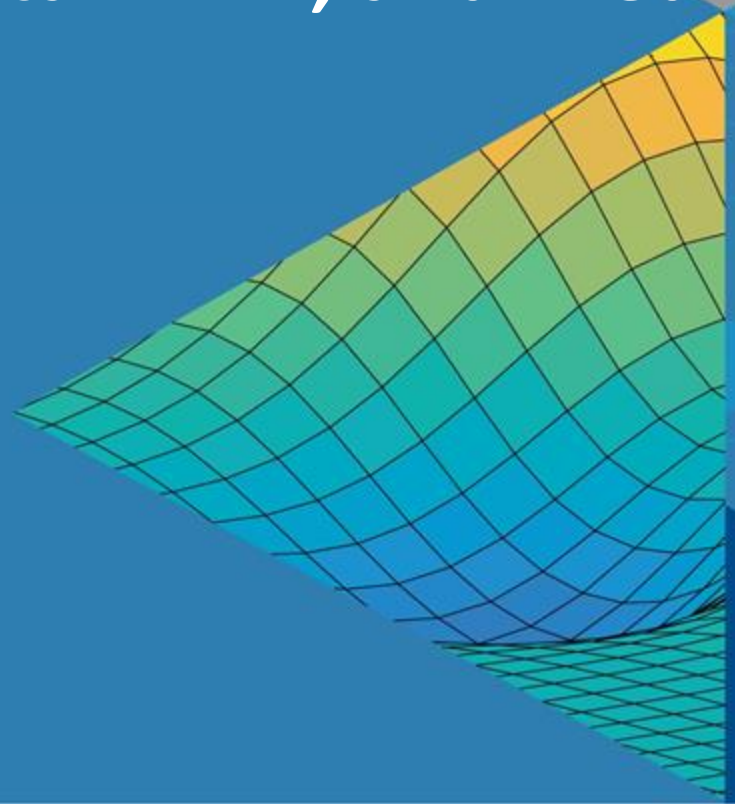
Demystifying Industry 4.0, Digital Twin, and Predictive Maintenance



Sameer M. Prabhu, Ph. D.
Worldwide Industry Marketing Director

Agenda

- **Practical Industry 4.0**

  What is Industry 4.0 and how can you use it?

- **Where does Industry 4.0 live**

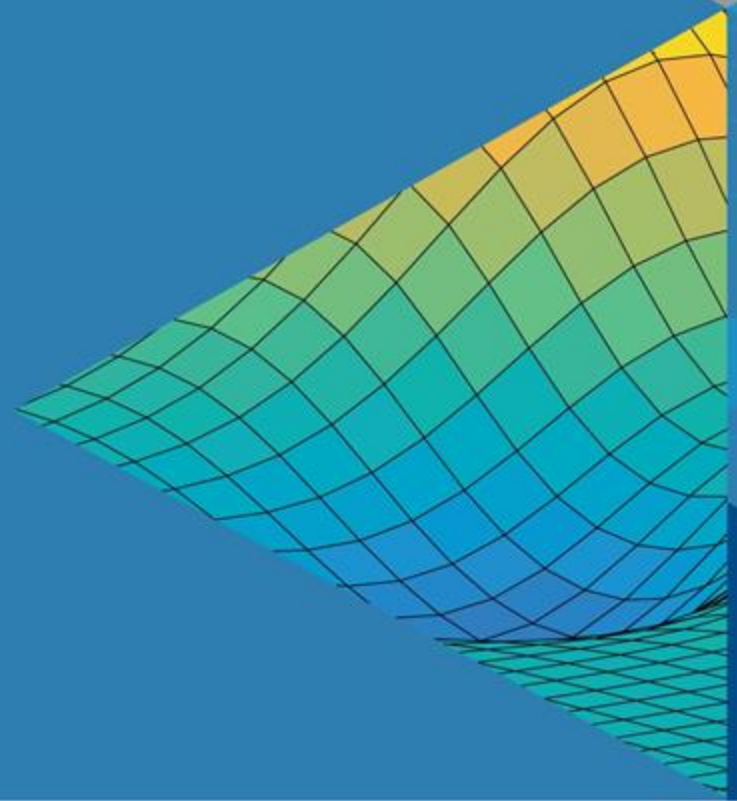
  How does Industry 4.0 fit into your IT/OT infrastructure and how does it relate to Digital Twins and IIoT?

