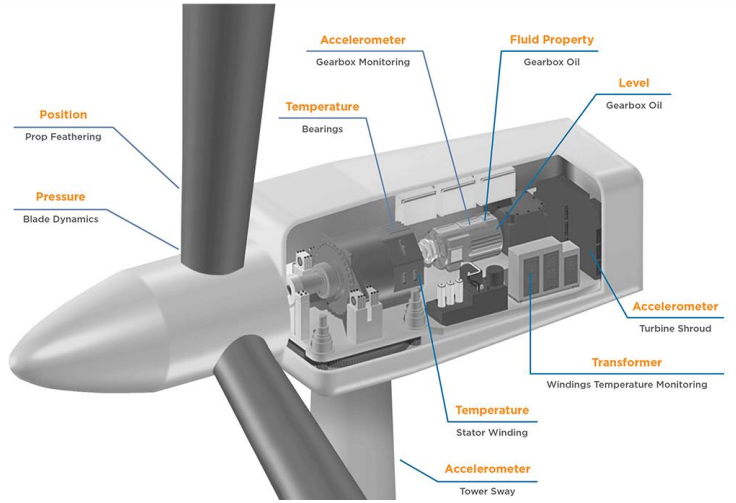
- MathWorks can help you get your project started with applications such as predictive maintenance, operations optimization, and fleet management

Megatrend: Digital Transformation and IoT

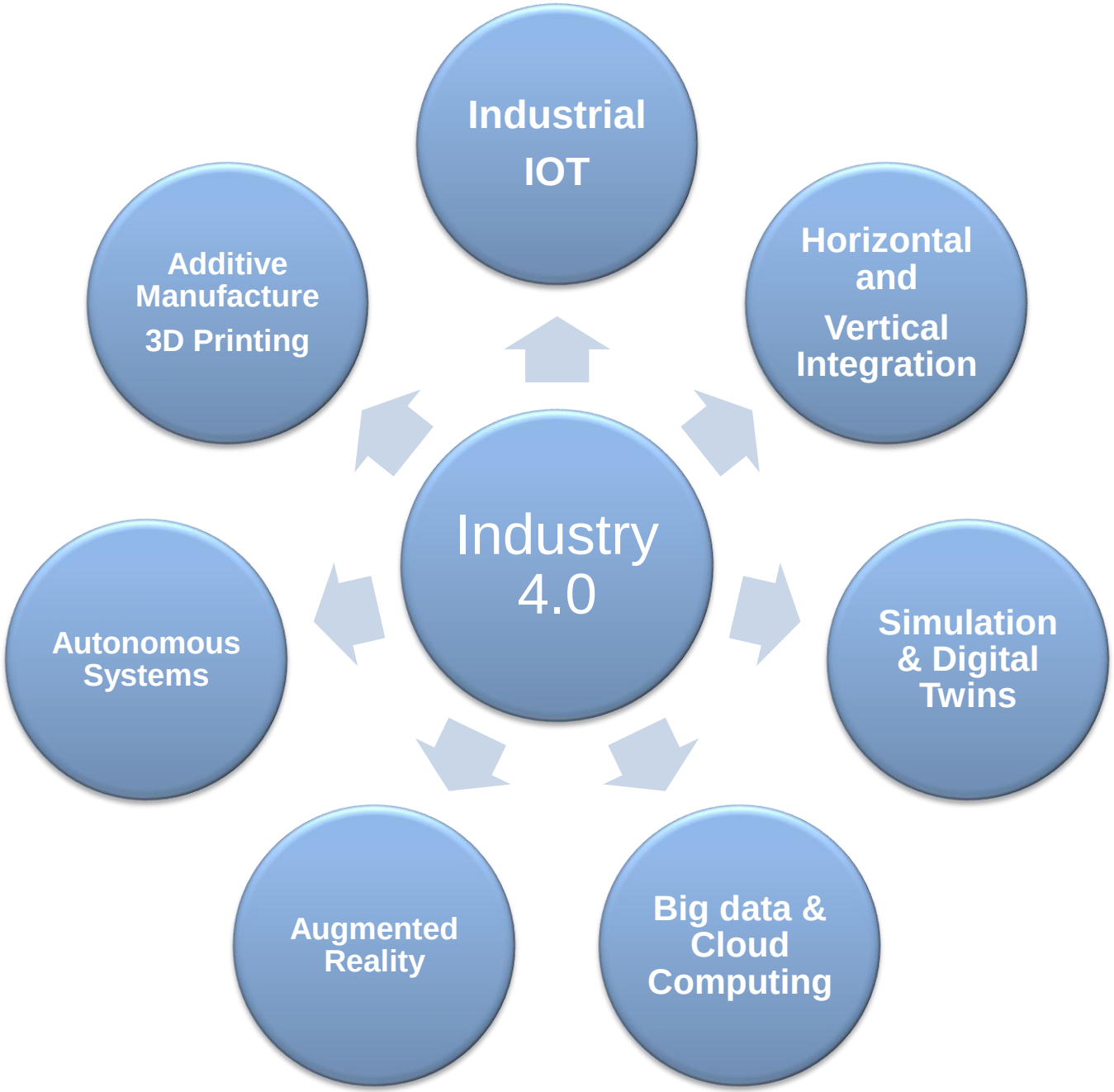
Overall Goals

By connecting machines in operation you can use data, algorithms, and models to make better decisions, improve processes, reduce cost, improve customer experience.

- **Industrial IoT**
- **Digital Twin**
- **Industry 4.0**
- **Smart ‘XYZ’**
- **Digital Transformation**



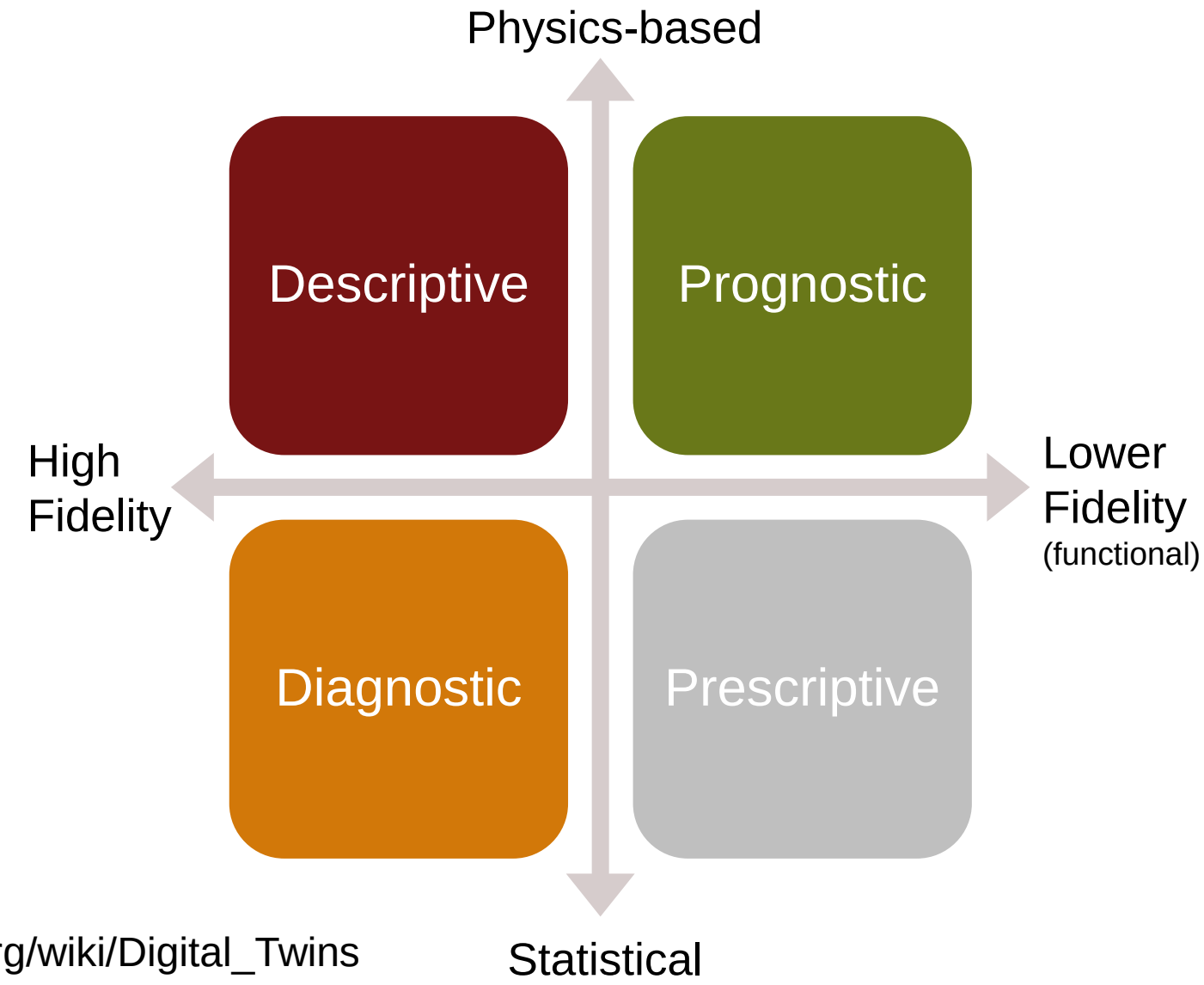
Industry 4.0


Industrial IOT
Horizontal and Vertical Integration
Simulation & Digital Twins
Big data & Cloud Computing
Augmented Reality
Autonomous Systems
Additive Manufacture 3D Printing
Industry 4.0

What is a Digital Twin?

