MATLAB EXPO 2019

Industrial IoT and Digital Twins

Pallavi Kar

Key Takeaways

- Use Industrial applications to learn about:
  - IIoT architecture
  - Building and Using Digital Twin

- MathWorks key building blocks for developing IIoT applications:
  - Data Analysis and Physical Modeling
  - Operational Deployment and Integration

- MathWorks teams can help you get your project started
  - Training
  - Consulting

Digital Transformation and IIoT

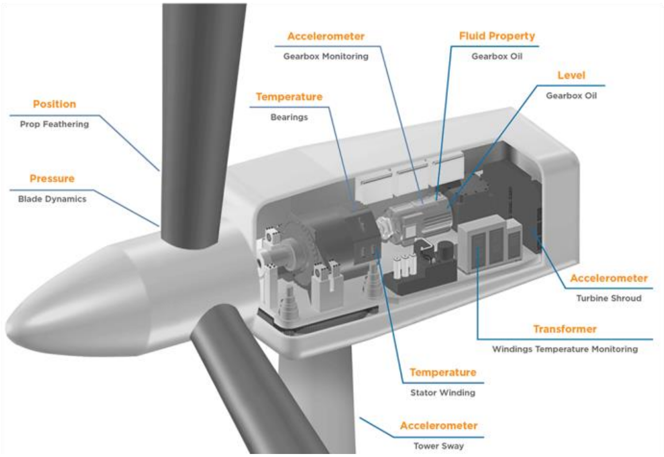
Customer Goal

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**



Transpower Ensures Reliability of New Zealand National Grid with Reserve Management Tool

"We record frequencies on the grid, inject them into our Simulink model, and compare the simulation results to the actual system response. With Simulink we can continually calibrate and improve our model, and ultimately improve the accuracy of our reserve estimates."

— *Heidi Heath, Transpower*

Transmission lines near Transpower's Benmore substation.

Challenge

Calculate the amount of reserve power needed to ensure that New Zealand's national grid can continue to operate if a generator fails

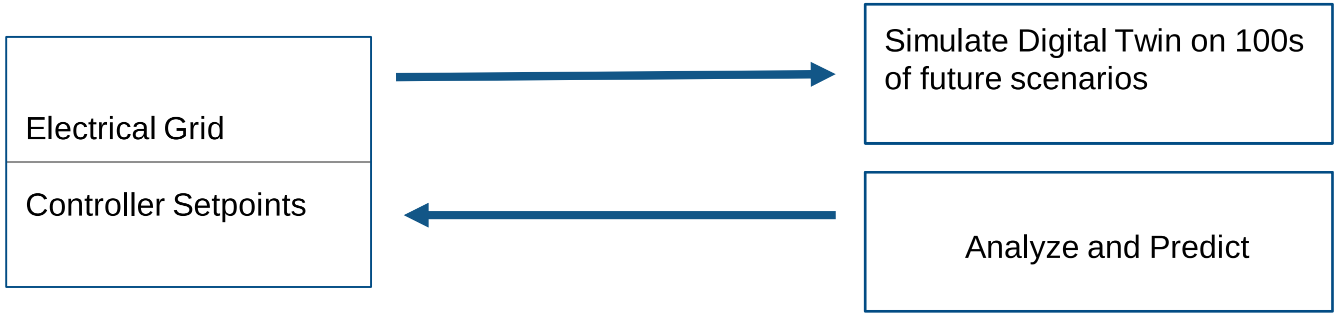
Solution

Use Simulink to run simulations of the entire grid, including generators, loads, and HVDC links, every 30 minutes

Results

- Critical updates rapidly implemented
- Simulations verified using real data
- Updates made in-house

Case Study:



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>
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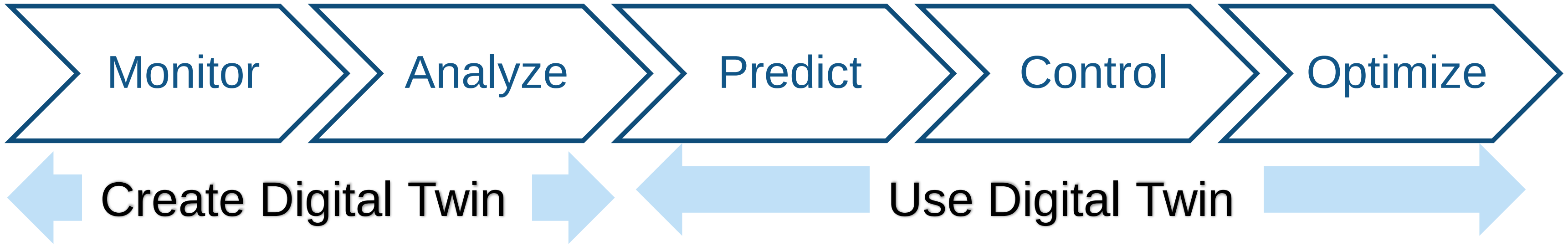
Objective: Always have enough reserve energy

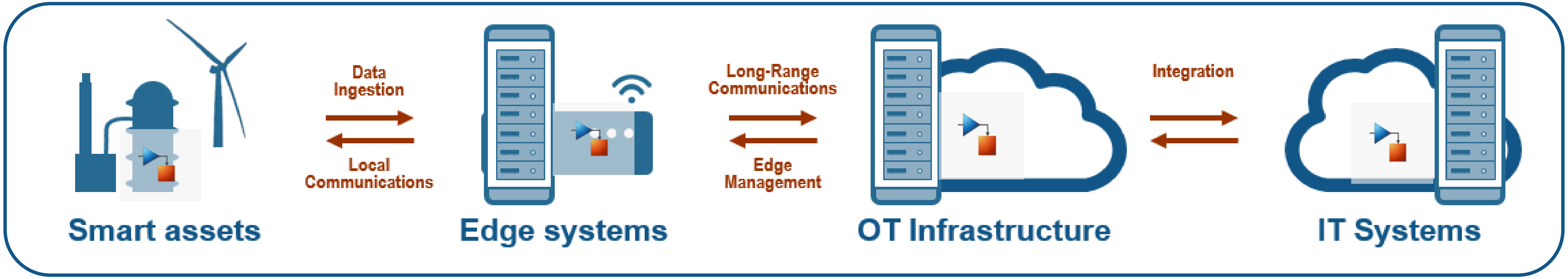
Digital Twin:

- Simulink model of entire grid
- Simulate 100s future scenarios to predict maximum energy needed.