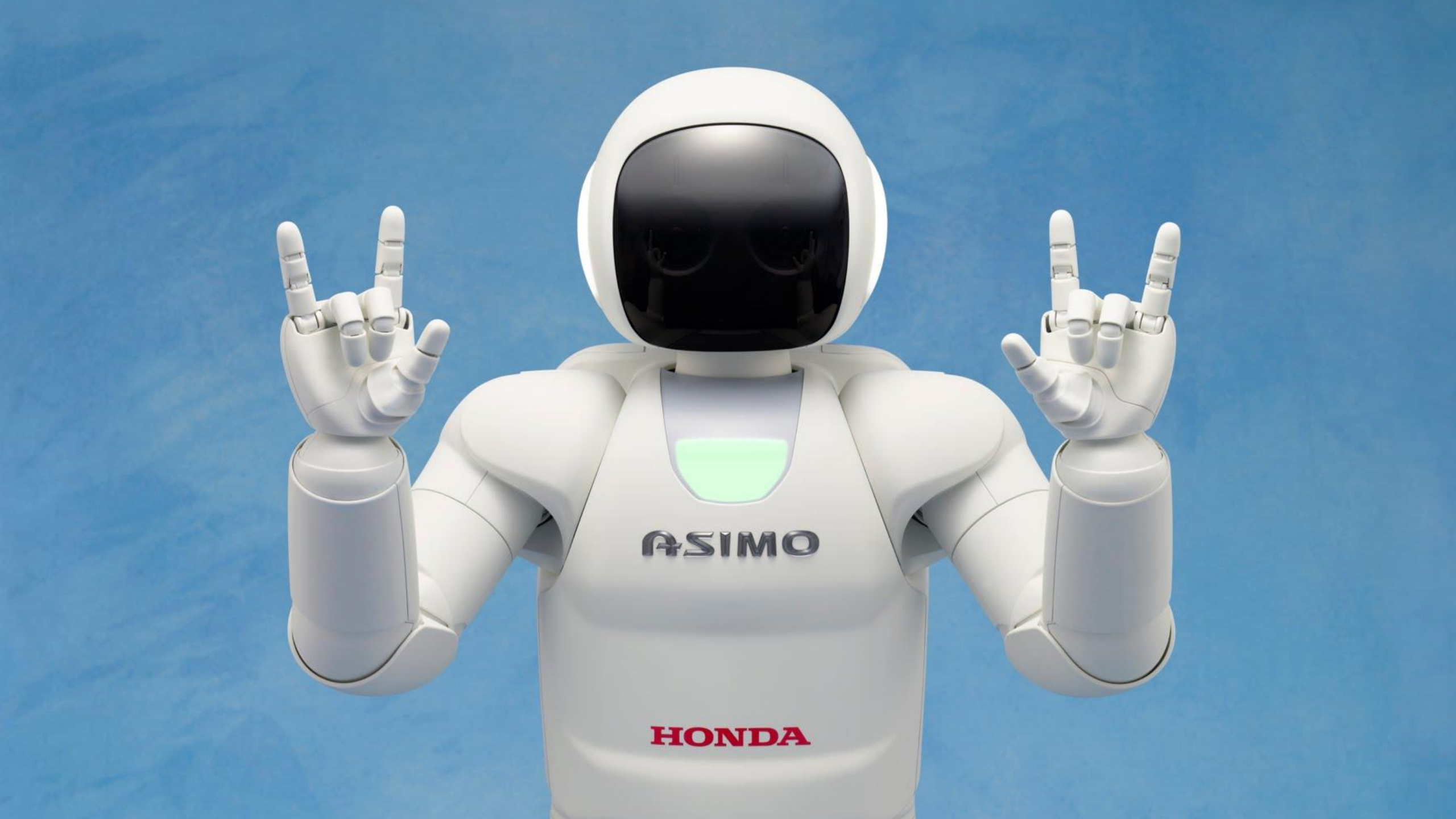
- **The benefits of Industry 4.0**

  Finally – does Industry 4.0 really pay off? Predictive Maintenance example.

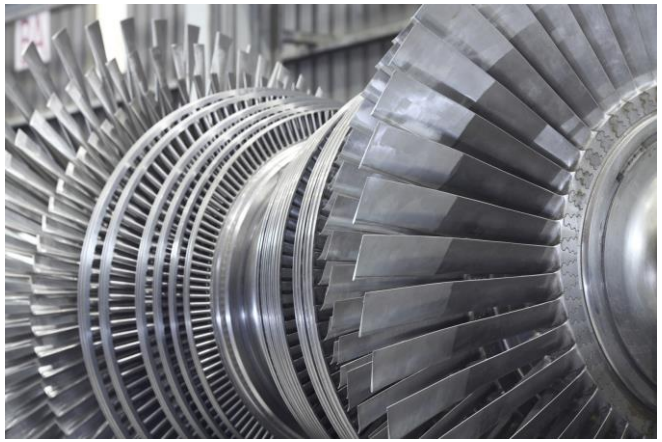
Practical Industry 4.0

What is Industry 4.0 and how can you use it?