Digital twins refer to computerized companions of physical assets that can be used for **various purposes**.[1]

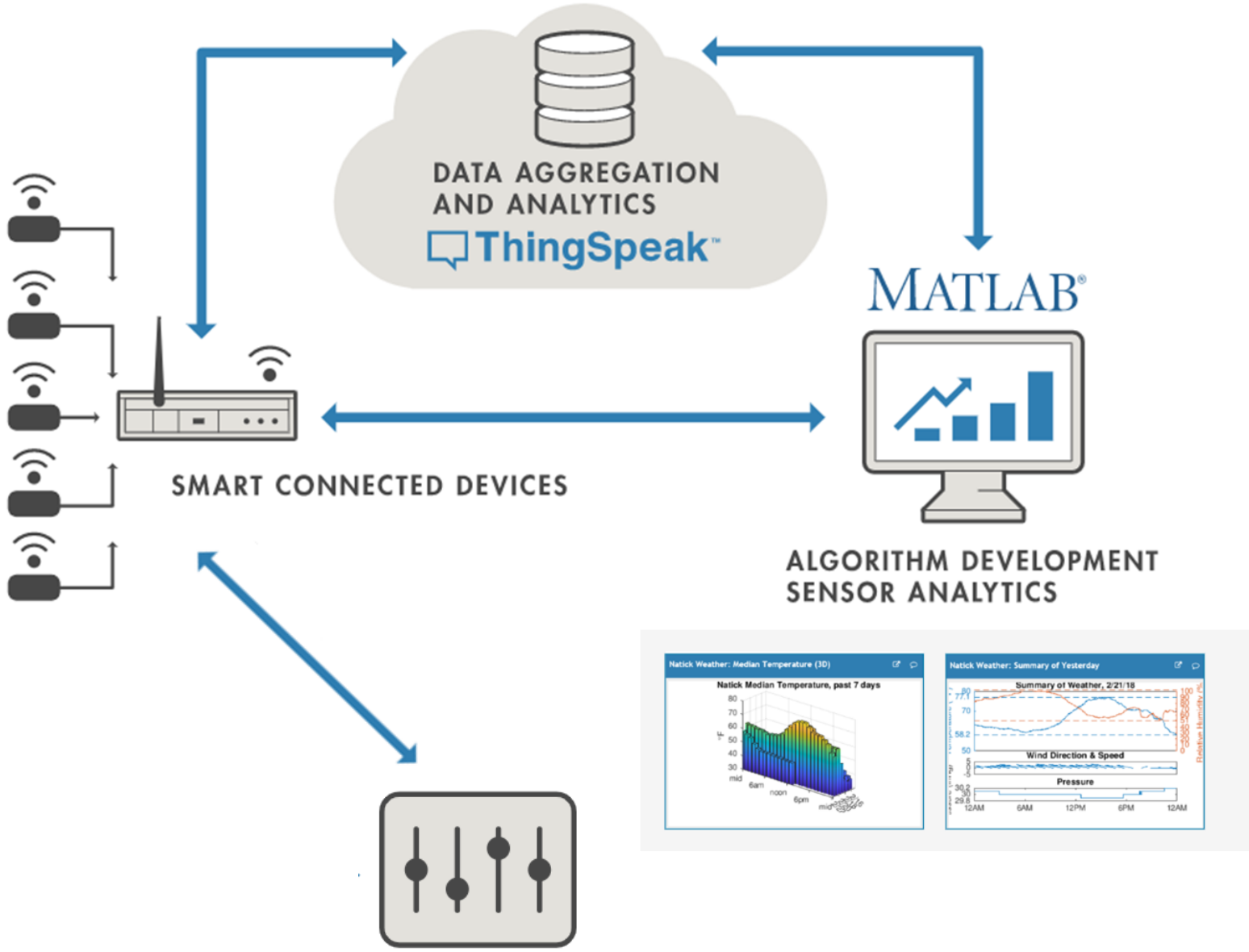
- **Digital twins** use data from sensors installed on physical objects to represent their near real-time status, working condition or position.
- **Digital twins** can be also used for monitoring, diagnostics and prognostics.



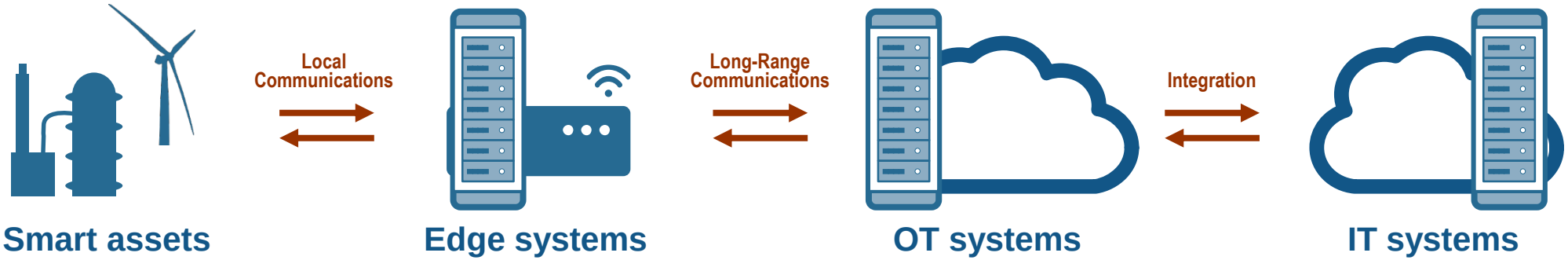
[1] https://en.wikipedia.org/wiki/Digital_Twins

Internet of Things

- Connect to Hardware
- Data Aggregation
- Control Devices
- Custom Computations and Visualization

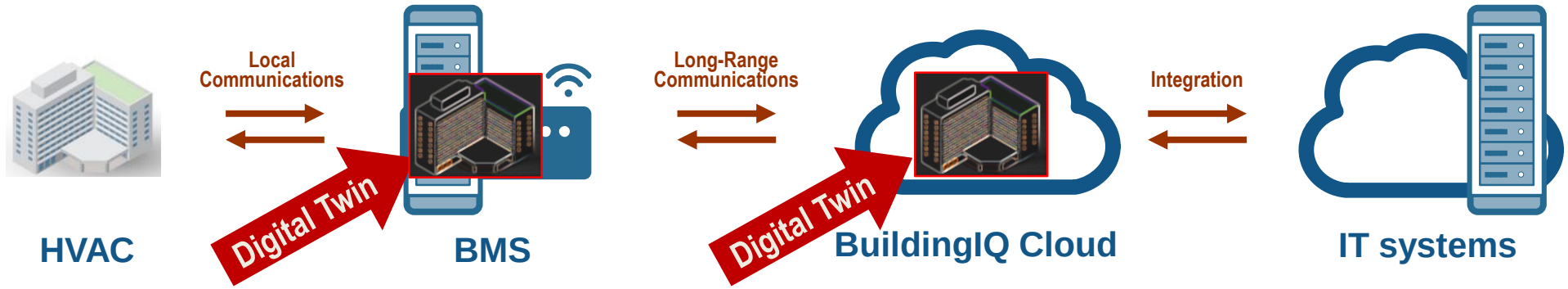


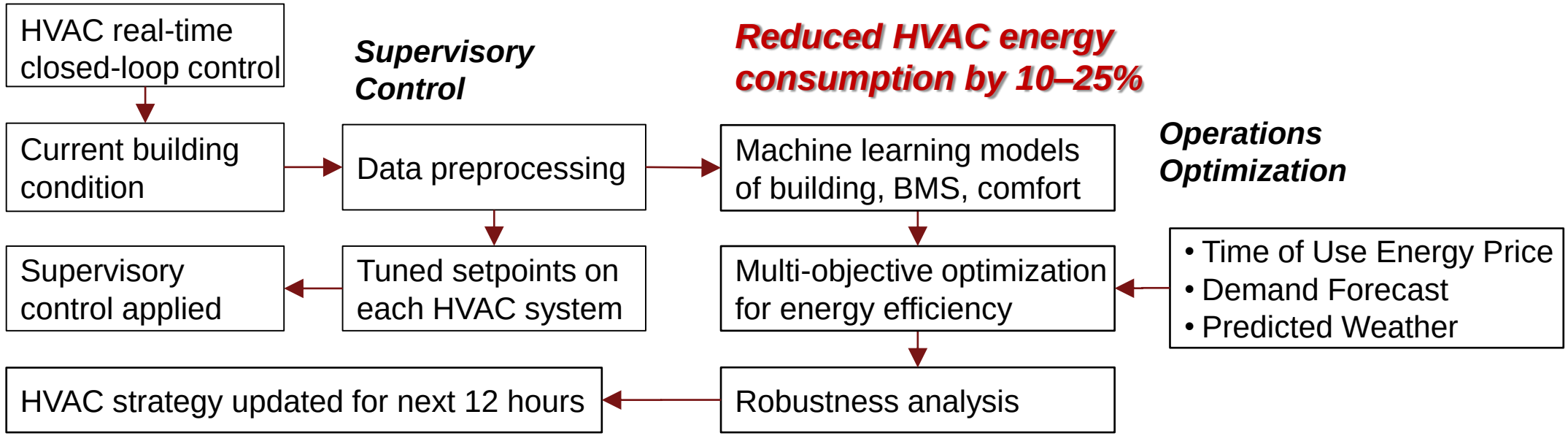
Organizations are Defining Infrastructure for Digitalization



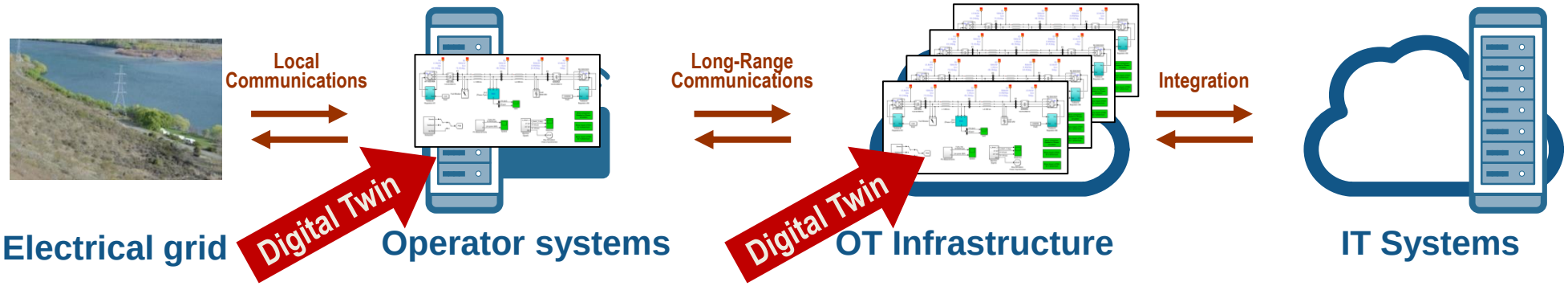
How are these used in an actual application?