Outcome: Provided operators control setpoints for sufficient energy reserves

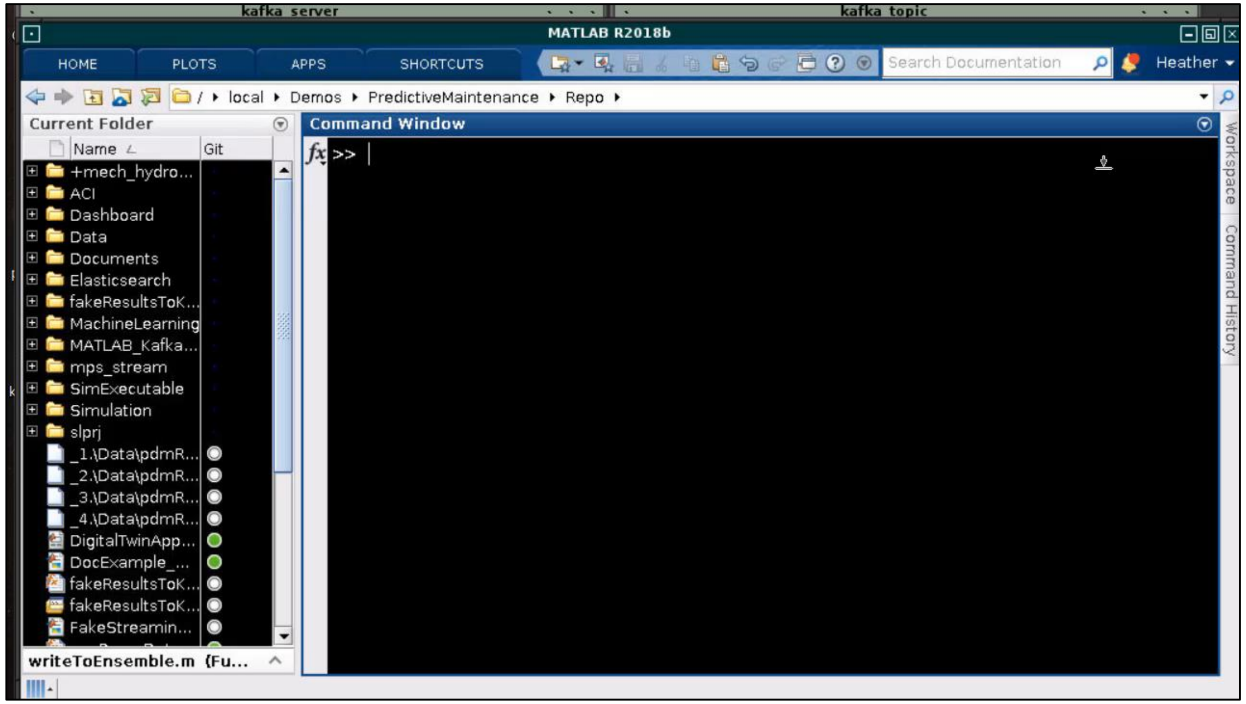


Industrial IoT architecture

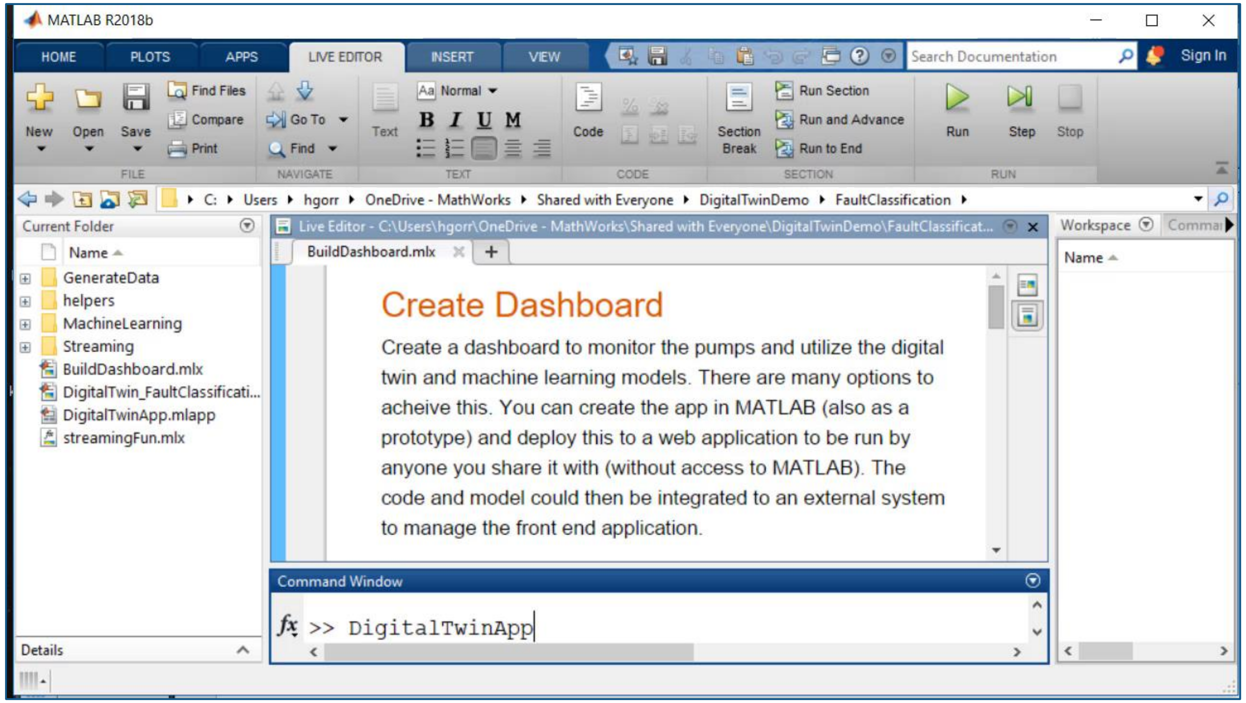


Hard real-time control	Real-time decisions	Time-sensitive decisions	Big Data processing on historical data
Model-Based Design with MATLAB & Simulink, code generation	**Edge Processing** Model-Based Design, code generation	**Stream Processing** with MATLAB Production Server	**Hadoop/Spark integration** with MDCS, Compiler
C/C++	MQTT.ORG C/C++	kafka Kinesis Event Hub	hadoop Apache Spark

Estimate Remaining Useful Life using Digital Twin



Edge Device Publishing Data



Consume data and Update RUL

Challenges in building IIoT applications:

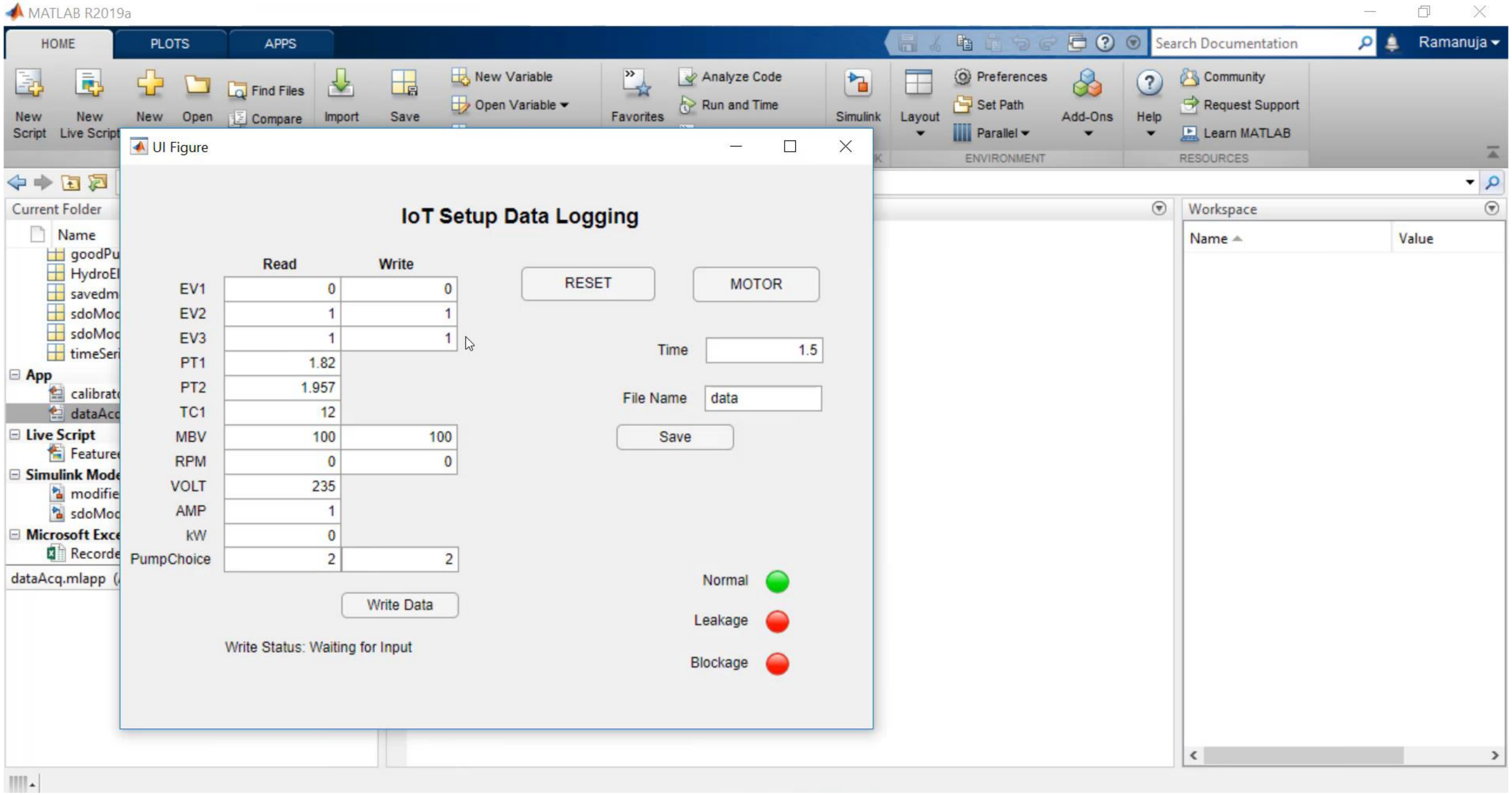
– Data is not available to represent every operating scenario

– Receive rapid streams of data to maintain effective Digital Twins

– Scale your Digital Twins to match the number of assets

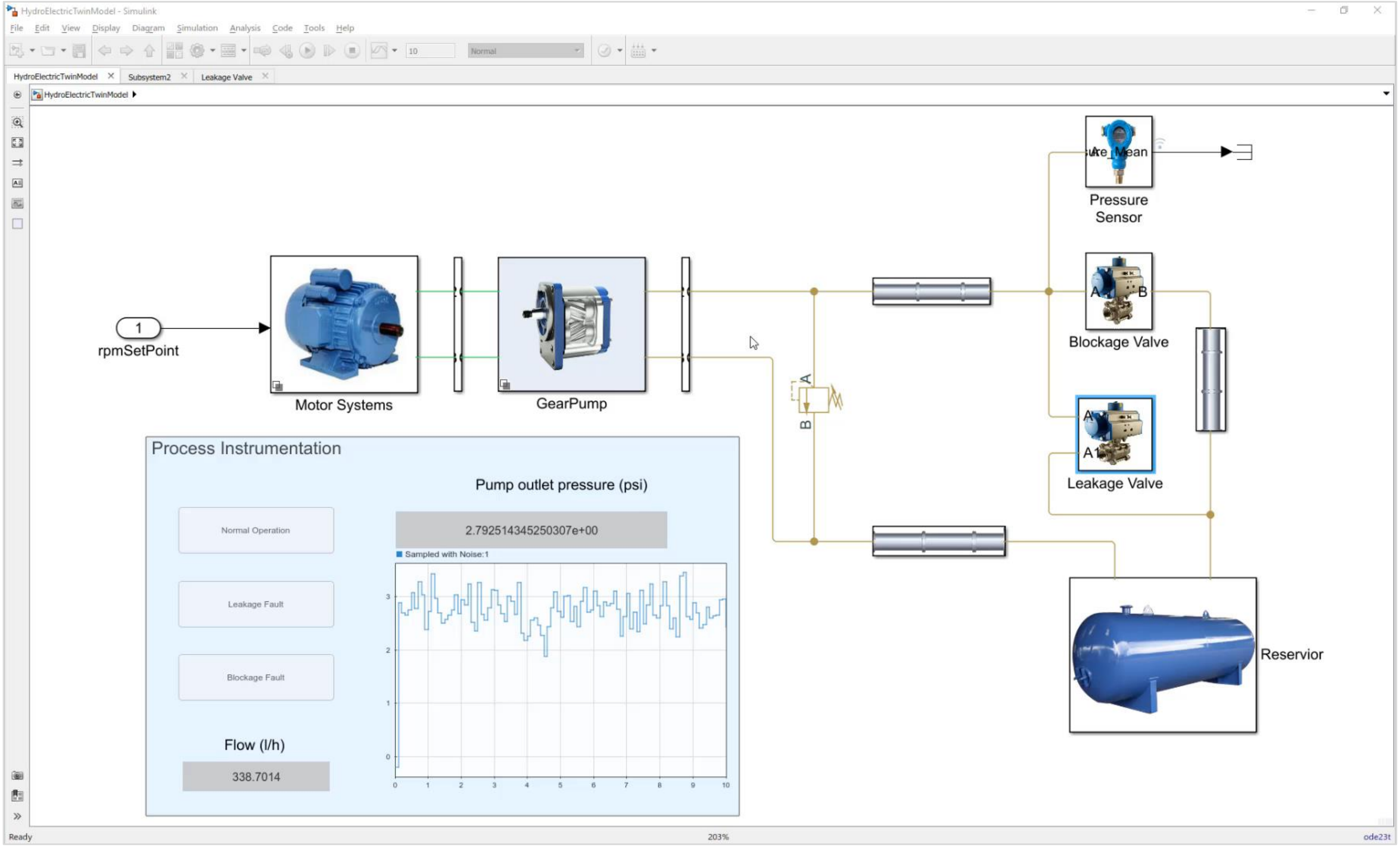
– Keep Assets, Digital Twins and Analytics connected at all times