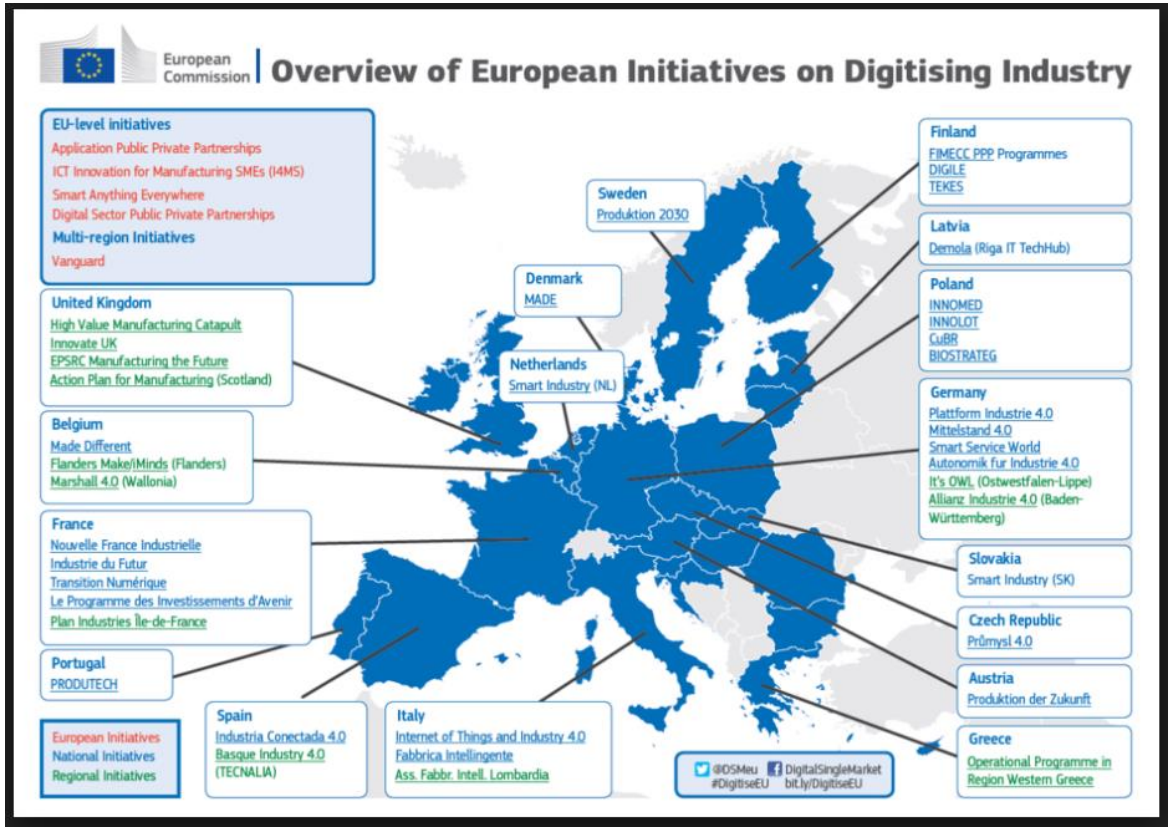



ASIMO
HONDA


amazon

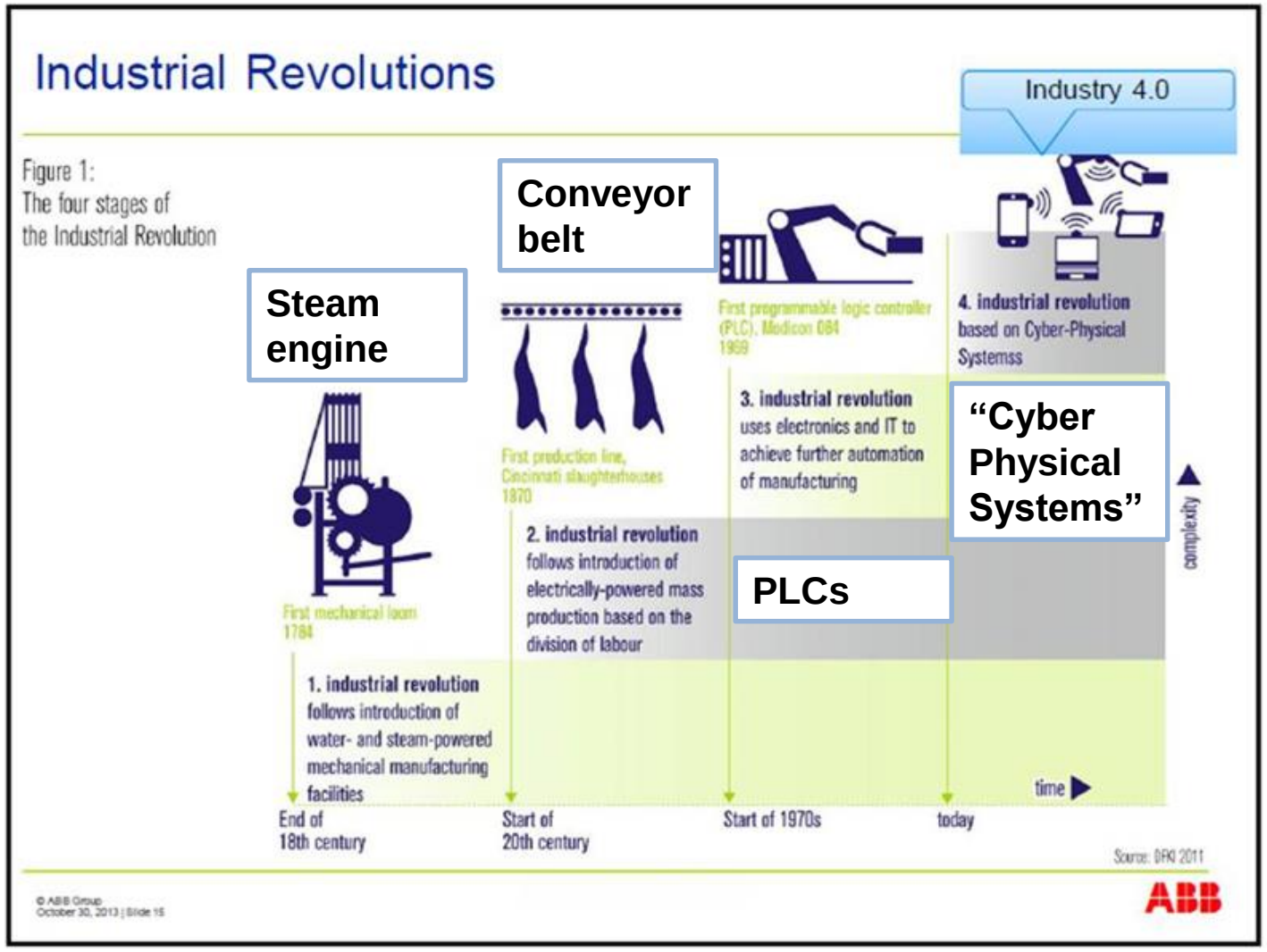


Digital Transformation of the industry is everywhere



- **Higher flexibility** given by small batches production with the economies of scale and to changing feedstock quality
- **Higher speed** from prototyping to mass production using innovative technologies
- **Increased productivity** thanks to shorter commissioning time and reduced downtime
- **Improved quality and efficiency** thanks to real time production monitoring
- **Higher competitiveness** of products thanks to additional functionalities enabled by the Industrial Internet Of Things (IIoT)

What is *Industry 4.0*



Source: ABB

Definition:

Production equipment, automation components and entire process lines are **connected** with each other and exchange information (= data). They build the "*Industrial Internet-of-Things*".

The goal is to **optimize** the entire process (for minimum energy consumption, maximum throughput, feedstock quality, etc.) and to make the production of small lots **more flexible** ("*mass customization*").