Operations Optimization: BuildingIQ

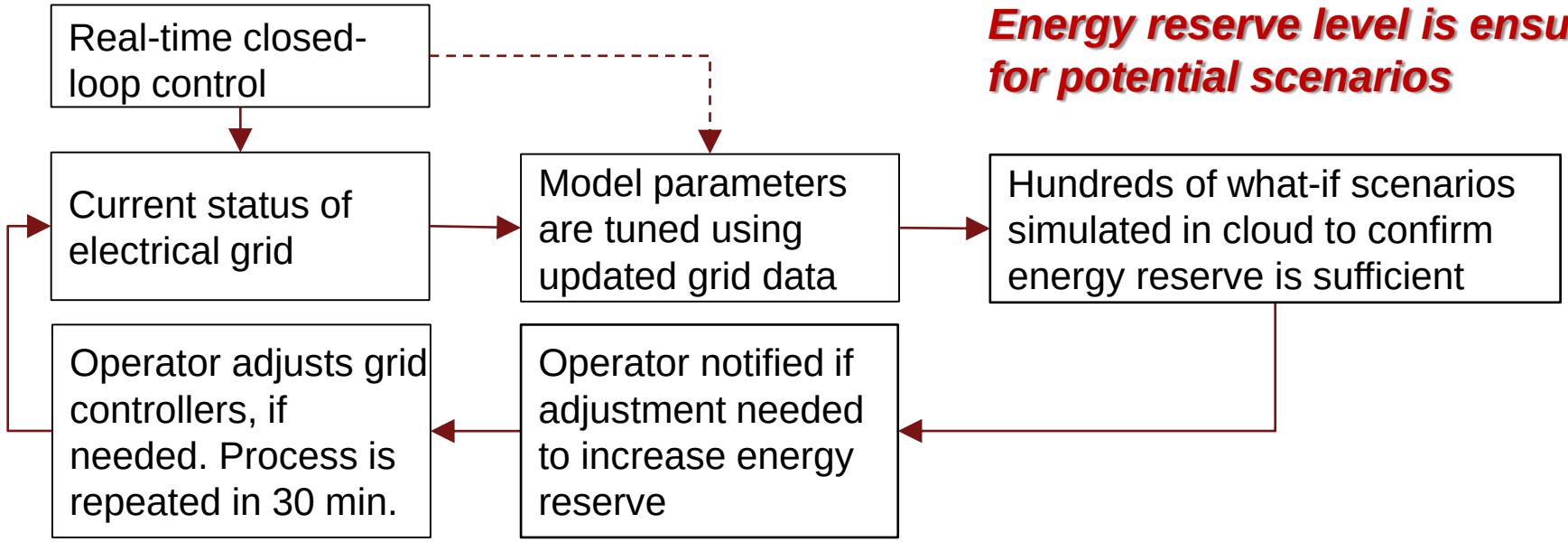




Performance Management: Electrical Grid Operator

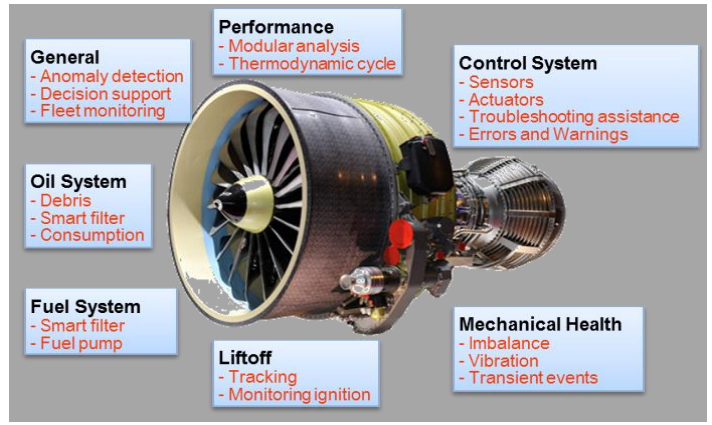


Energy reserve level is ensured for potential scenarios



Other Examples of Digital Twins Across Industries

Commercial Vehicles
Driving-data logs and digital twin used to verify and tune automatic braking system

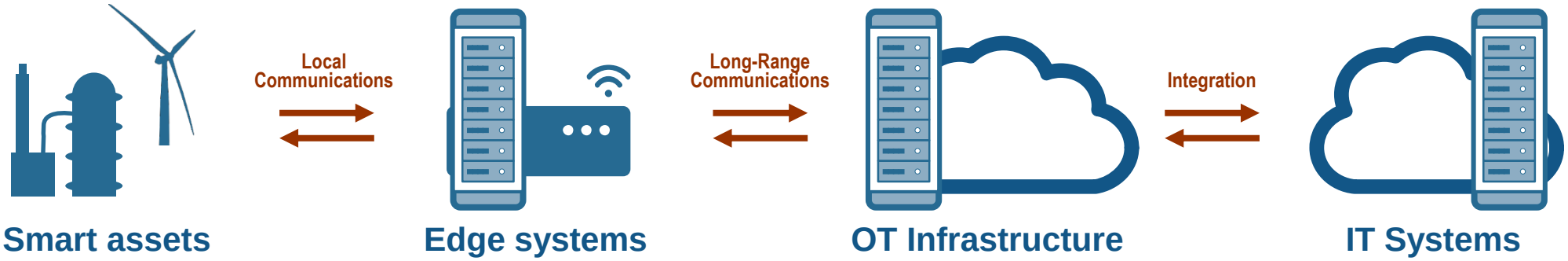


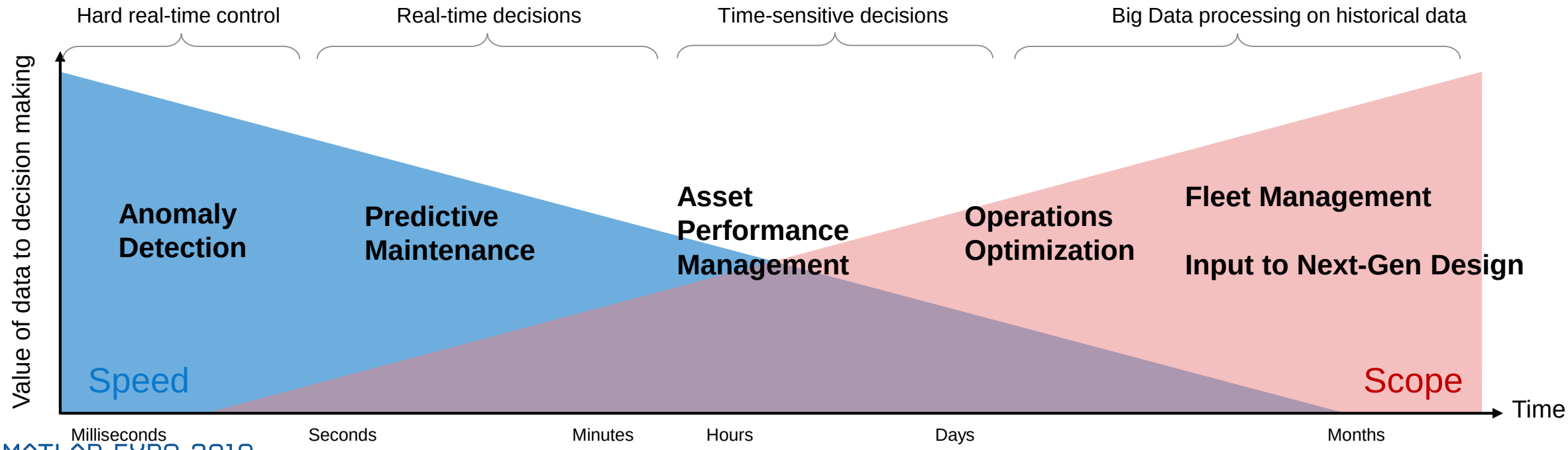
Aerospace
Operation data used to plan maintenance, improve aircraft availability, and reduce engine out-of-service time

Space
Controller retuned to adjust for degraded thruster, confirmed with digital twin, and uploaded during deep space mission

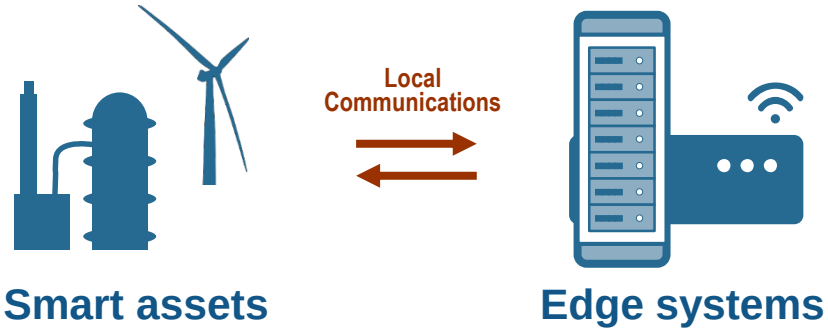
Industrial Automation
Statistical models constantly updated to inform operators when plant is performing outside of optimal range

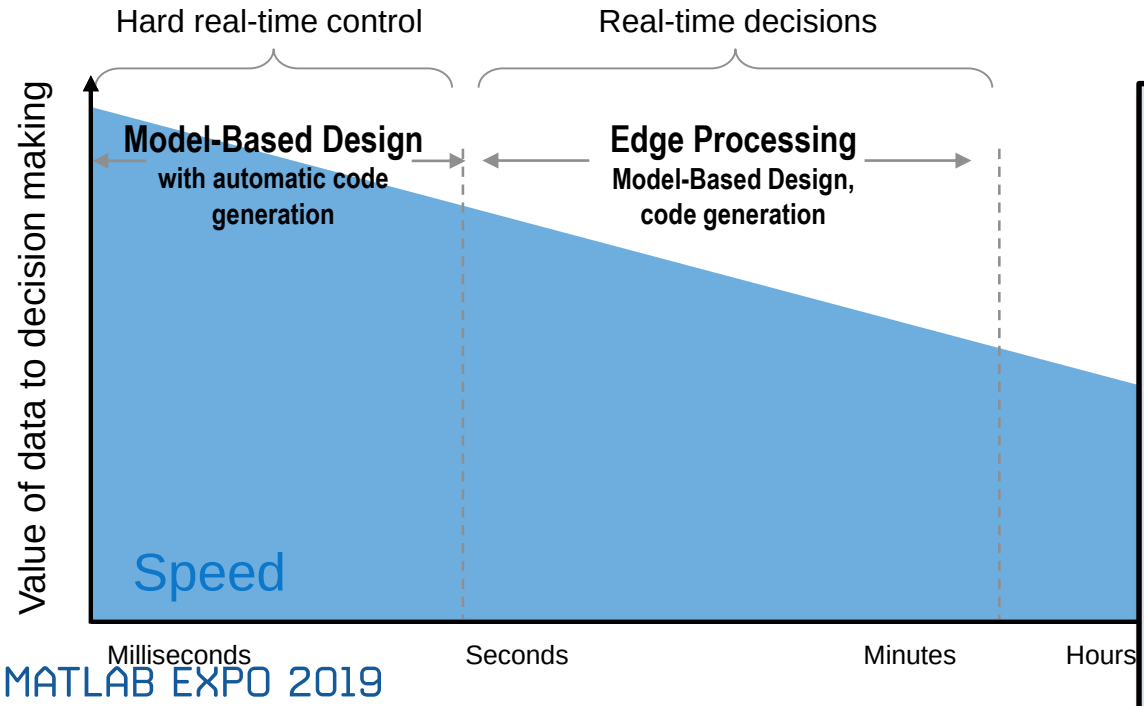
Applications at the Asset, the Edge, or Operational Technology Platform