Realtime Condition Monitoring Detection



Creating Multi-Domain Physical Models using Simscape

Monitor → Analyze → Predict → Control → Optimize



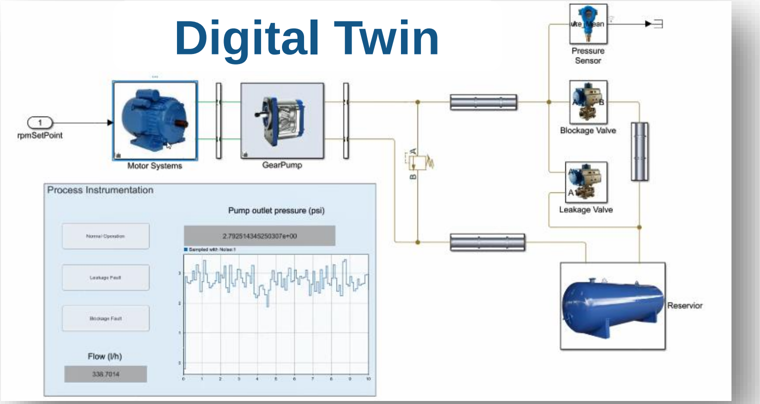
Pump Hardware

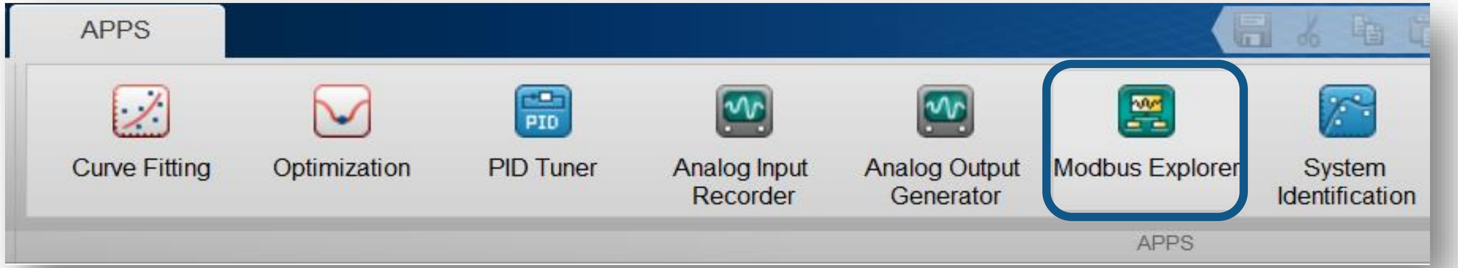
Acquire Real-Time Data for Updating Digital Twin

Monitor → Analyze → Predict → Control → Optimize

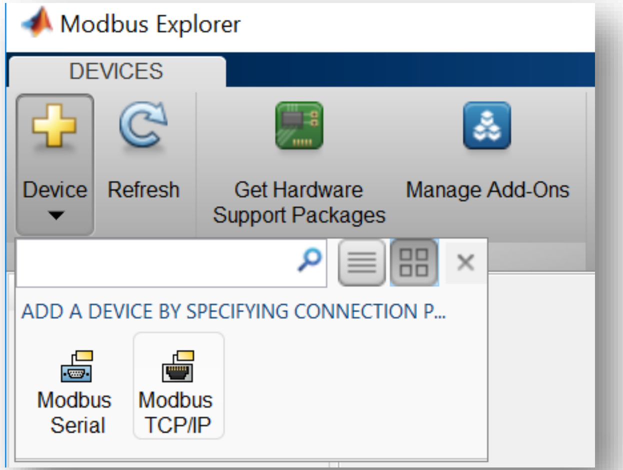
Pump Hardware

MODBUS TCPIP



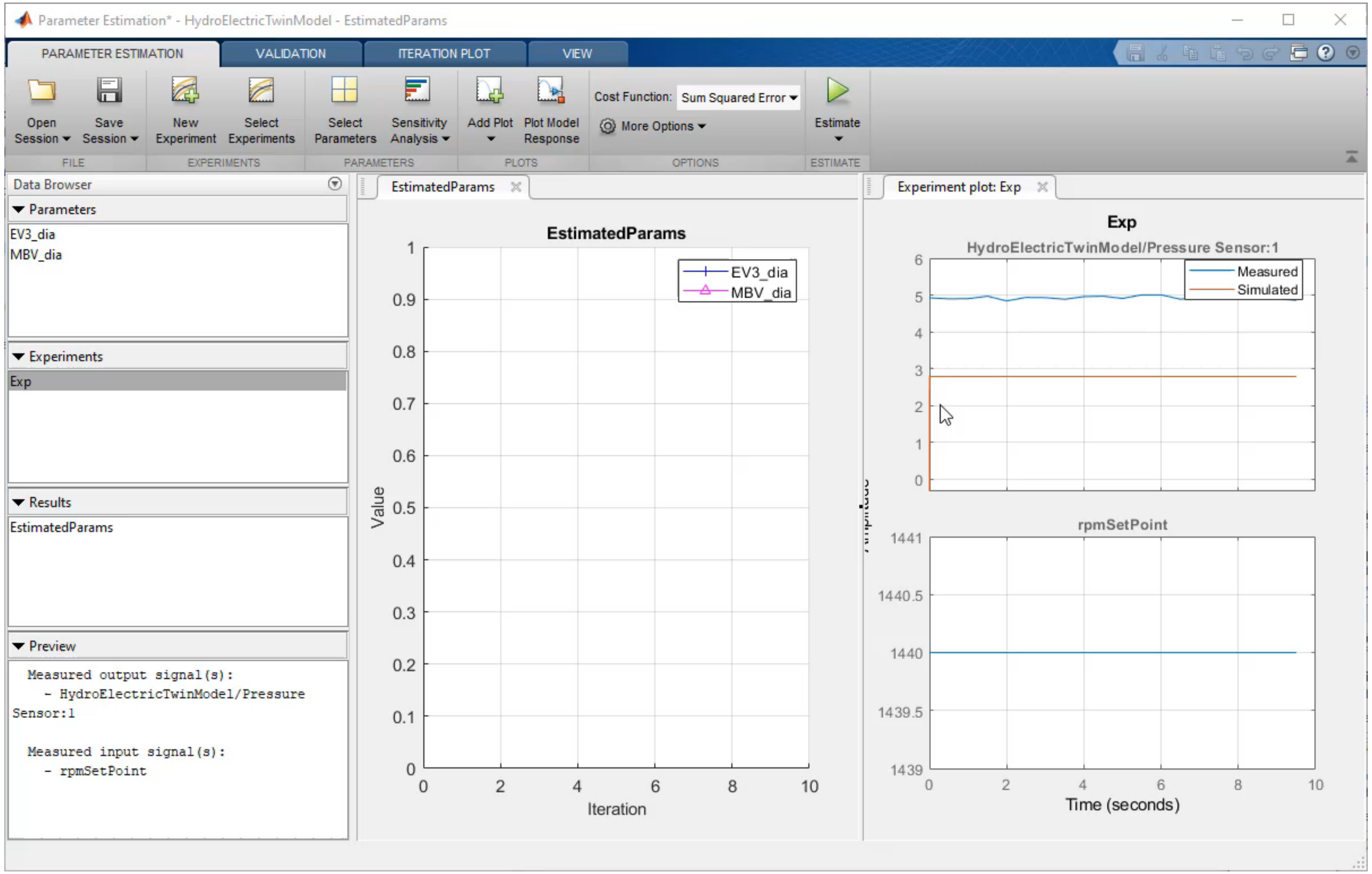


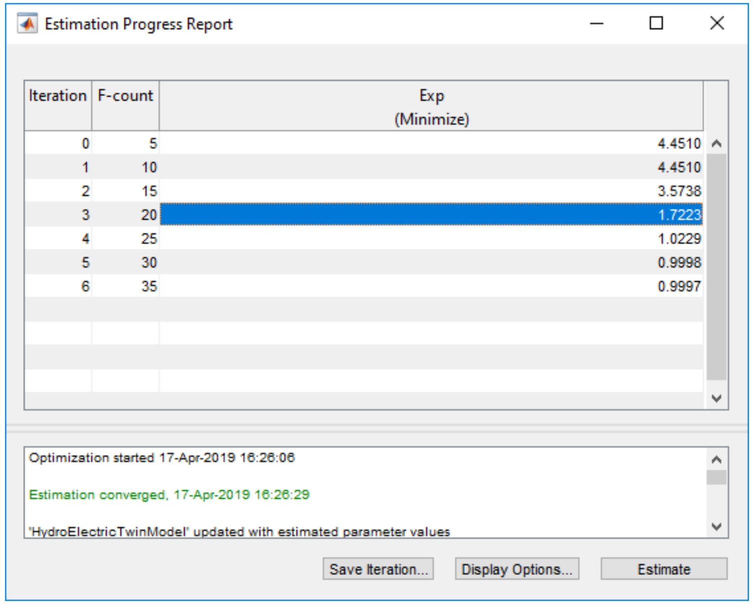

```
m = modbus('tcpip', '192.168.2.1', 308)

m =

   Modbus TCPIP with properties:

     DeviceAddress: '192.168.2.1'
              Port: 308
            Status: 'open'
        NumRetries: 1
           Timeout: 10 (seconds)
         ByteOrder: 'big-endian'
         WordOrder: 'big-endian'
```