Taiwan's Industry 4.0 Innovations Highlighted at IMTS 2018 Panel Discussion

Achievements & Challenges Discussed at Virtual Reality Press Conference

NEWS PROVIDED BY
Taiwan Machine Tools
Sep 17, 2018, 13:00 ET

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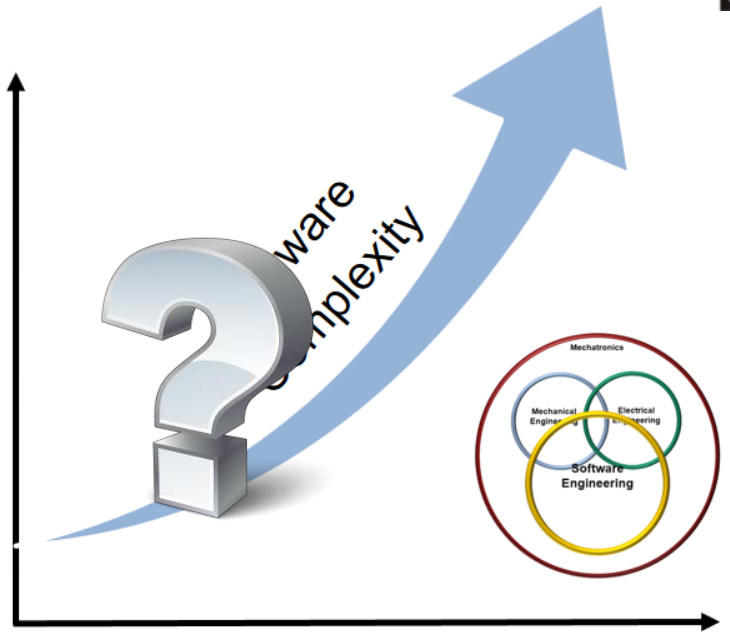
CHICAGO, Sept. 17, 2018 /PRNewswire/ -- Prominent Taiwanese machine tool and accessory manufacturers provided their perspectives on the present state of smart manufacturing as well as the challenges faced in areas ranging from customer customization requirements to the lack of a universal machine control language and the impact of electric cars on the machine tool industry in a panel discussion at this week's 2018 IMTS in Chicago. The panel was part of "Taiwan: Make Tomorrow Come True," a press conference that also included a 360° virtual reality tour of major Taiwanese advances in smart machinery and associated technologies.

Source:
https://www.prnewswire.com/news-releases/taiwans-industry-4-0-innovations-highlighted-at-imts-2018-panel-discussion-300713815.html