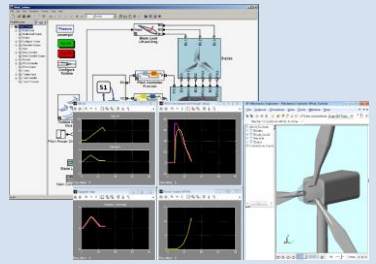


Development for Fast and Highly-Deterministic Systems

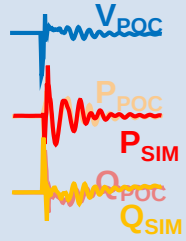




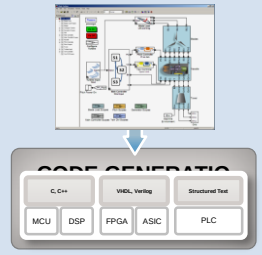
Model-Based Design



Multi-domain system Modelling

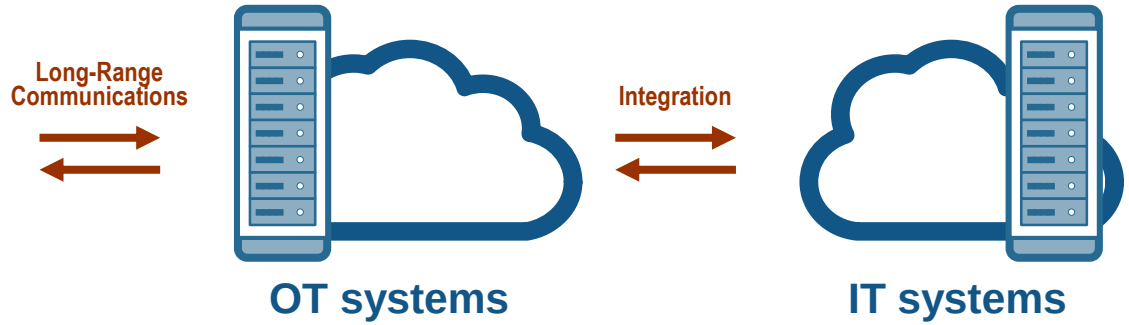


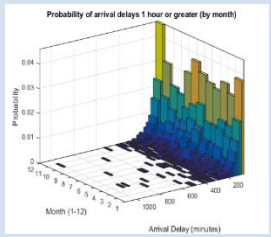
Parameter estimation



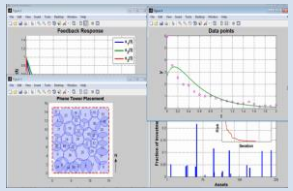
Automatic code generation

Development to OT/IT On-Prem and in Cloud

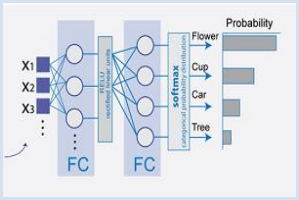




Variety and Volumes of Data

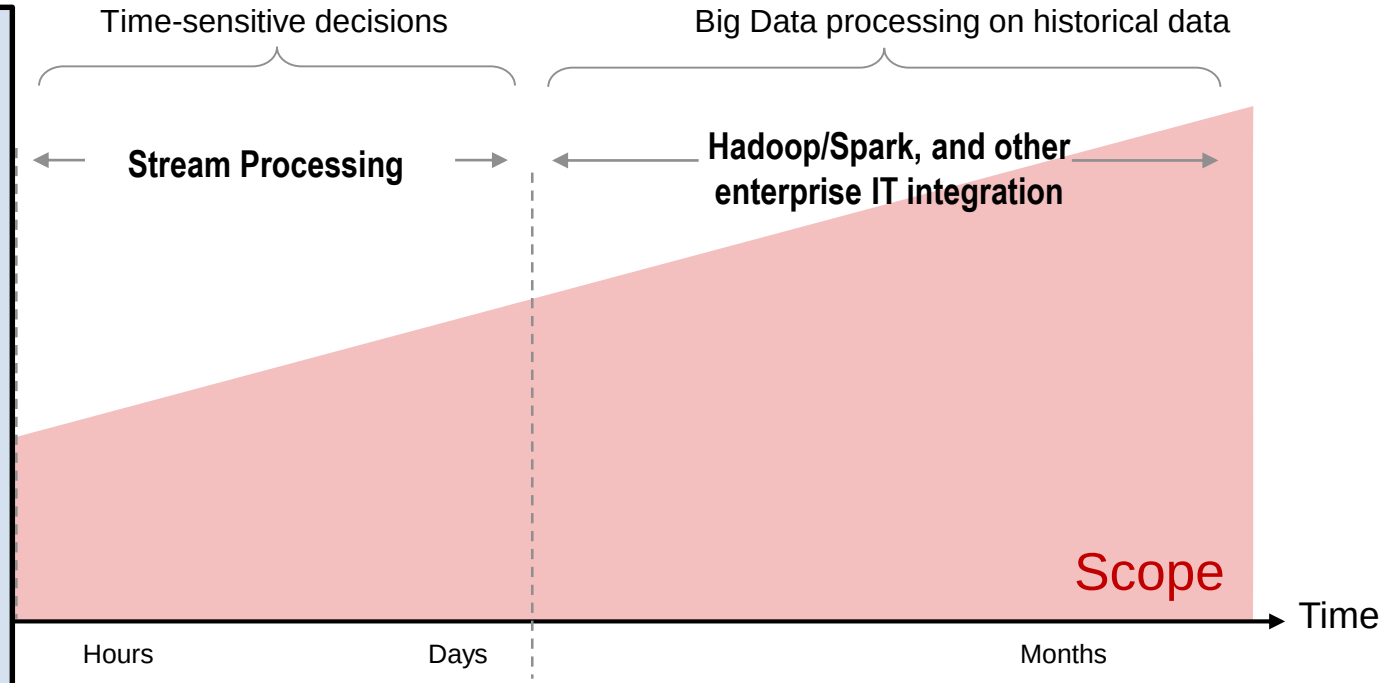


Optimization

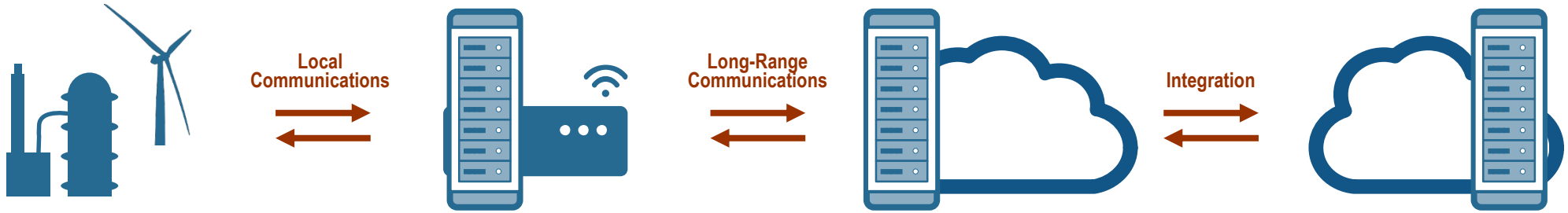


Machine Learning and Deep Learning

Enterprise system integration, (on-prem/cloud)