Use Simulink Design Optimizer to

Monitor → Analyze → Predict → Control → Optimize





- ✓ Setup Experiments
- ✓ Parameterize
- ✓ Save Sessions
- ✓ Generate Code

Parameter Estimation – Behind the scenes

Monitor → Analyze → Predict → Control → Optimize

```
% Group the model parameters and initial states to be estimated together.
%
v = [p;s];

% Estimation Function
estFcn = @(v) sdoPumpEstimation_Objective(v, Simulator, Exp);


% Optimization options
opt = sdo.OptimizeOptions;
opt.Method = 'lsqnonlin';

% Estimate the Parameters
vOpt = sdo.optimize(estFcn, v, opt)
```

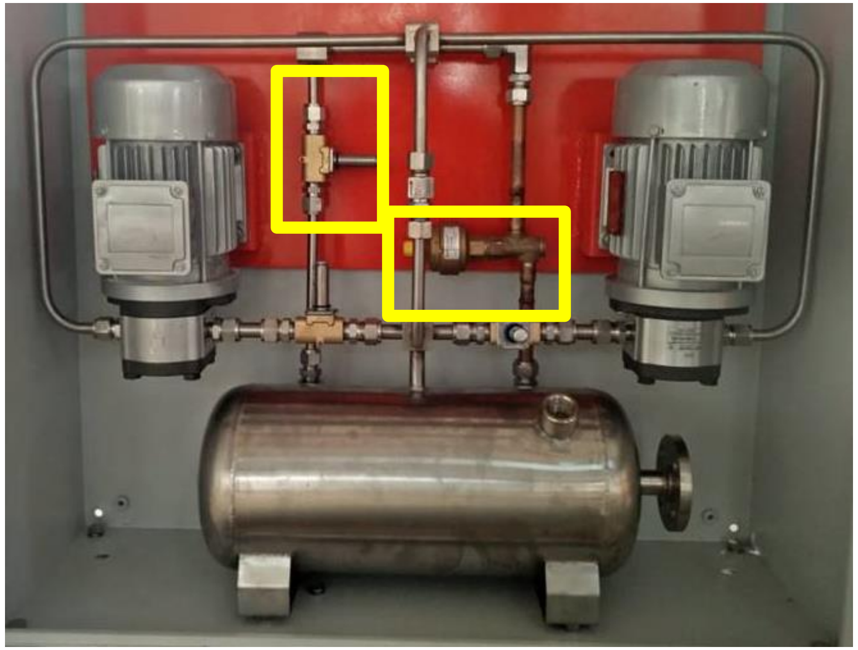
- Initialize
- Set Objective
- Select solver
- Estimate

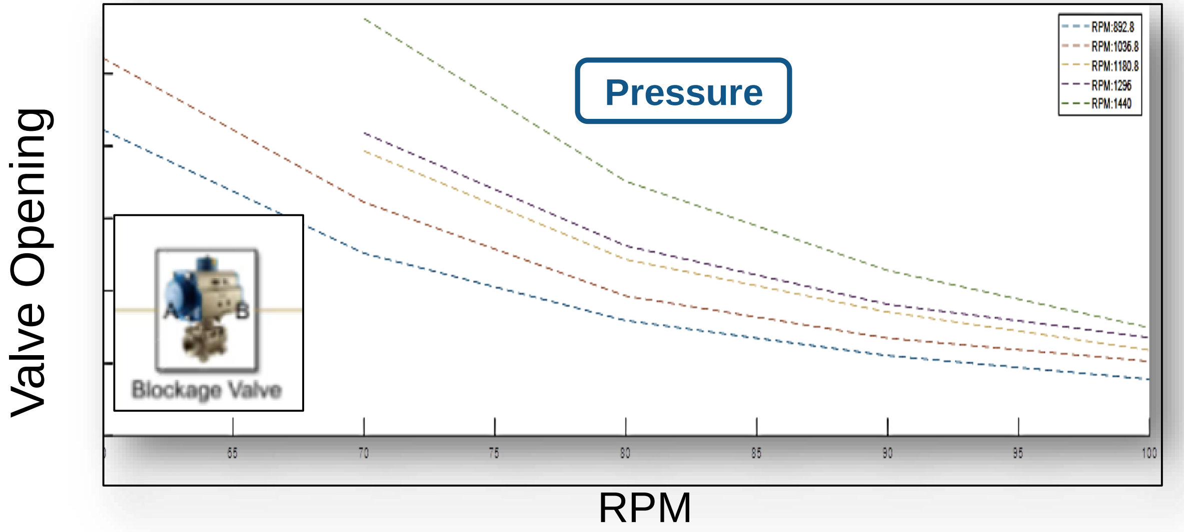
Why Predictive Maintenance ?

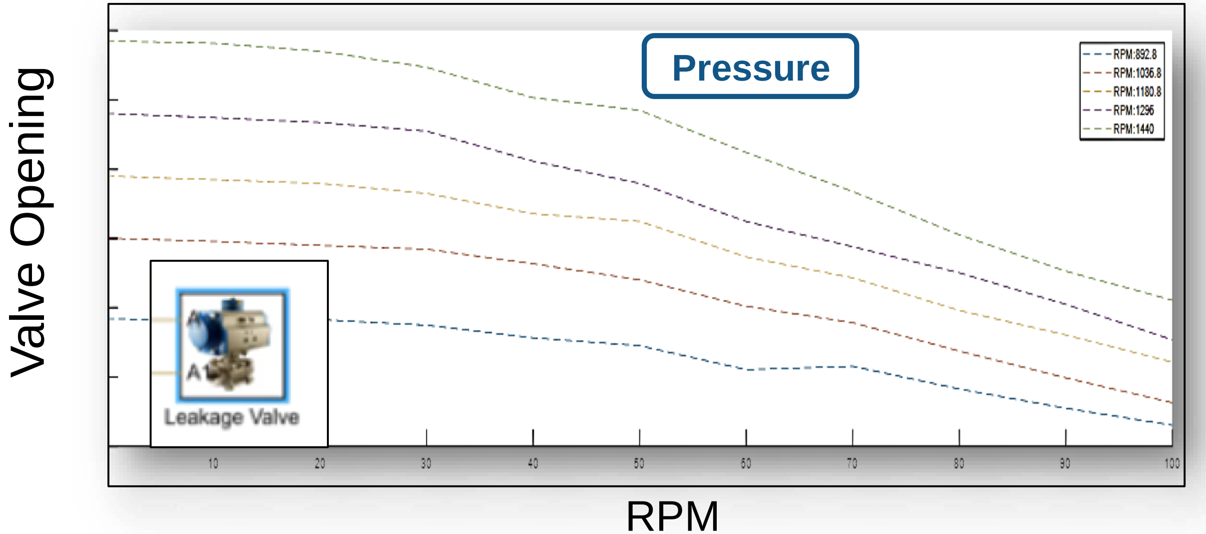
- Operating conditions vary
- Variance in component life