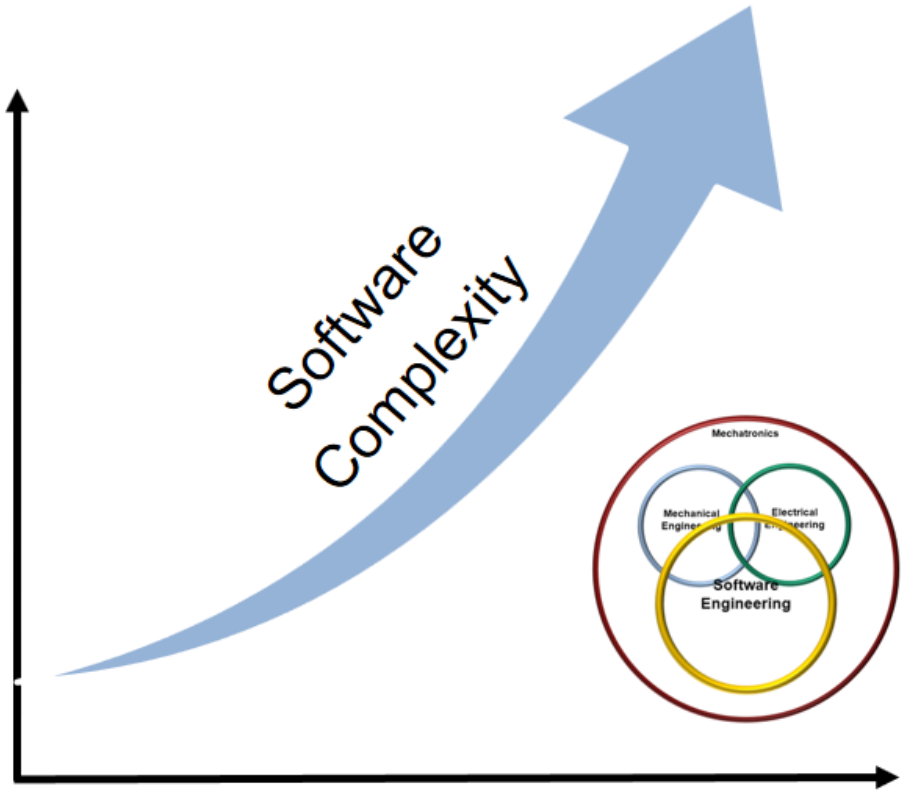
What are the major components of *Industry 4.0*



Growing complexity of **Software**

Increasing amount of **Data**

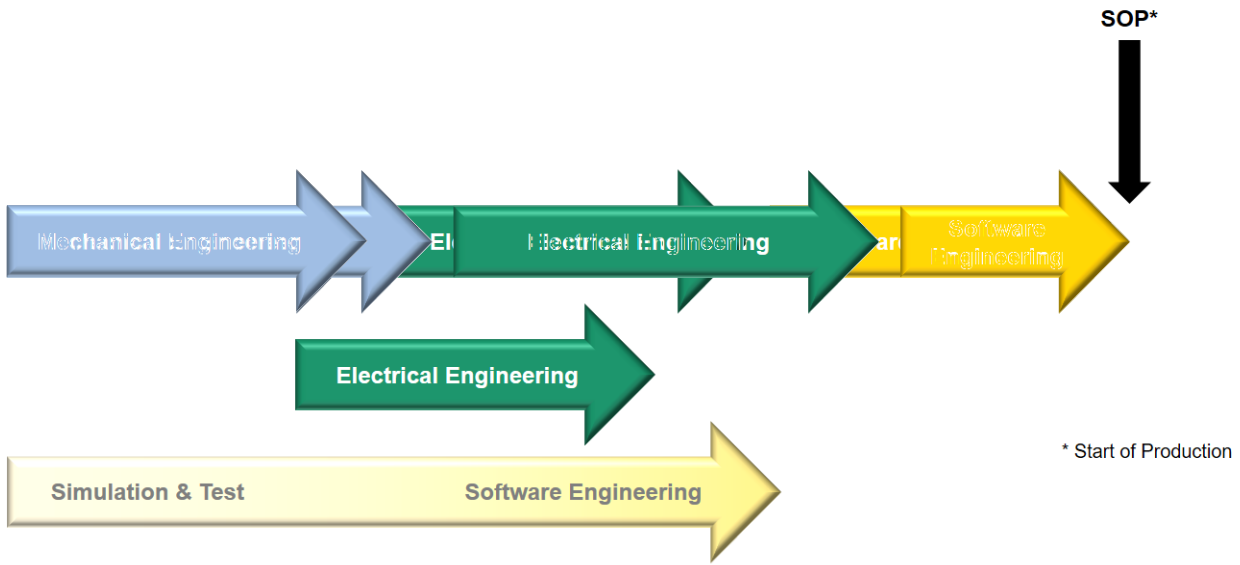
Growing complexity of Software



Growing complexity of mechatronic systems

- Modularity and reusability
- More (embedded) software
- Risk of long commissioning times and insufficient software testing
- Increased focus on IP protection and IT security