A Complex Collection of Tools, Platforms and Protocols



TCP/IP

MQTT

Rest APIs

Azure Stream Analytics

Azure IoT Hub

Azure

TIBCO Spotfire

amazon web services

tableau

amazon Kinesis

AWS IoT

docker

Power BI

Windows

MindSphere

thingworx

NXP

ARM

XILINX

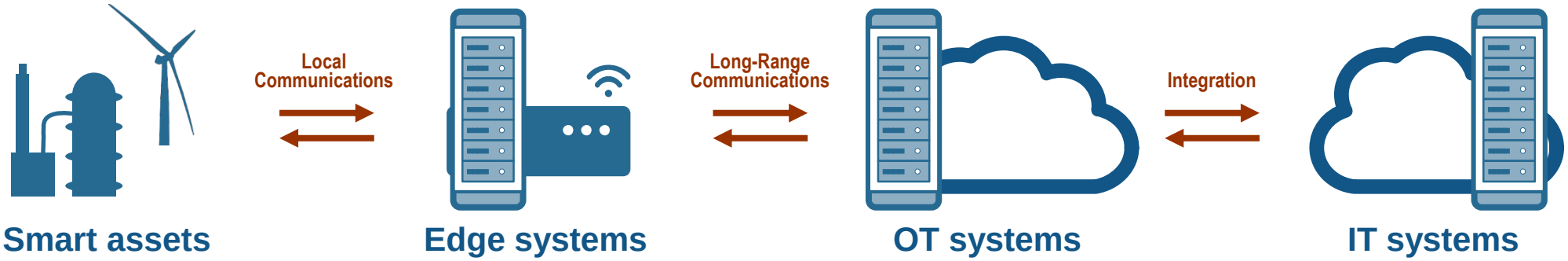
NVIDIA

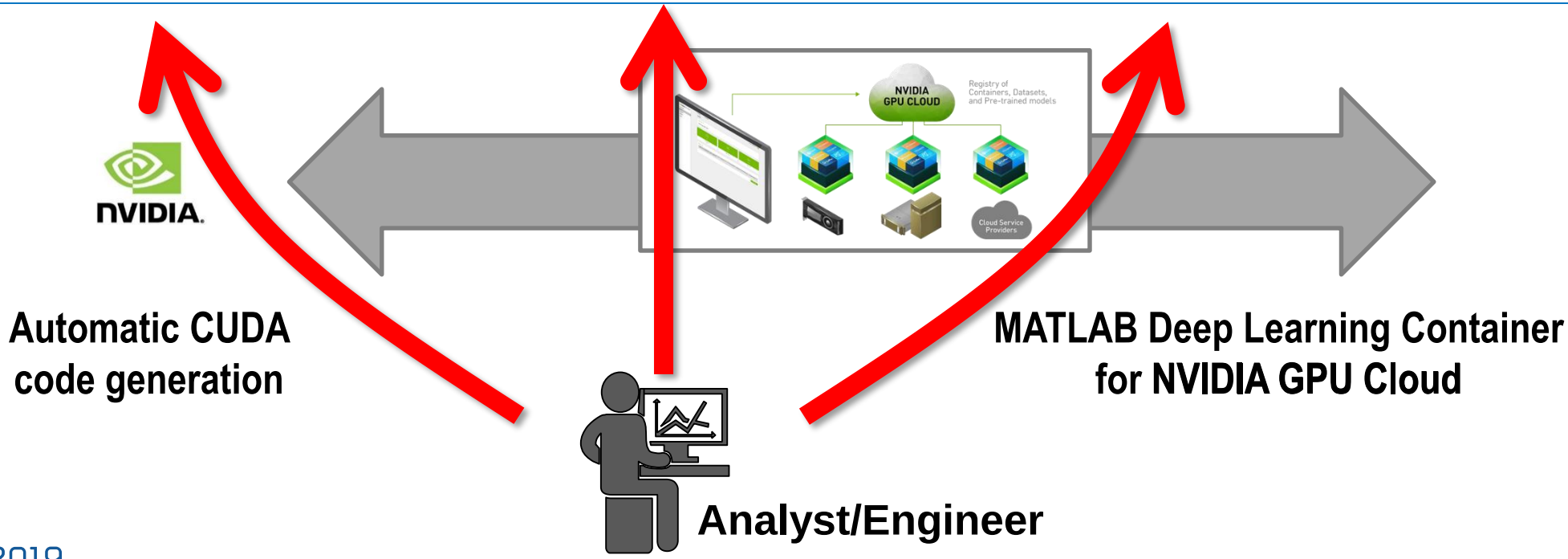
intel

life.augmented

Analyst/Engineer

A Complex Collection of Tools, Platforms and Protocols

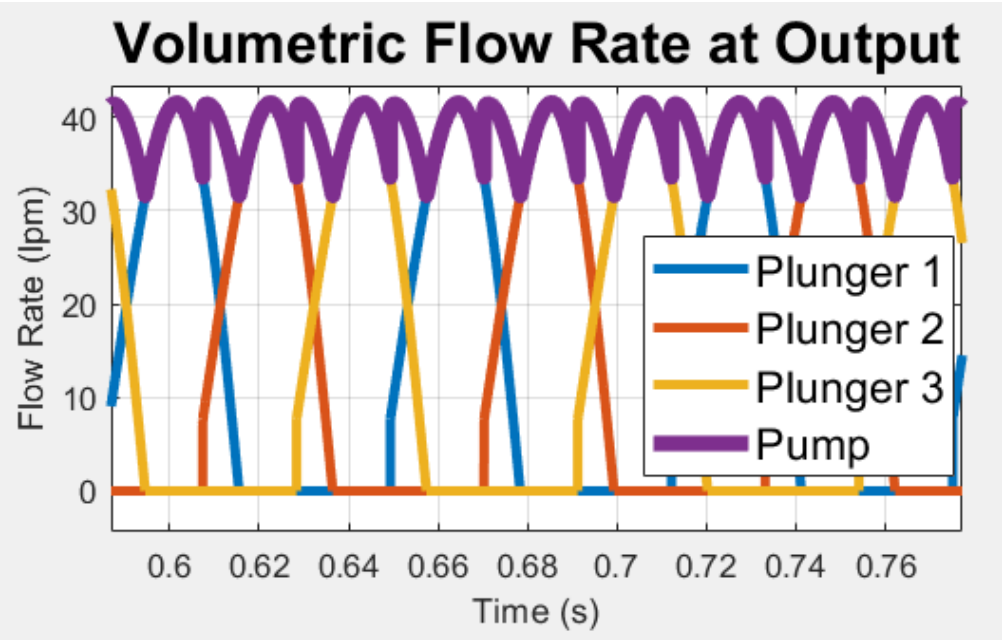


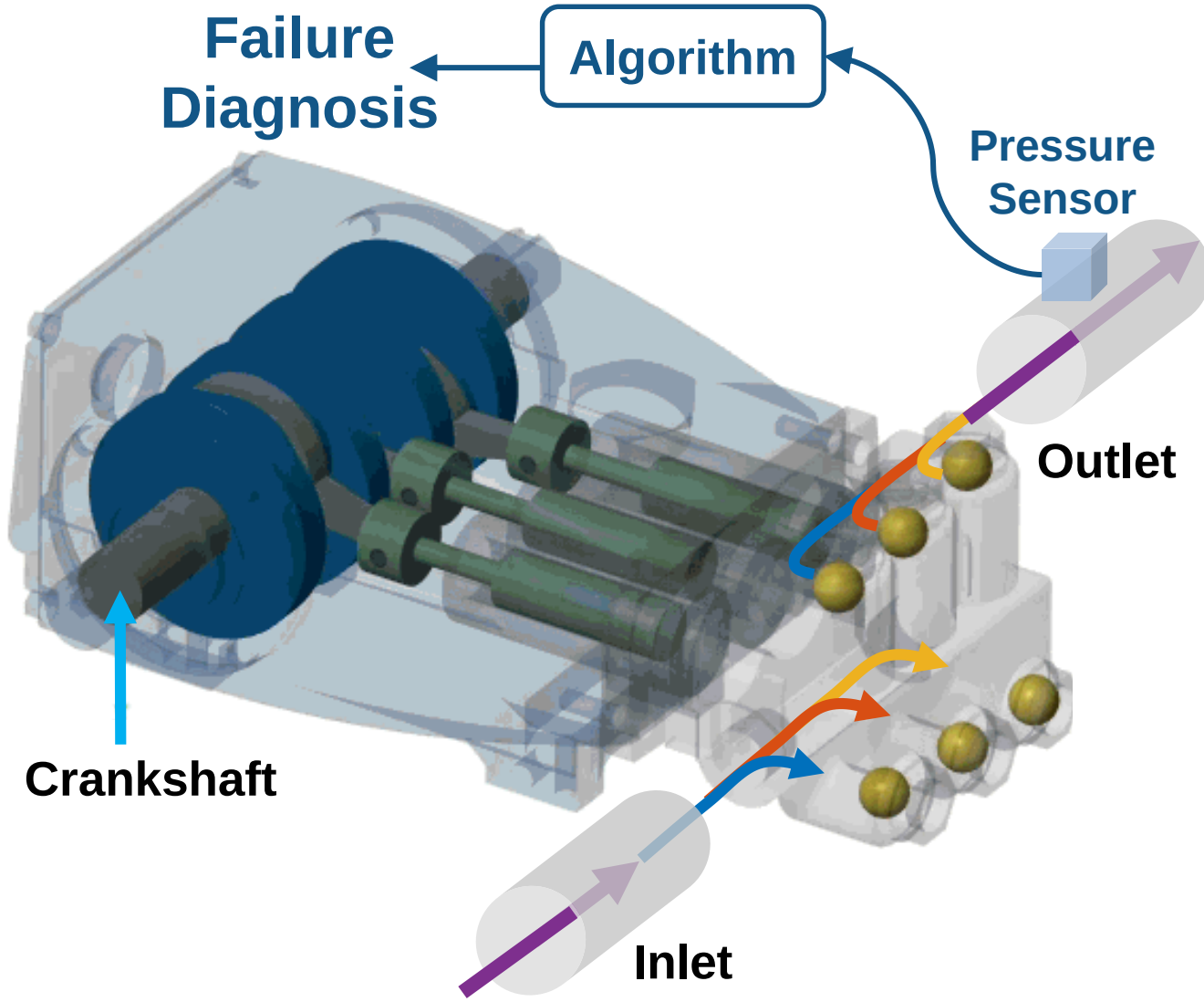


Triplex Pump

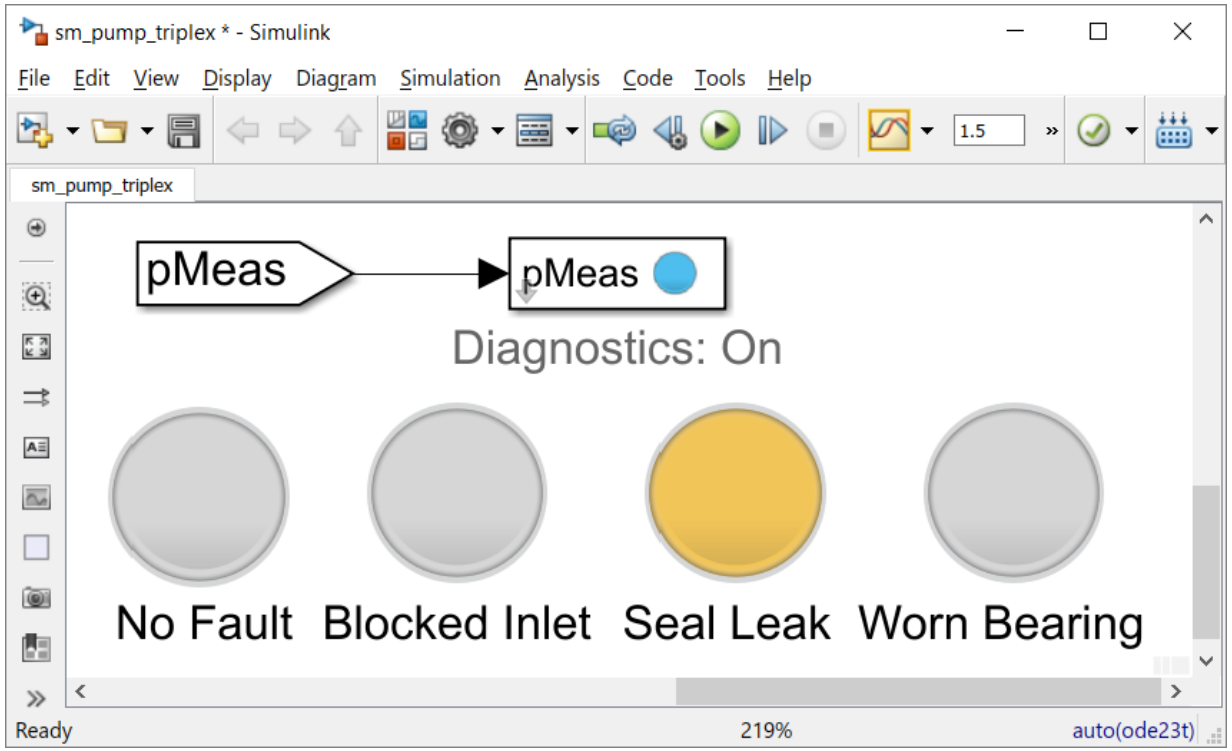
Triplex Pump

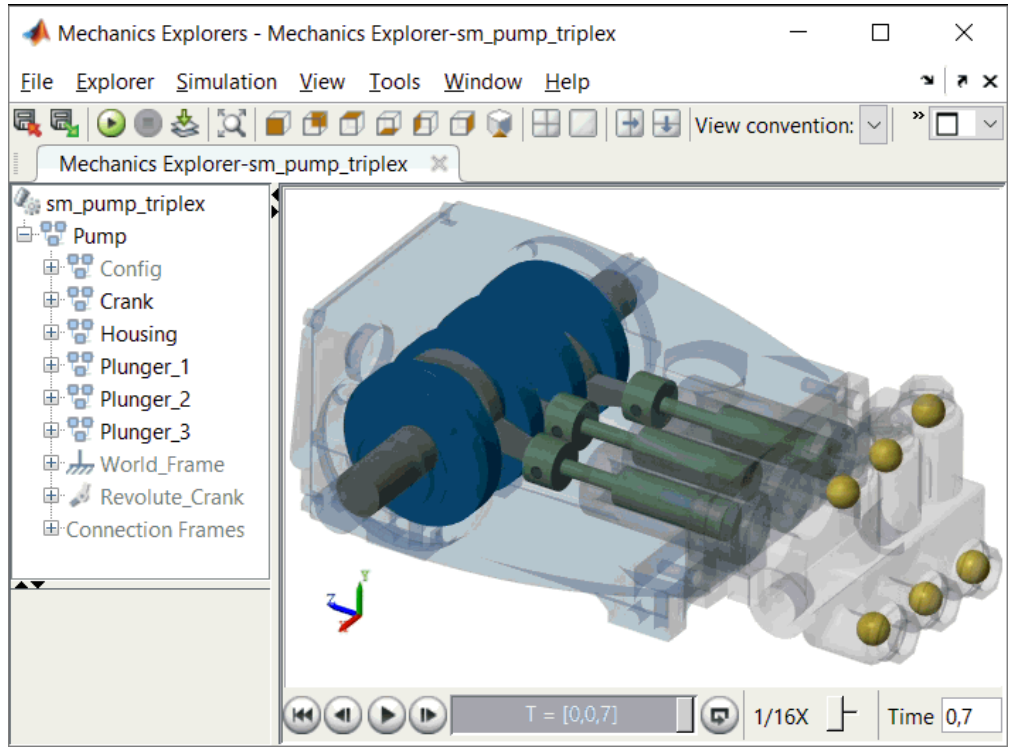
- Crankshaft drives three plungers
  - Each 120 degrees out of phase
  - One chamber always discharging
  - Smoother flow than single or duplex piston pumps