Generate Possible in-field Scenarios

Monitor → Analyze → Predict → Control → Optimize

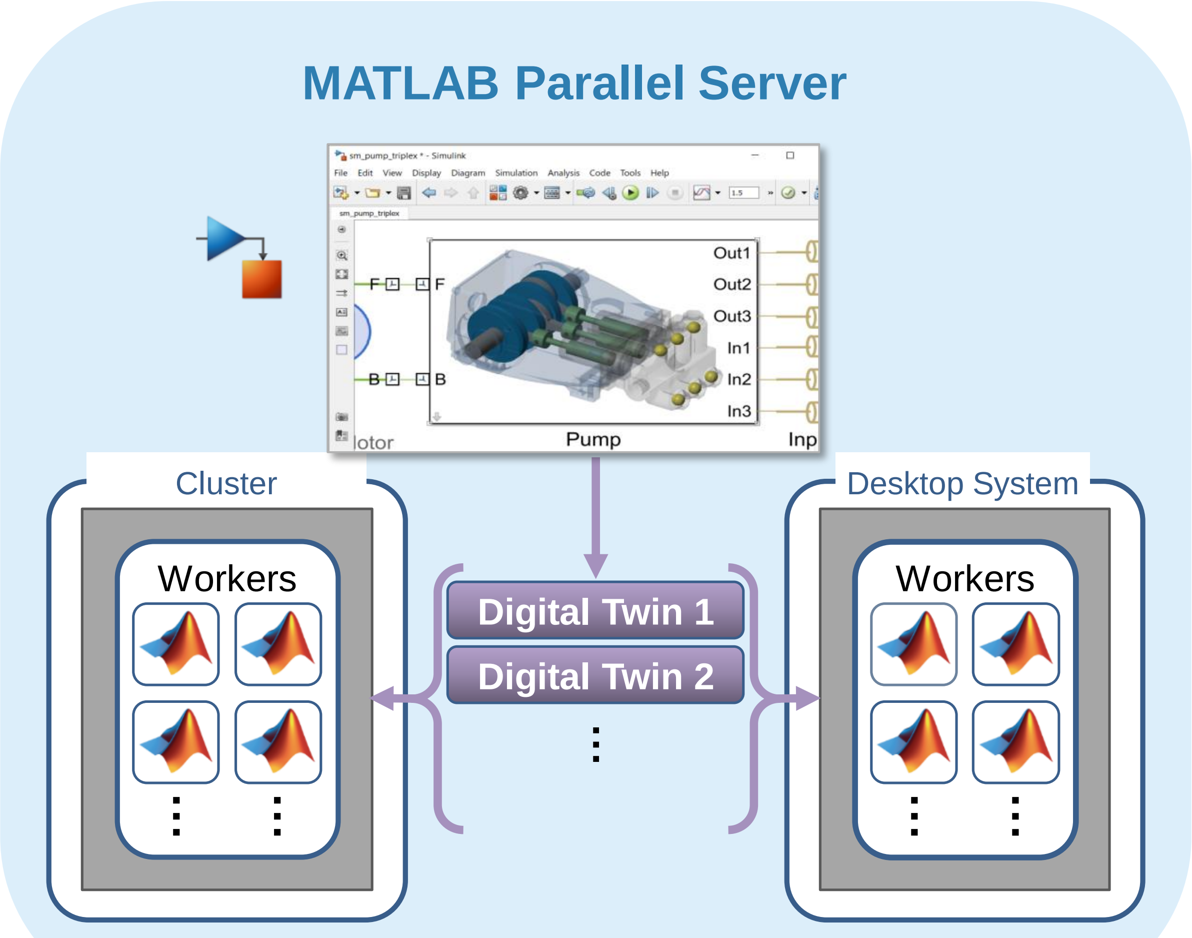


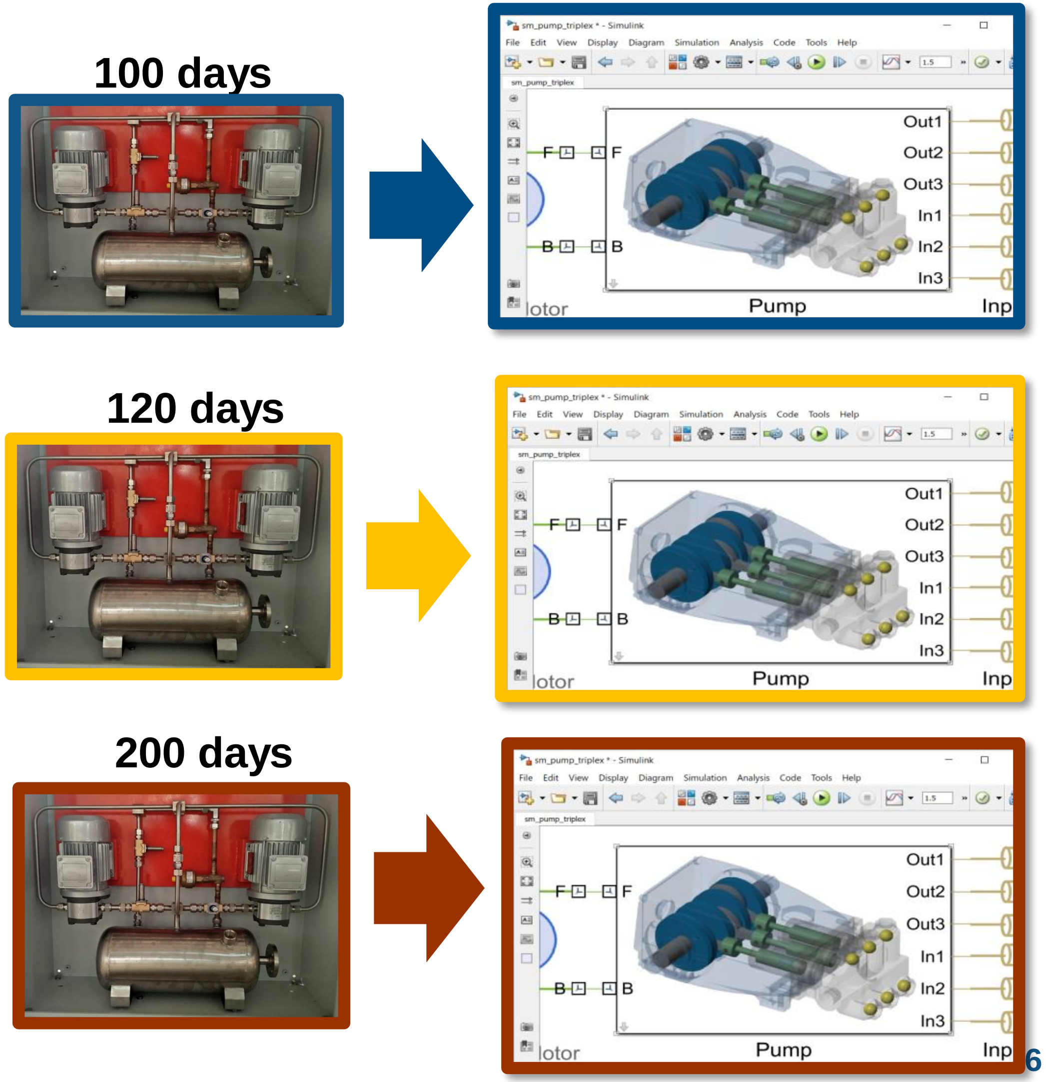




Scale up with MATLAB Parallel Server

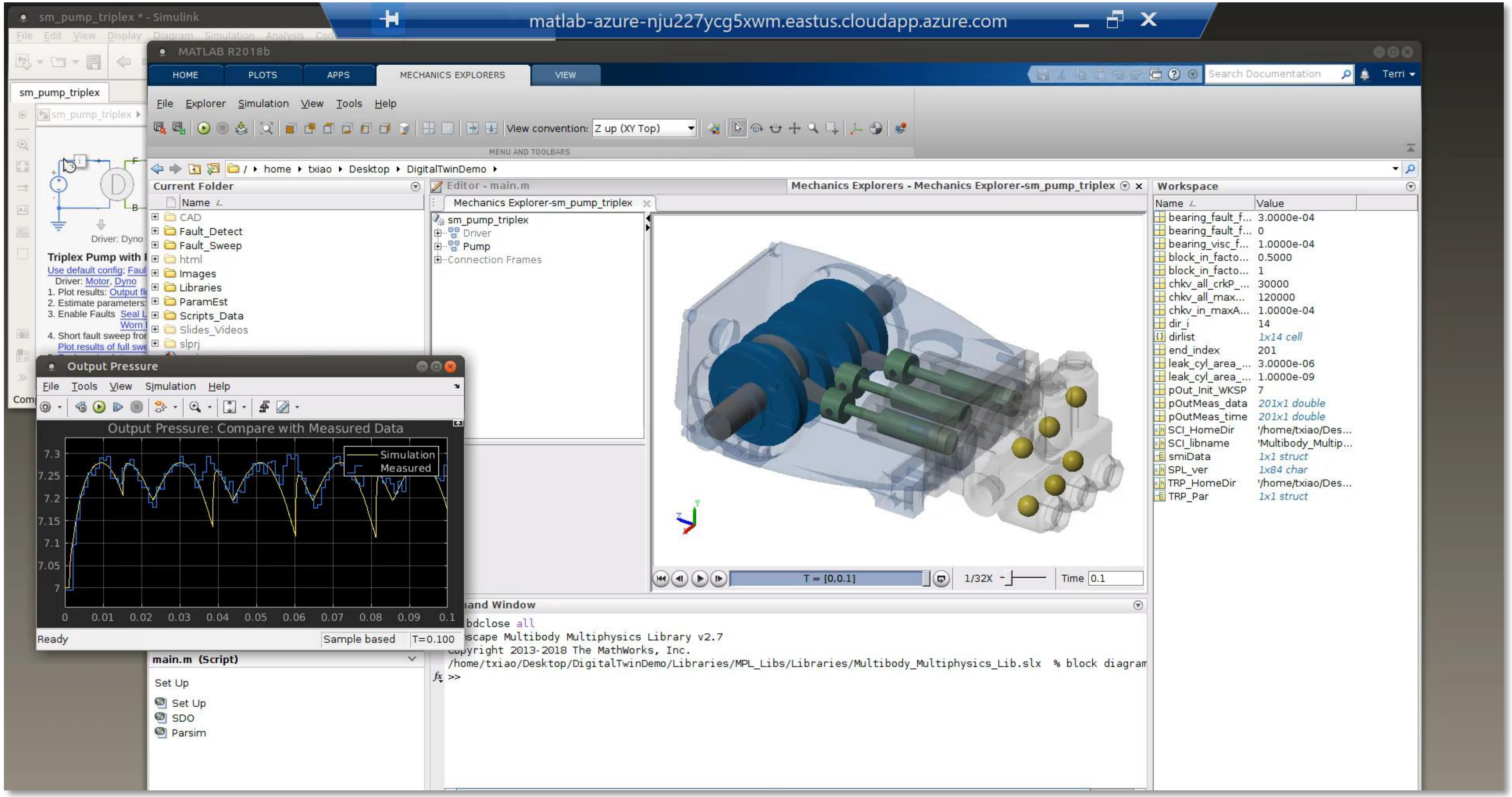
Monitor → Analyze → Predict → Control → Optimize





Use Parallel Simulation Manager to scale up

Monitor → Analyze → Predict → Control → Optimize

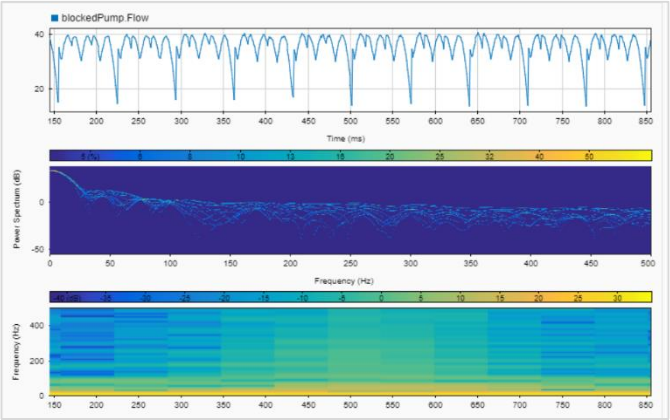


Develop Predictive Models using Digital Twin

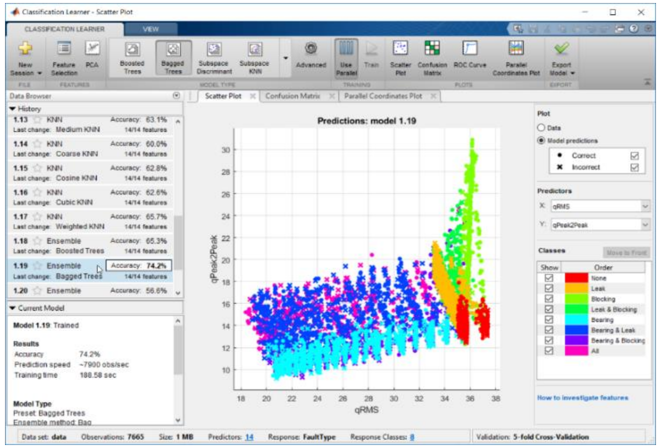
Monitor → Analyze → Predict → Control → Optimize