Growing complexity of Software



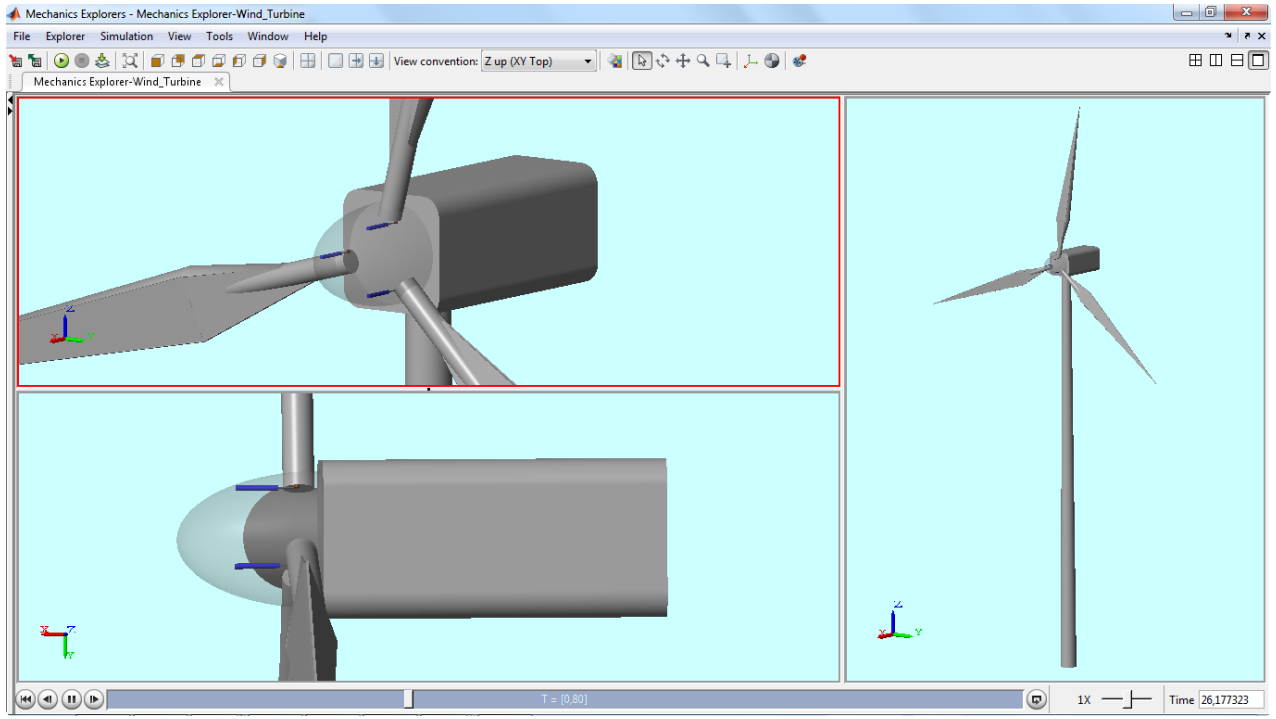
Growing complexity of mechatronic systems, especially of the software…

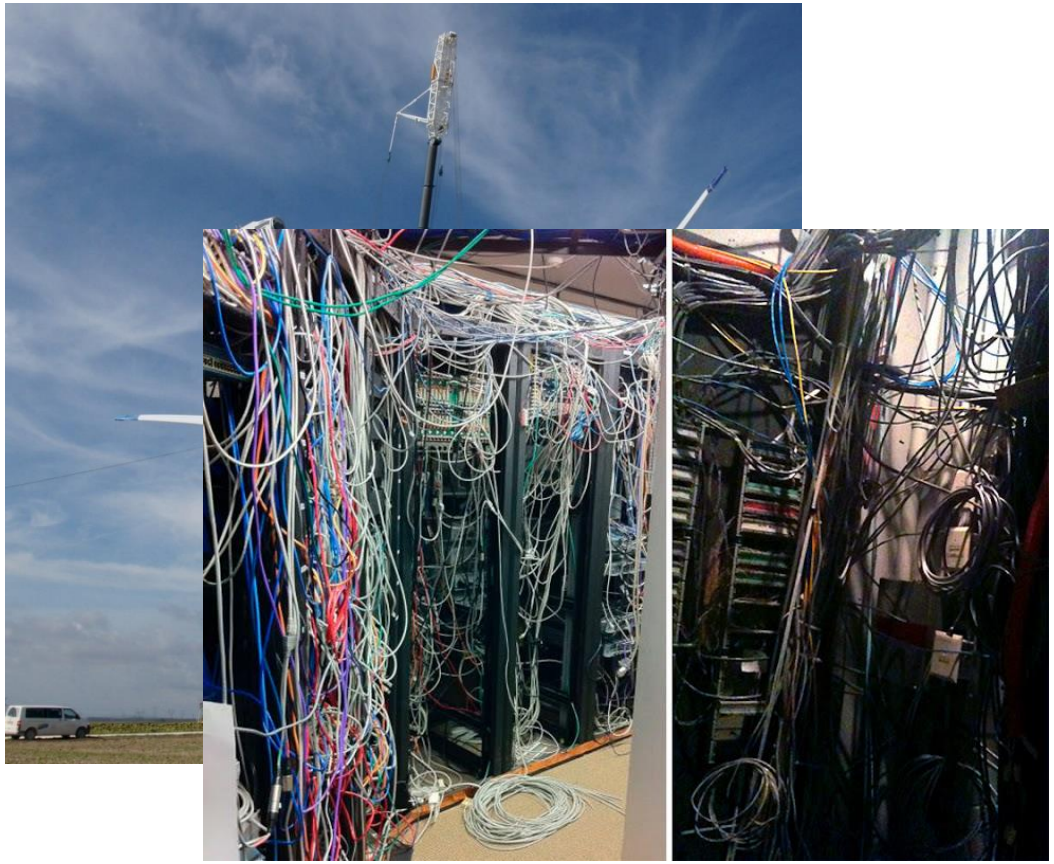
…requires new design methods.