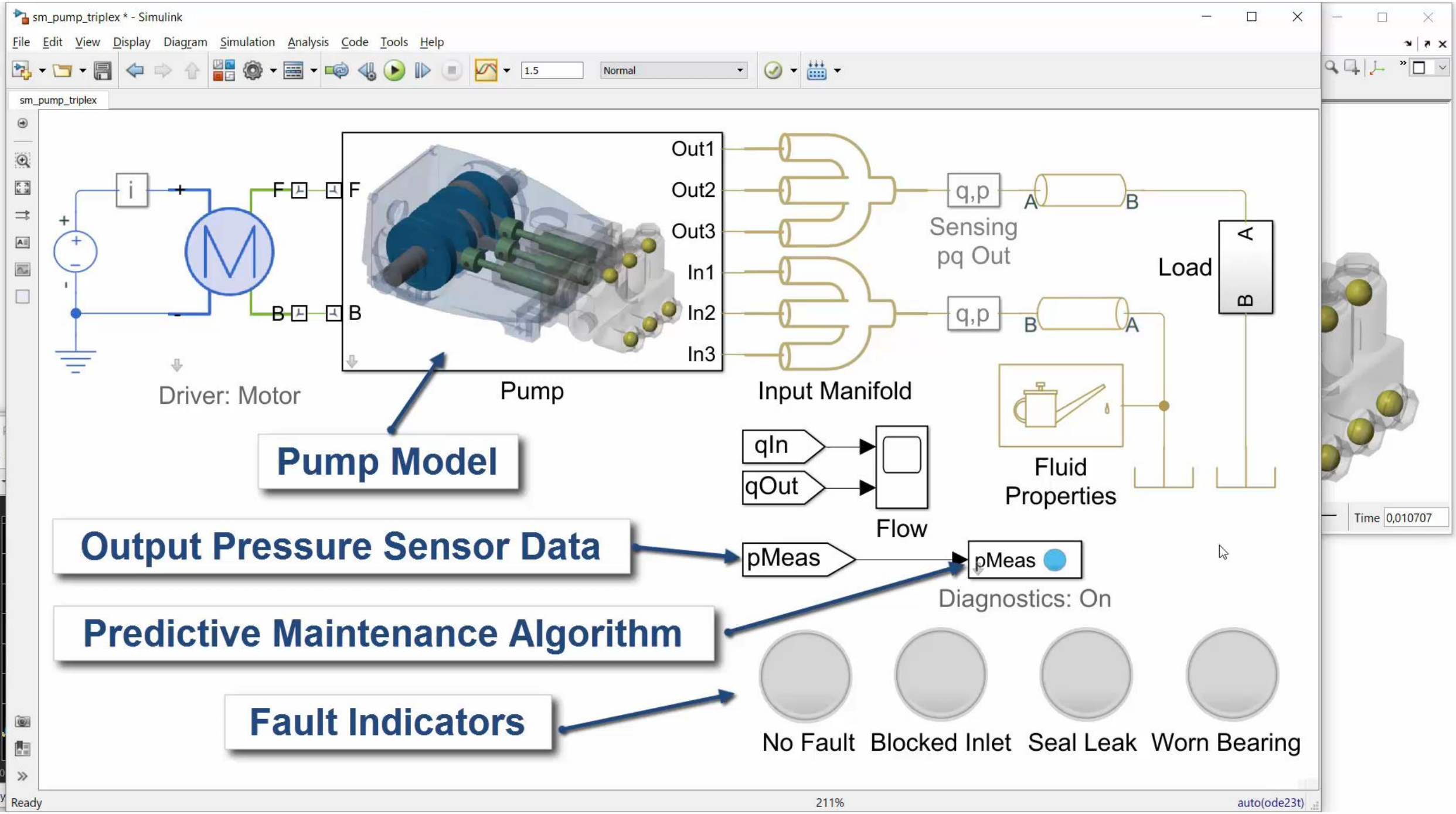




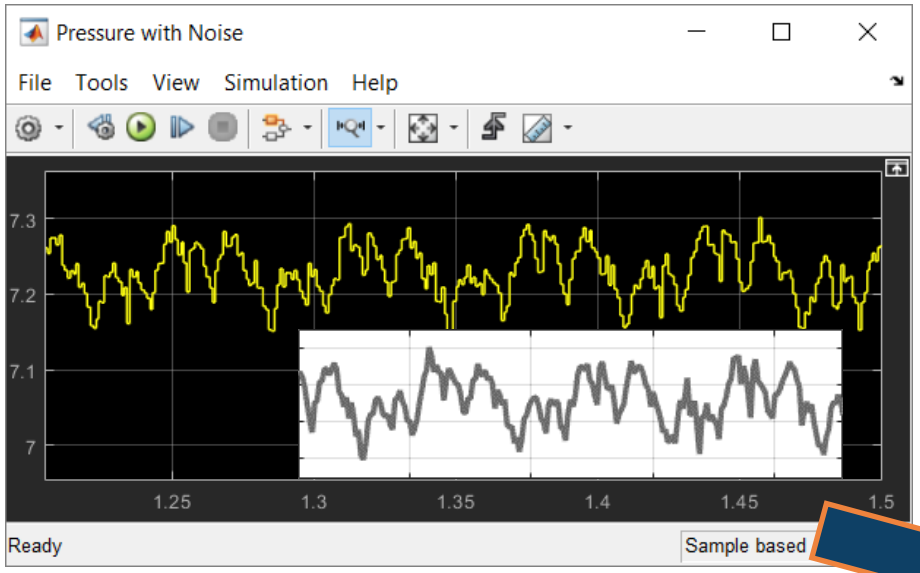
Predictive Maintenance Using Digital Twins





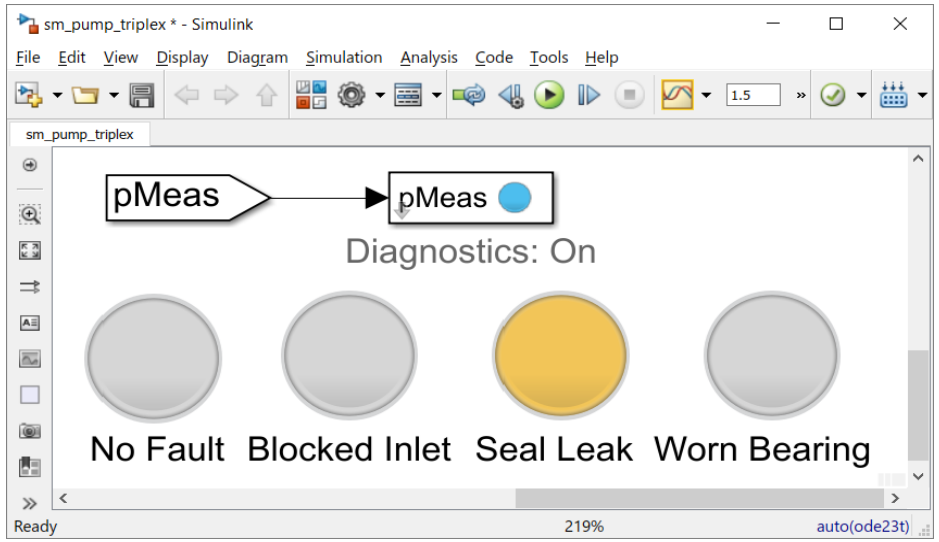

sm_pump_triplex * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
sm_pump_triplex
Driver: Motor
Pump
Input Manifold
Sensing
pq Out
Load
Fluid
Properties
Flow
Pump Model
Output Pressure Sensor Data
Predictive Maintenance Algorithm
Fault Indicators
qIn
qOut
pMeas
Diagnostics: On
No Fault
Blocked Inlet
Seal Leak
Worn Bearing
Ready
211%
auto(ode23t)

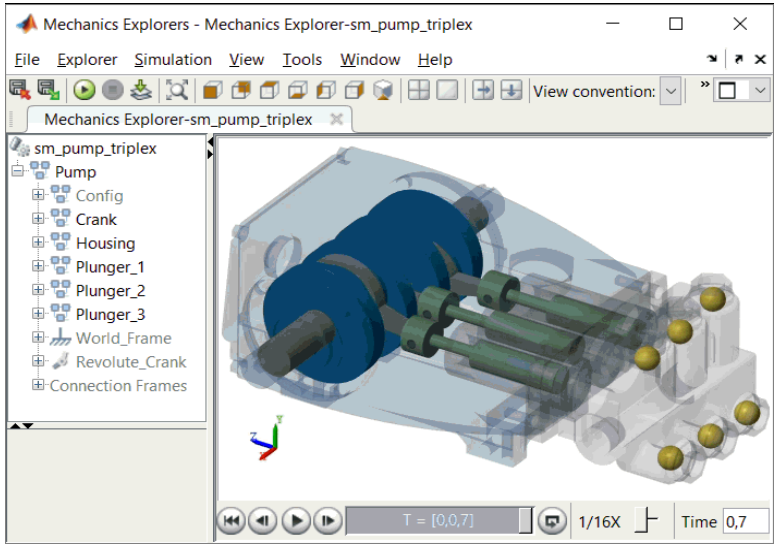
Prevent system downtime



by sending
Sensor Data

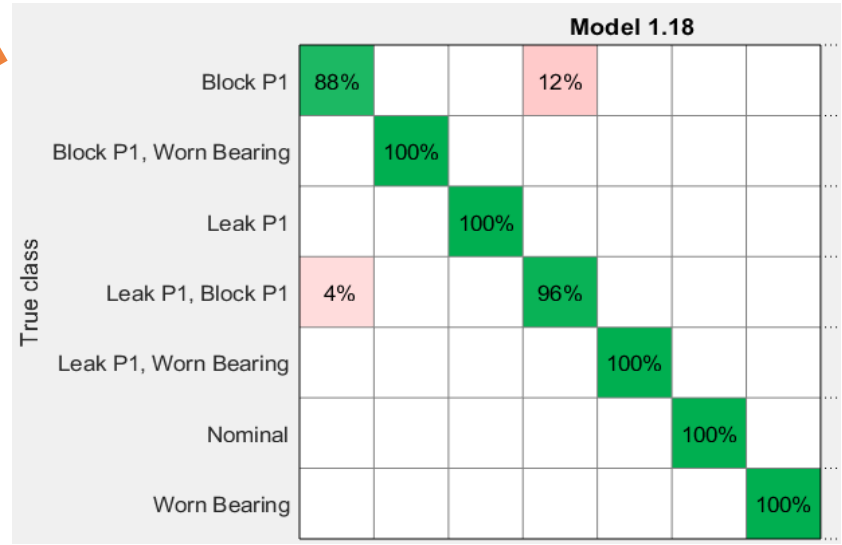
to a Predictive Maintenance algorithm





created using a
Digital Twin and

Machine Learning model in MATLAB.