	Time	1 LeakFault	2 BlockingFault	3 BearingFault	4 FaultType
1	0 sec	2.8472	-0.1477	1.8000	All
2	0.001 sec	-0.1498	-0.4207	1.3103	Bearing & Blocking
3	0.002 sec	0.6511	1.6521	-0.5557	Leak
4	0.003 sec	0.1469	-0.2775	1.0074	All
5	0.004 sec	-0.6480	0.7065	-0.8878	Blocking
6	0.005 sec	-0.8165	-0.5434	-0.3079	Blocking
7	0.006 sec	-1.0061	1.2083	0.0661	Bearing
8	0.007 sec	1.0125	-1.9098	-0.7027	Leak & Blocking

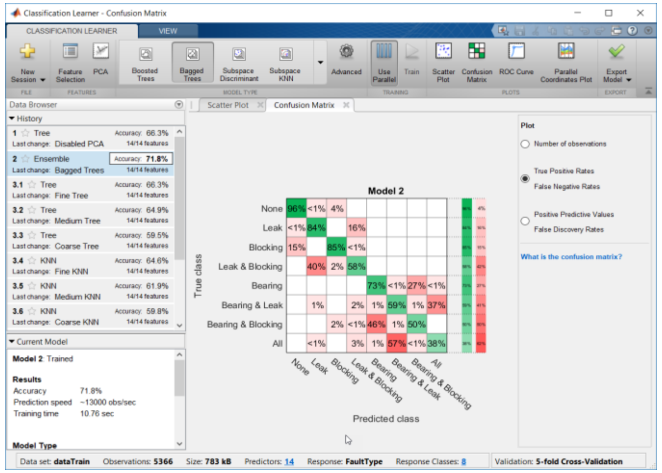
Label Faults



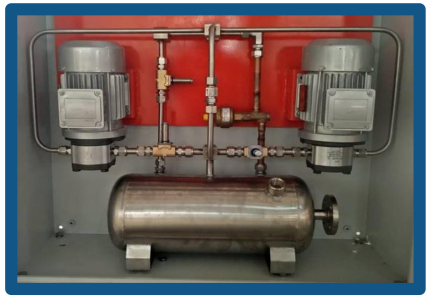
Represent Signals



Train Model



Validate Model



Realtime decisions in field

Monitor → Analyze → Predict → Control → Optimize

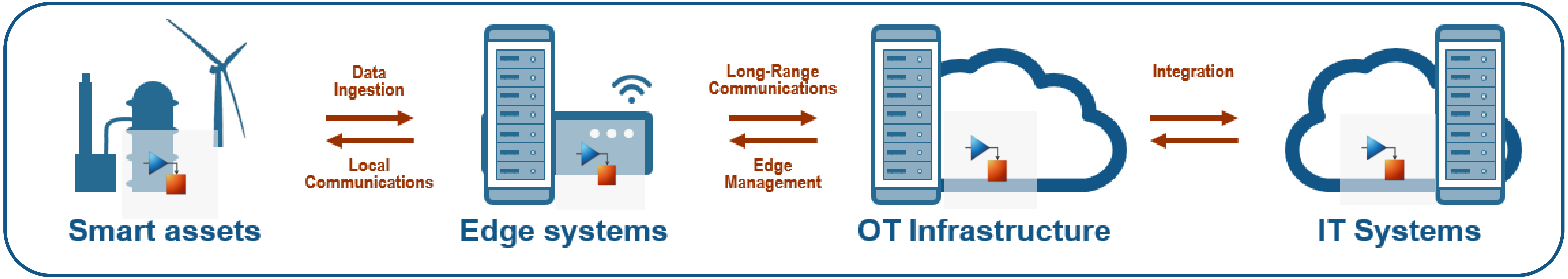
"A blowout preventer (BOP) is an expensive pressure control safety device used during drilling and completion of wells. Approximately 50% of the unplanned downtime for an offshore drilling rig is caused by the BOP. Providing a solution that improves the availability of a BOP will benefit the drilling process and safety." Link

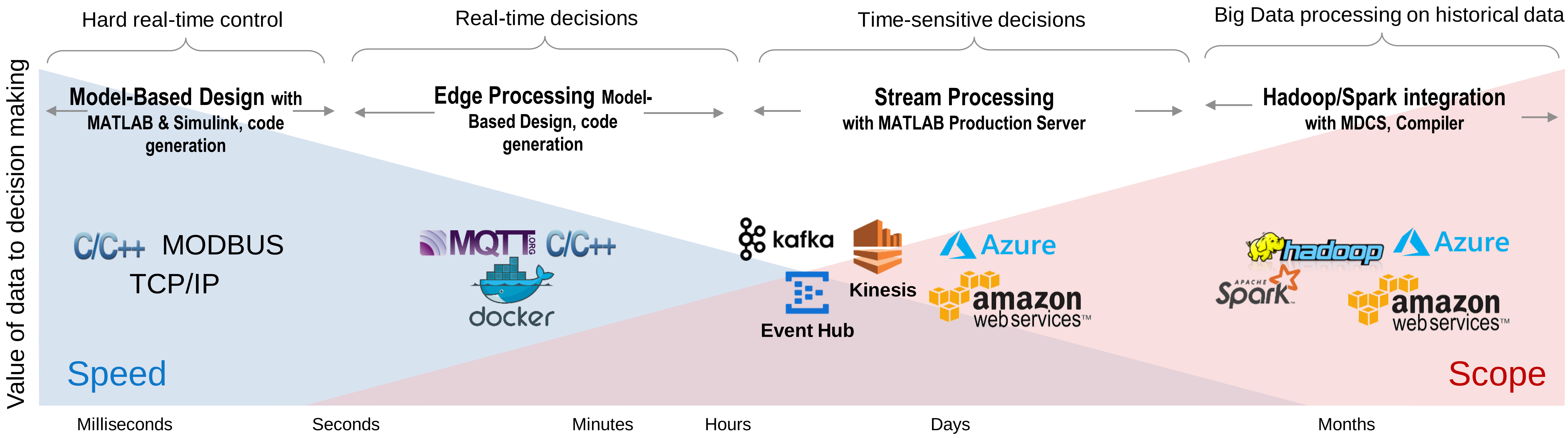
Transocean performed CPM of a BOP using an adaptive physics-based modeling approach with Simscape.

"If we can reduce the energy consumption of the pump and the cooling fan, then energy will be saved significantly. To do that, we have to install the VFD (Variable Frequency Drive) instead of the control valve. VFD is the final control element," informed Dr Sarkar. Link

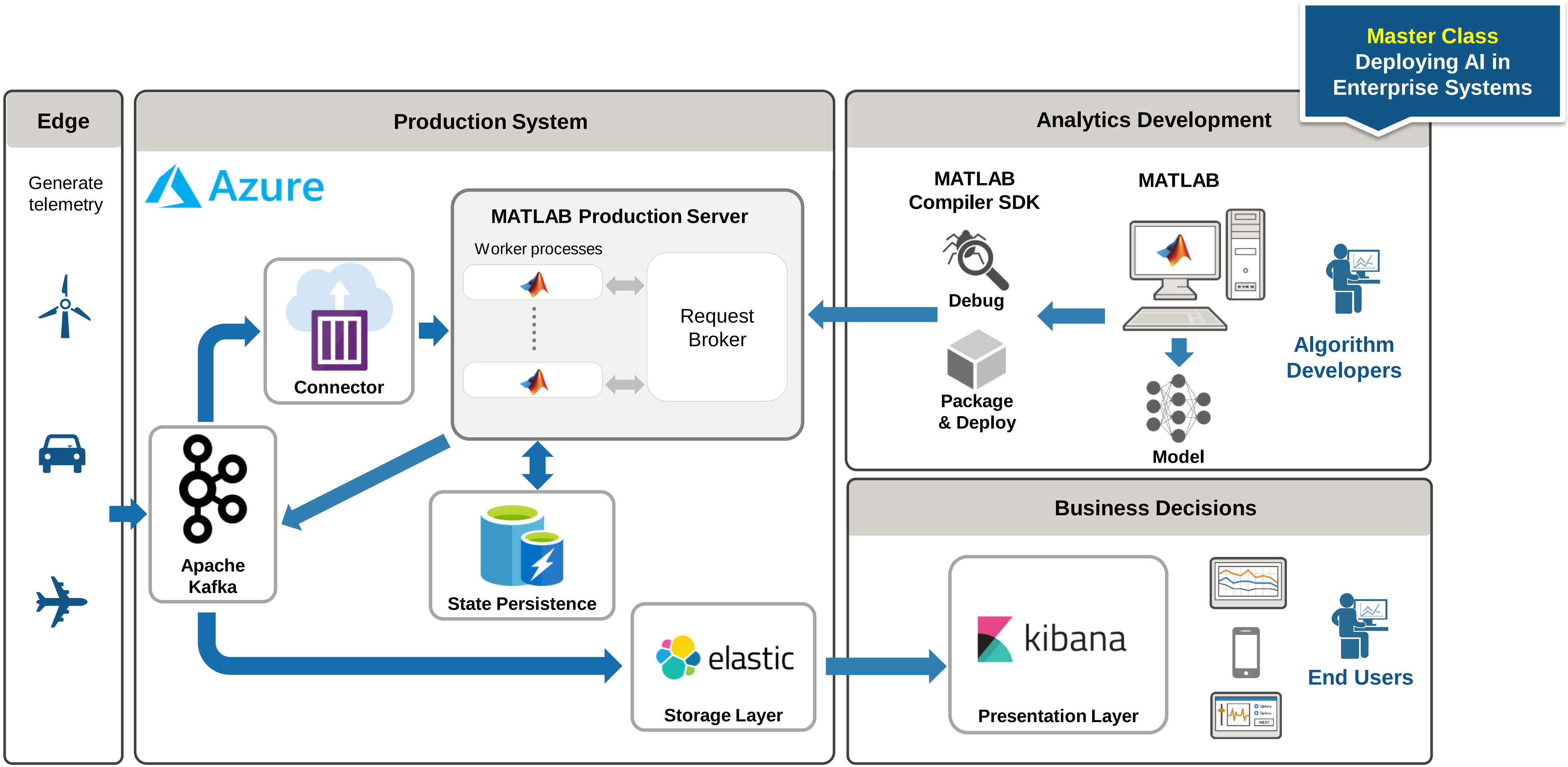
A digital twin model of VFD controller was created to make physical controller (VFD) more efficient.