Model-Based Design for Virtual Commissioning

Virtual Commissioning

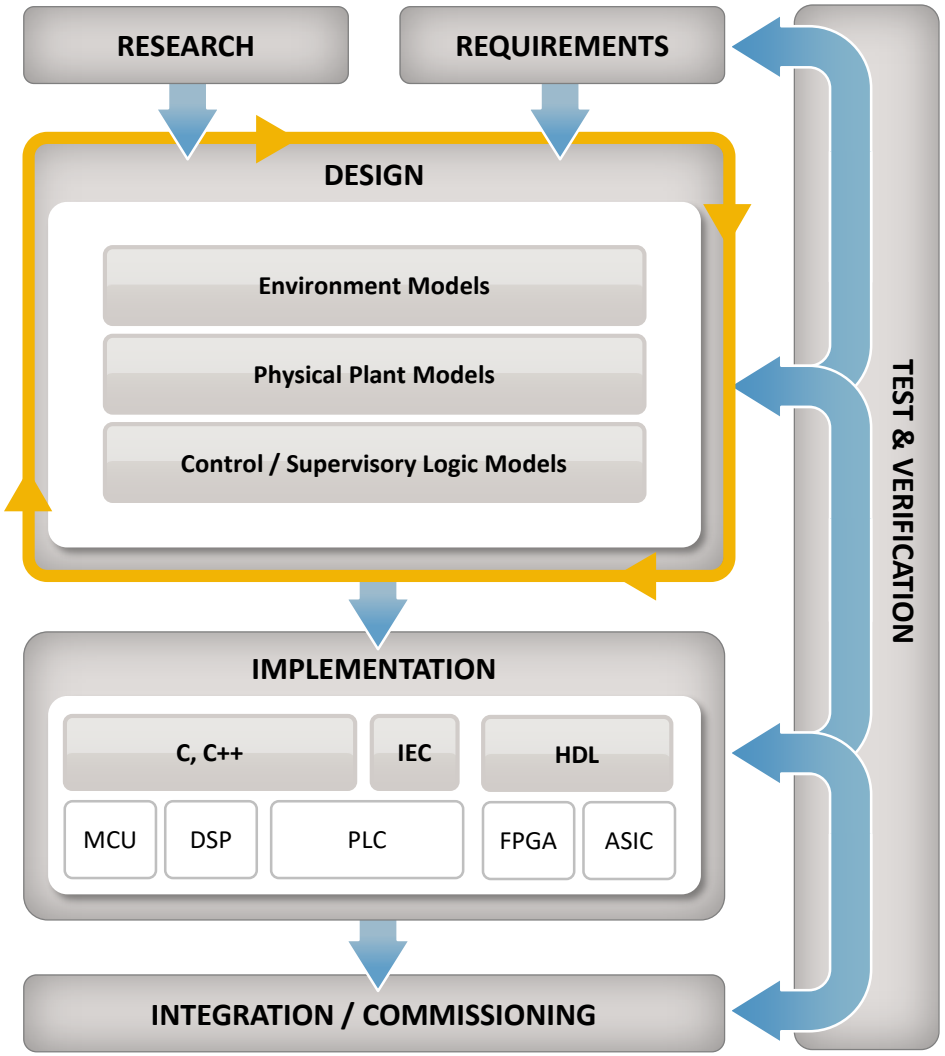
…enables engineers to test the system behavior when the physical system is not yet available





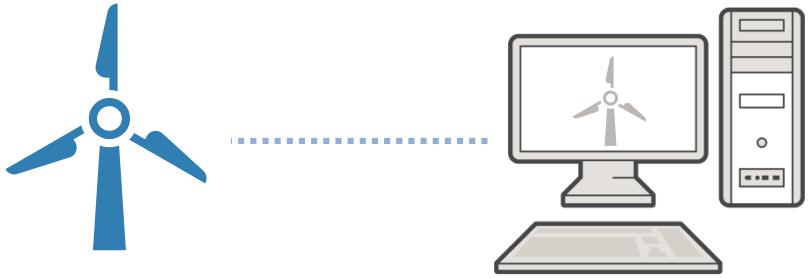
Is this really enough?

Model-Based Design for Virtual Commissioning



What if you were able to verify your system's behavior **through the entire design process**?

What if you could use your models not only for design simulation but also as a **Digital Twin** during lifetime of your system?



Model-Based Design

Baker Hughes Improves Precision of Oil and Gas Drilling Equipment

Challenge

Improve the quality and precision of directional measurement algorithms for oil and gas drilling equipment

Solution

Use Model-Based Design to design and simulate measurement algorithms, run HIL tests, and generate production code

Results

- Expensive field tests minimized
- Future development effort halved
- Firmware quality improved