Example Problems with a Triplet Replicating Pump

Triplex Pump

1 *Fault Classification is a time consuming manual process*

Current system requires operator to manually monitor operational metrics for anomalies. Their expertise is required to detect and take preventative action

2 *Trouble using data to update digital twin and make use of it*

Current system gathers operational data from the pump, but not expertise on how to leverage data to update the digital twin and apply it to run what-if analysis in a scalable way

Two Demos

Triplex Pump

1 *Fault Classification Using MATLAB*

kafka · Azure · kibana

Machine Learning fault classifier model ↔ Visualization dashboard

- MATLAB
- Statistics & Machine Learning Toolbox
- MATLAB Production Server

2 *"What-If" Analysis Using Simulink/Simscape Digital Twin*

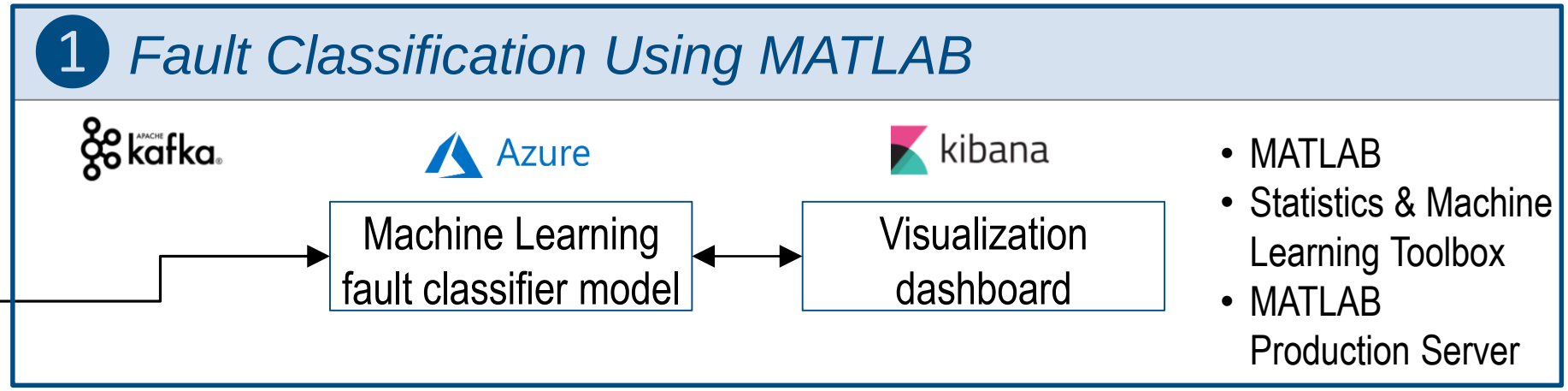
S3 Azure Blob Storage · Windows · Azure

Model tuned during operation ↔ Parallel sims to explore scenarios

- Simulink/Simscape
- Simulink Design Optimization
- MATLAB Parallel Server

Demo 1

Triplex Pump



Fault Classification is a time consuming manual process

Current system requires operator to manually monitor operational metrics for anomalies. Their expertise is required to detect and take preventative action

Demo 1

Triplex Pump

1 *Fault Classification Using MATLAB*

kafka · Azure · kibana

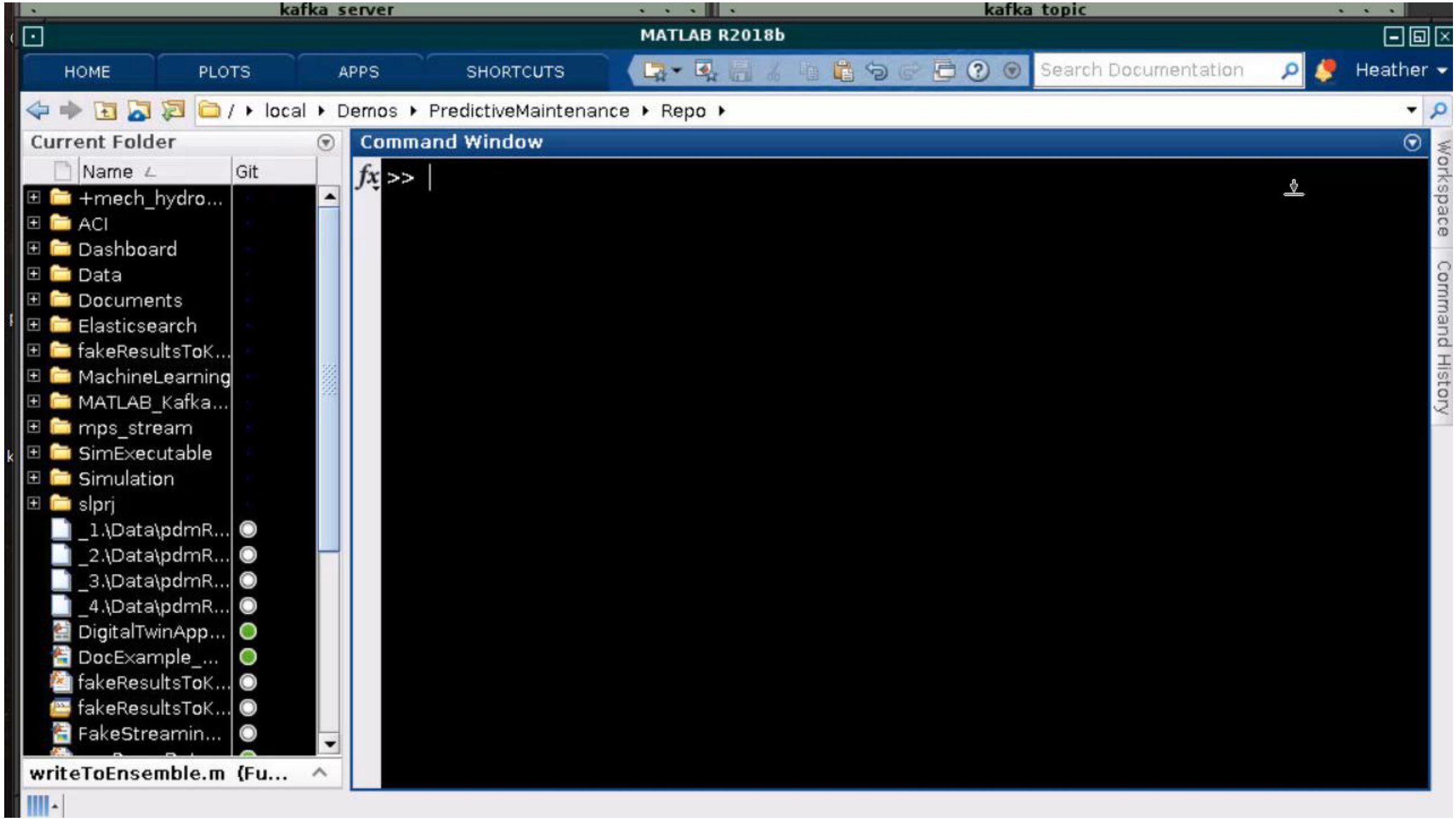
Machine Learning fault classifier model → Visualization dashboard

- MATLAB
- Statistics & Machine Learning Toolbox
- MATLAB Production Server

Data:
- Processed in chunks or
- Streaming continuously via Kafka

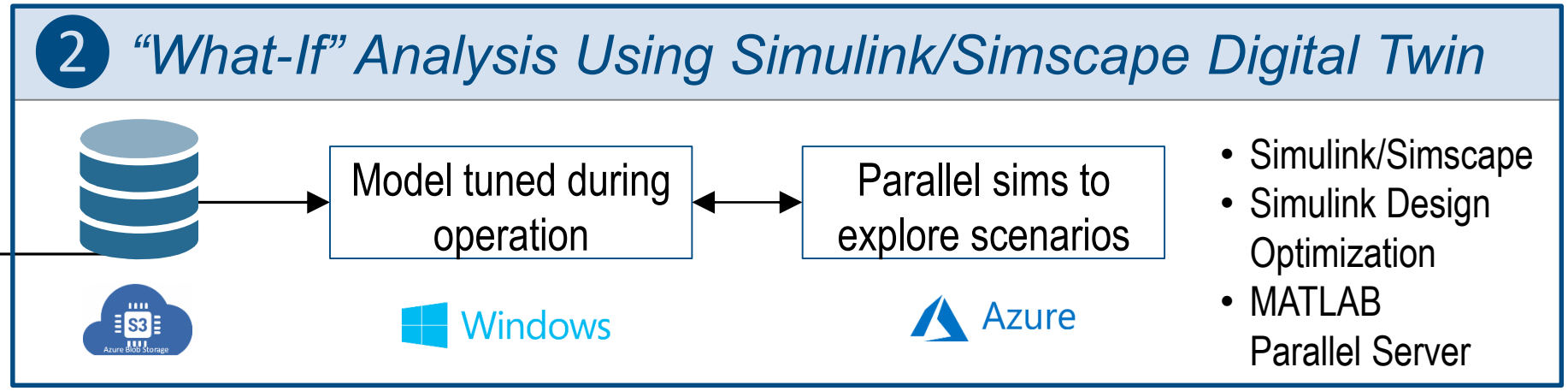
- A previously designed classifier, processes incoming stream, identifying faults
- Processing is elastic and can scale to any number of incoming streams/pumps via MATLAB Production Server

- Visualization dashboard (Kibana) shows data stream and deduced fault classification


kafka server
kafka topic
MATLAB R2018b
HOME
PLOTS
APPS
SHORTCUTS
Search Documentation
Heather
/ ▸ local ▸ Demos ▸ PredictiveMaintenance ▸ Repo ▸
Current Folder
Name
Git
+mech_hydro...
ACI
Dashboard
Data
Documents
Elasticsearch
fakeResultsToK...
MachineLearning
MATLAB_Kafka...
mps_stream
SimExecutable
Simulation
slprj
_1.\Data\pdmR...
_2.\Data\pdmR...
_3.\Data\pdmR...
_4.\Data\pdmR...
DigitalTwinApp...
DocExample_...
fakeResultsToK...
fakeResultsToK...
FakeStreamin...
writeToEnsemble.m (Fu...
Command Window
fx >>
Workspace
Command History

Demo 2

Triplex Pump



Trouble using data to update digital twin and make use of it

Current system gathers operational data from the pump, but not expertise on how to leverage data to update the digital twin and apply it to run what-if analysis in a scalable way