Backbone Infrastructure for *Preventive, Predictive, Reactive, Actionable*

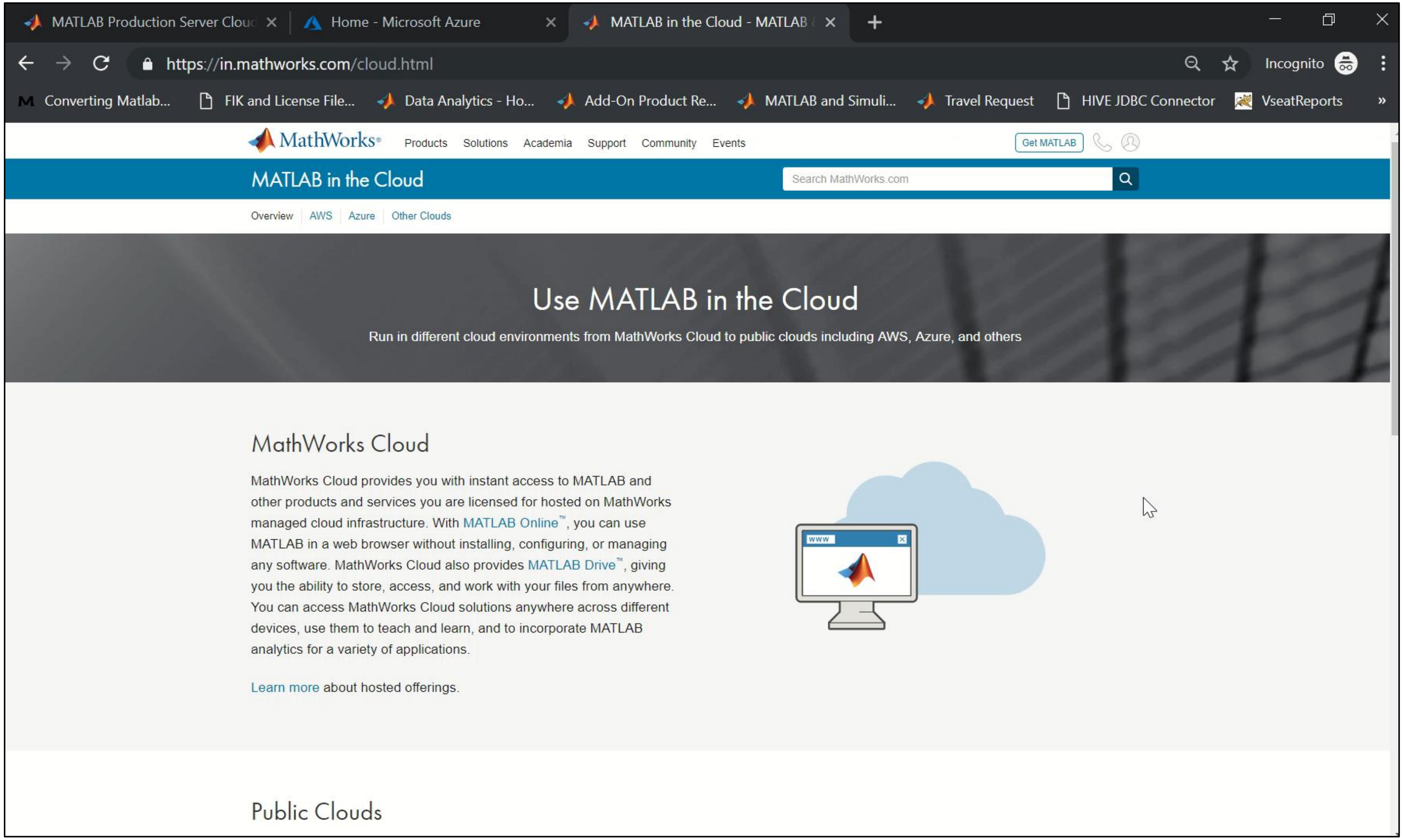




Keep Assets, Digital Twins and Analytics connected at all times

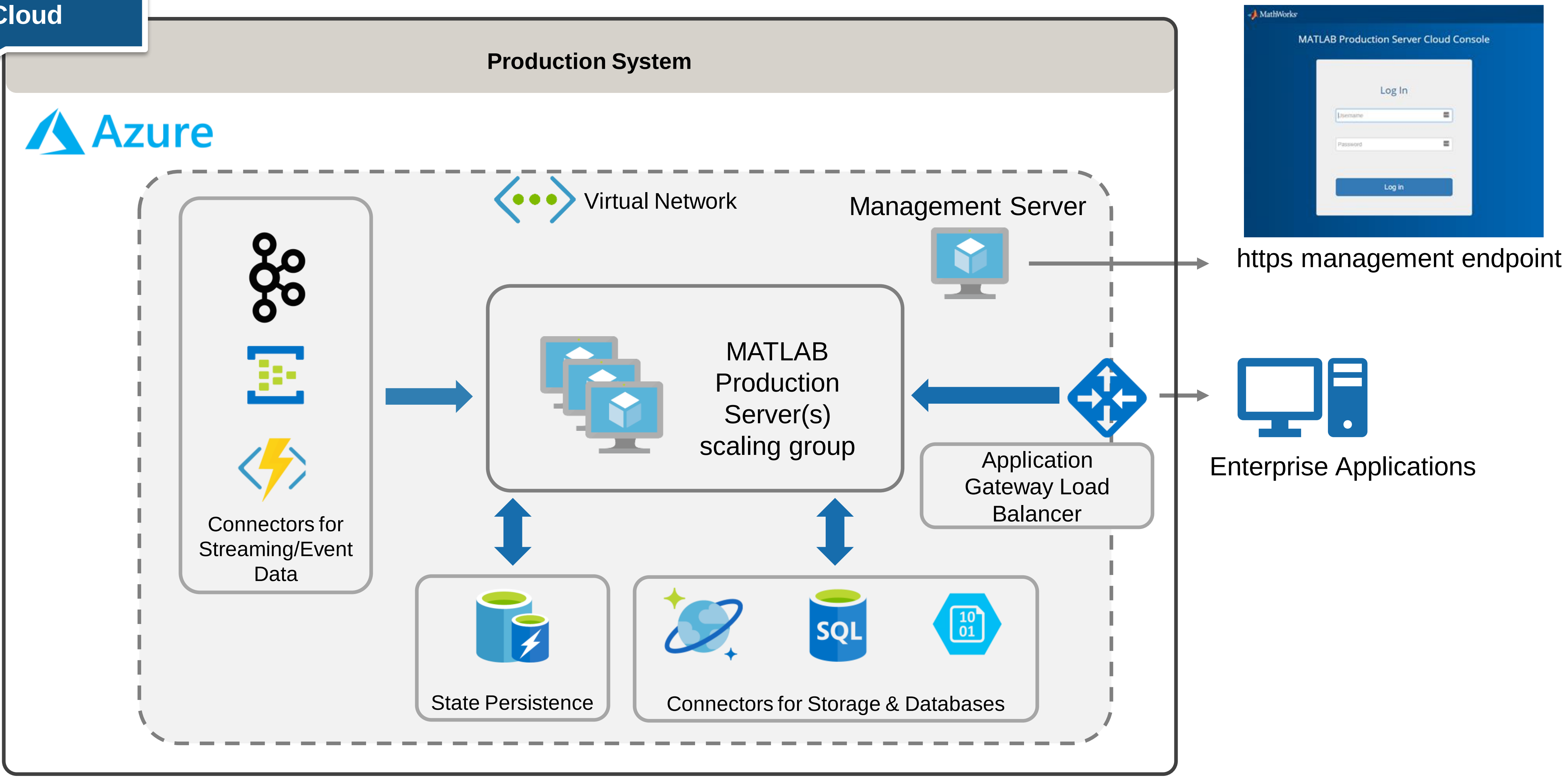


MathWorks Cloud Reference Architecture

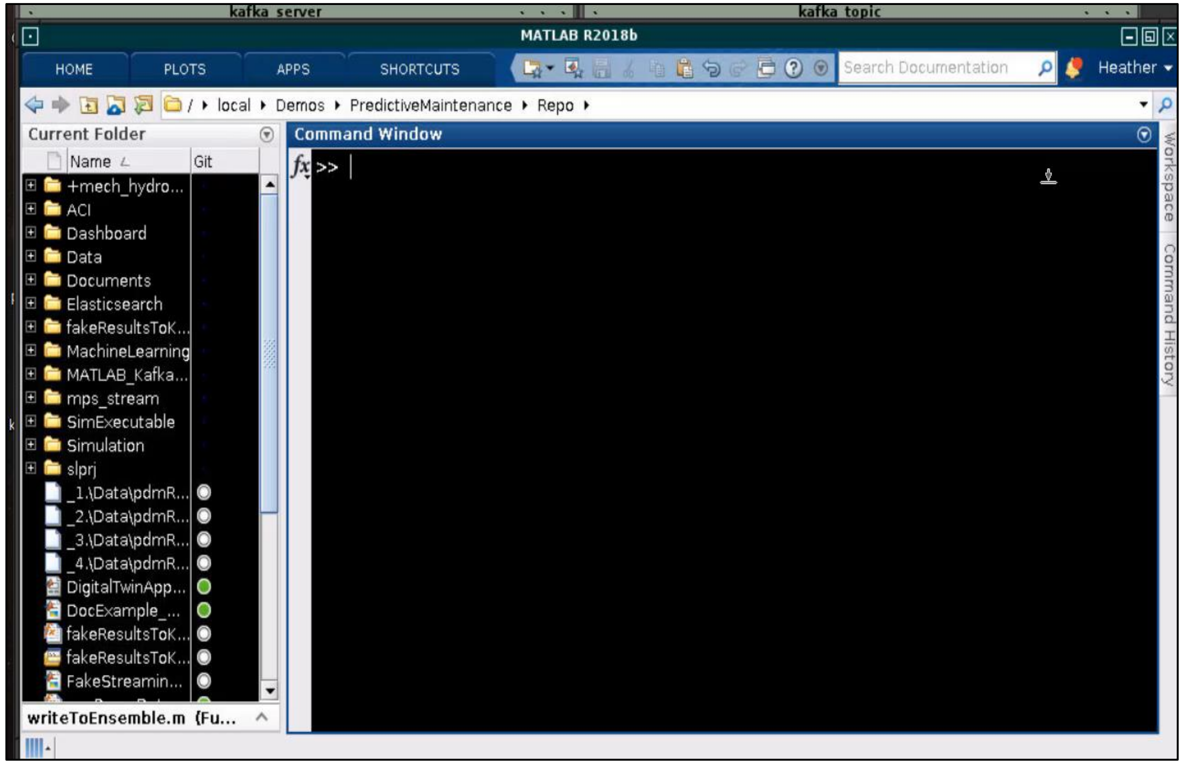


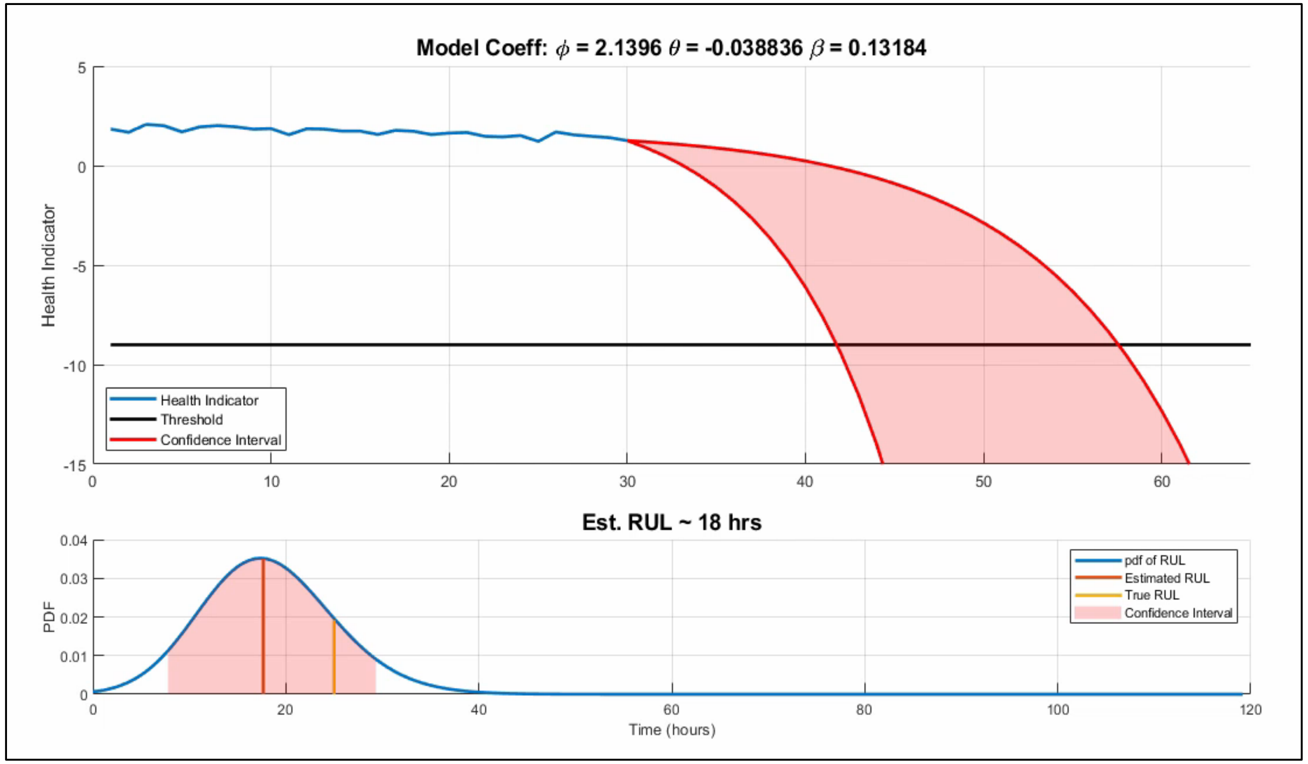
Receive rapid streams of data to maintain effective Digital Twins

DEMO BOOTH:
Deploying AI in Cloud



Develop and Deploy: Live Estimation for Remaining Useful Life





In Conclusion

MathWorks is investing in this area and has key building blocks for your solution:

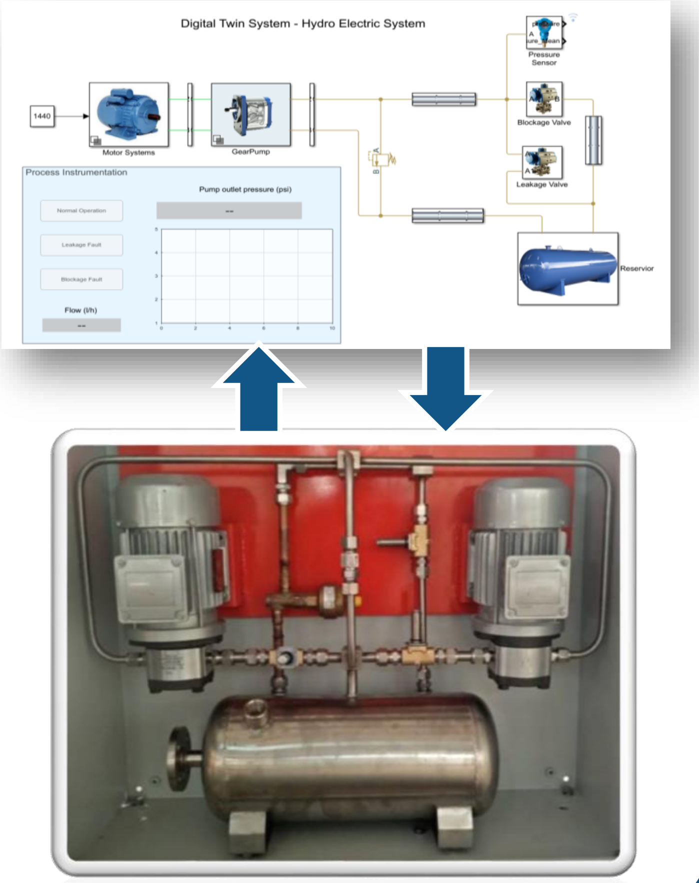
- Physical Modeling libraries to **build Digital Twins and Operating Scenarios**
- Data Science libraries to build **Intelligent & Insightful Applications**
- Deployment workflows for **edge, on premise server & cloud platforms**

IIoT and Digital Twin are new areas evolving rapidly

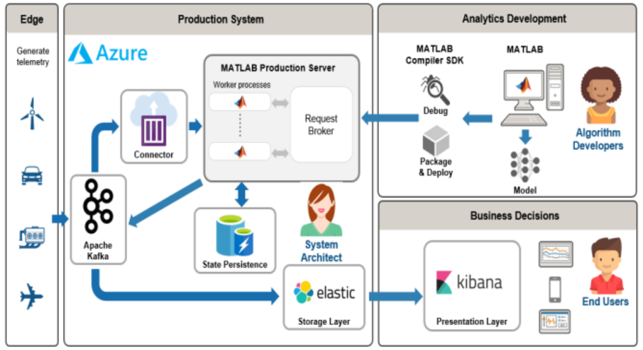
"Come talk to us about your IoT application and discuss how we can support you !"

Call to Action

>>IIoT & Digital Twin Booth



>>Master Class



Deploying AI Algorithms on Cloud for Near Real-Time Decision Making
Pallavi Kar, MathWorks

>>Attend Data Science Sessions

14:30	Developing and Deploying Machine Learning Solutions for Embedded Applications *Nitin Rai, MathWorks*
15:00	Predictive Maintenance with MATLAB *Amit Doshi, MathWorks*
16:45	Building and Sharing Desktop and Web Apps *Dr. Lakshminarayan Viju Ravichandran, MathWorks*
16:15	Innovative Method of Deploying MATLAB Based Applications Across an Organization Using MathApps, a Web-Based Platform *Chandrakant Deshmukh, Saifee Aliakbar, and Jannat Manchanda, Mahindra and Mahindra Ltd.*

Resources: IIoT and Digital Twin

- Building IoT solutions
- Developing and Deploying on Cloud
- Build Digital Twins with Physical Modeling workflow
- Learn: How to build Predictive Maintenance Applications?
- Learn Data Science with MATLAB

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