Demo 2

Triplex Pump

2 "What-If" Analysis Using Simulink/Simscape Digital Twin

Model tuned during operation

Parallel sims to explore scenarios

Windows

Azure

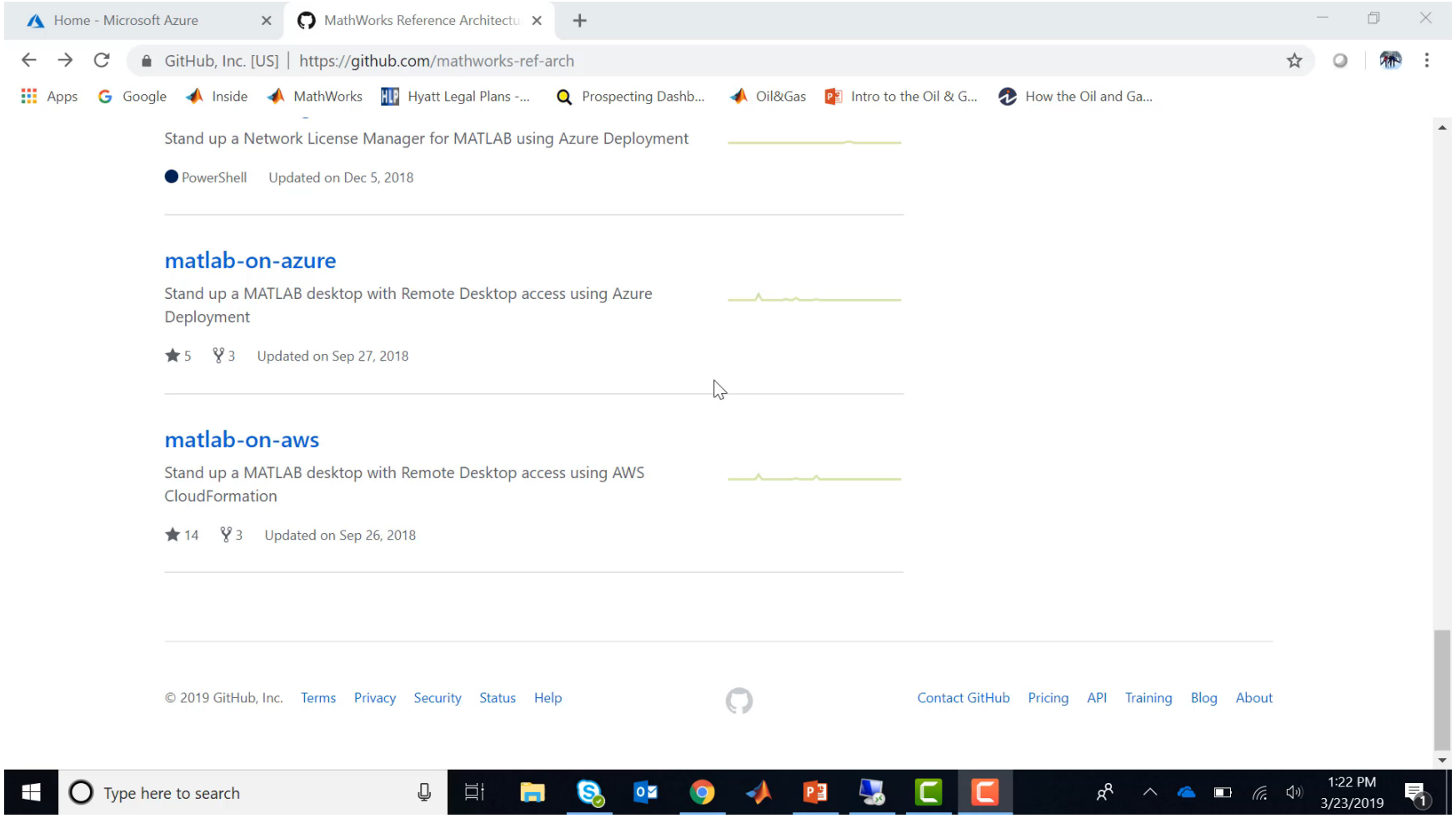
- Simulink/Simscape
- Simulink Design Optimization
- MATLAB Parallel Server

- Data streaming from asset, saved and selected for tuning using cloud storage connectivity

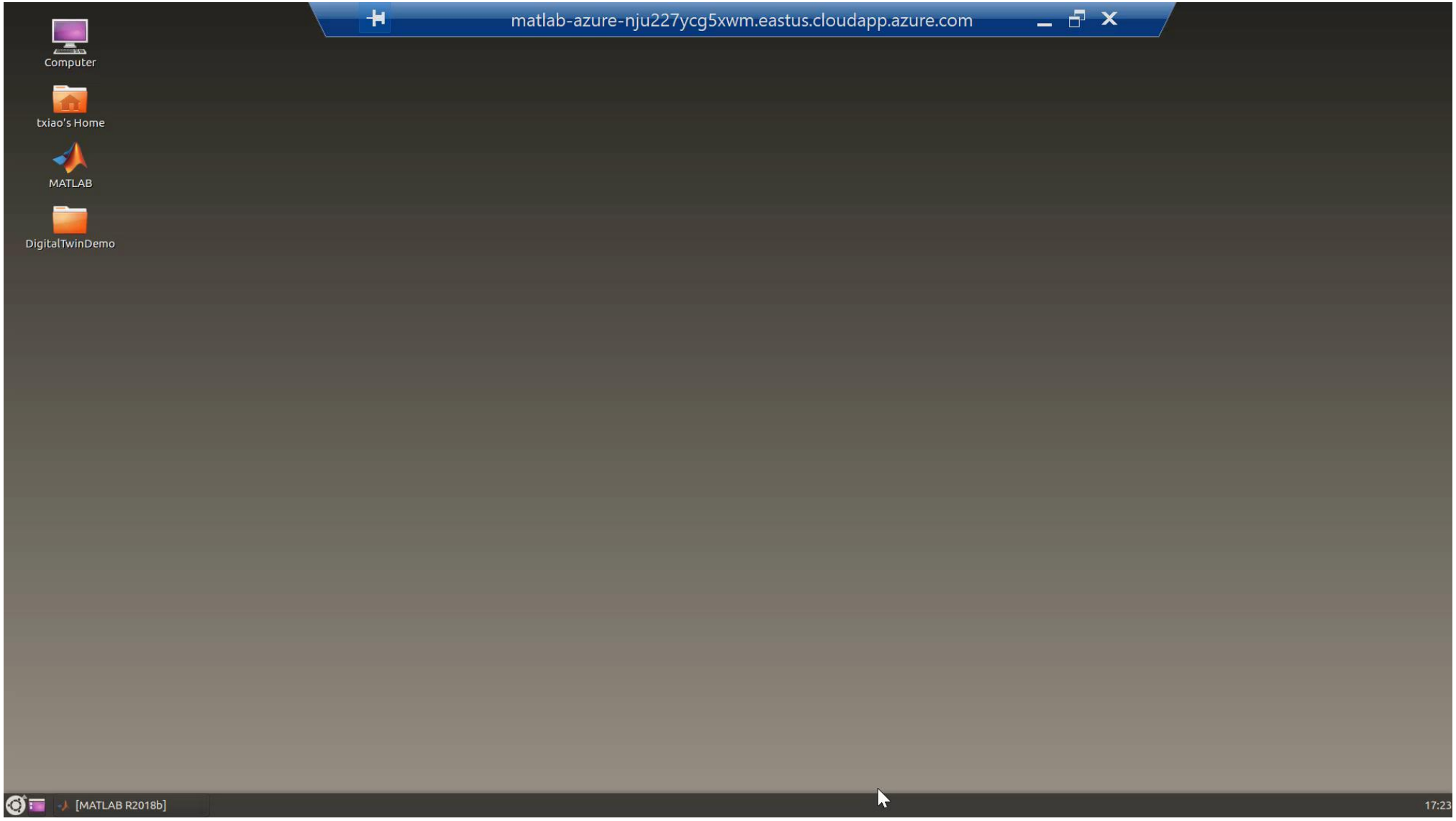
- Tune Digital Twin Parameters from latest available data from real asset using Simulink Design Optimization

- Run 100s "what-if" Scenarios with
- Parallel Server reference architecture on Azure
- Process output for possible operational decision

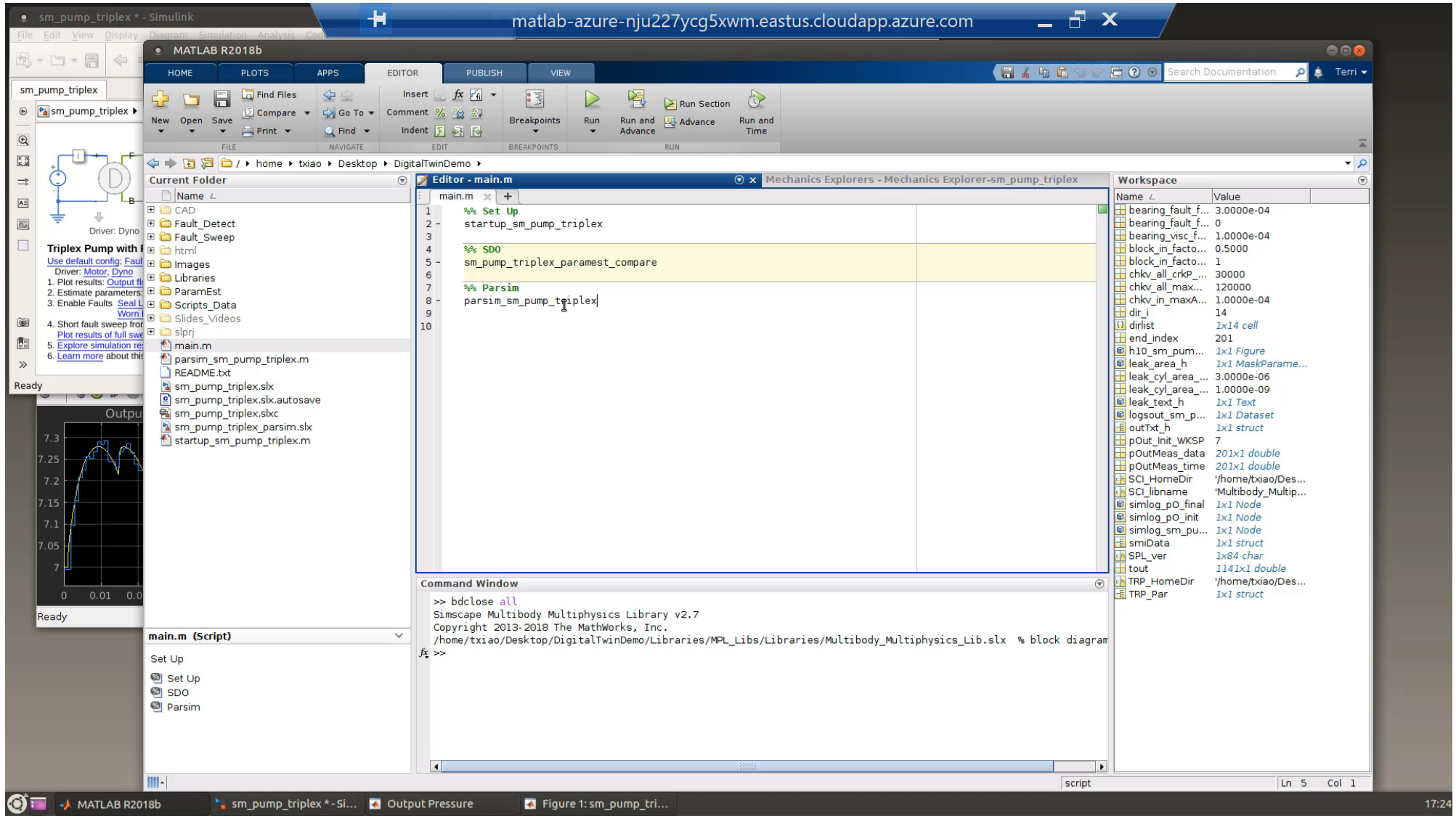
Demo 2 part I: Setting up MATLAB Reference Architect on Azure



Demo 2 Part II: Updating Digital Twin with Parameter Estimation



Demo 2 Part III: Run What-if Analysis From Current State



Two of Many Options

Triplex Pump

- In addition to the approaches shown in these two demos, there are other ways to use MATLAB and Simulink to operationalize your applications
- These include running MATLAB and Simulink directly on the platform, deploying compiled applications, running generated code, and more
- We can work with you to define the right approach, based on your application requirements

In Conclusion

- You can use MATLAB and Simulink for IIoT and Digital Twin applications, leveraging their strong Modelling, system simulation, and data analytics capabilities

- MathWorks can help you get your project started with applications such as predictive maintenance, operations optimization, and fleet management

Call to Action:

Talk to us about your IIoT and Digital Twin applications today

IIoT and Digital Twin Relevant Solution Pages

- A view on the breath of MathWorks IIoT integration options
- MathWorks support on-prem and public cloud operations
- Physical Modelling
- Predictive Maintenance
- Data Science with MATLAB
- MathWorks products access for startups
- Service offering with consulting
- Third Party Connections