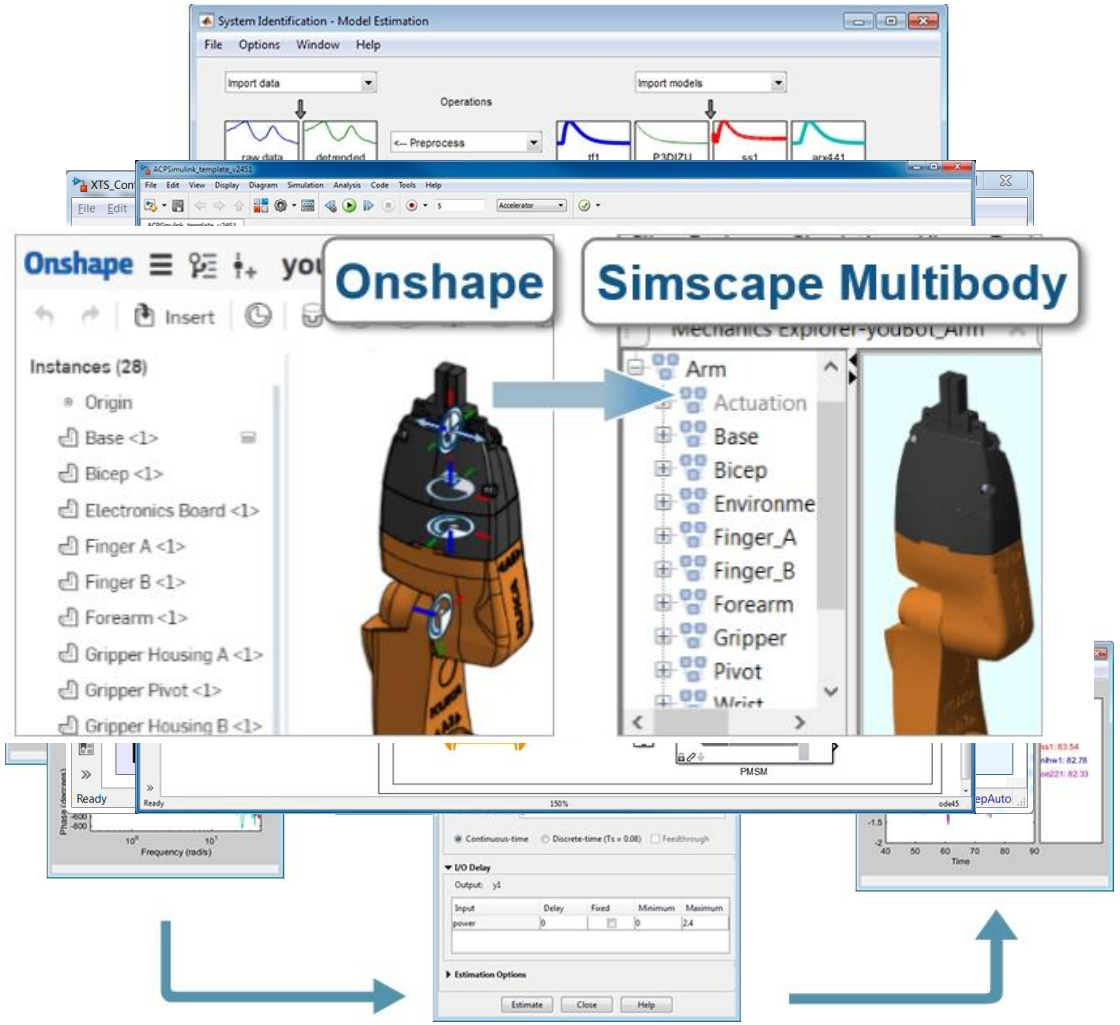
The AutoTrak™ Curve Rotary Steerable System with a Kymera™ hybrid drill bit

"We add value for our customers with our design expertise and knowledge, not through coding. Simulink and Embedded Coder enabled us to accelerate development by shifting our resources and our focus from code implementation to system design and system-level testing."

- Ingolf Wassermann, Baker Hughes

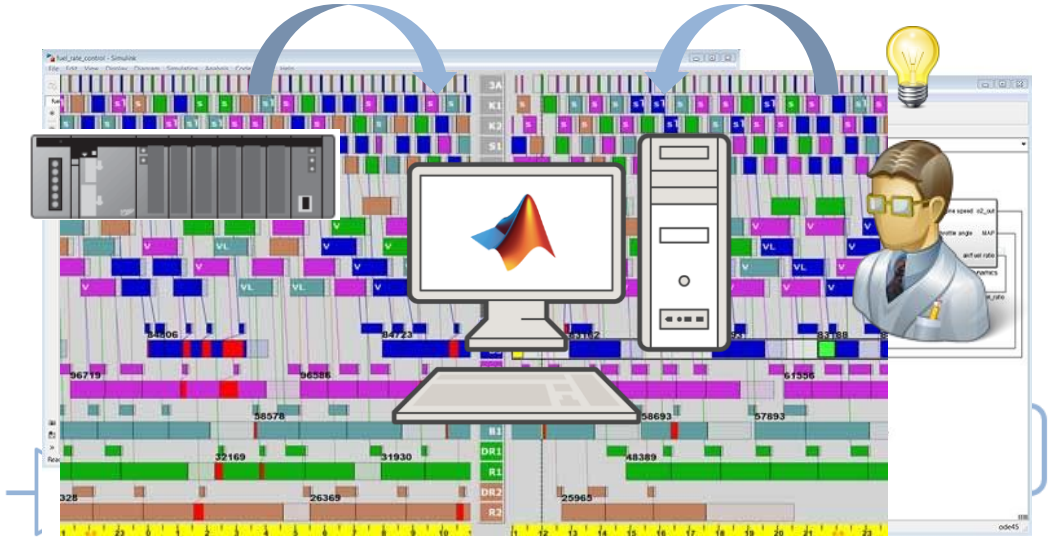
Link to user story

Step 1: System Modeling



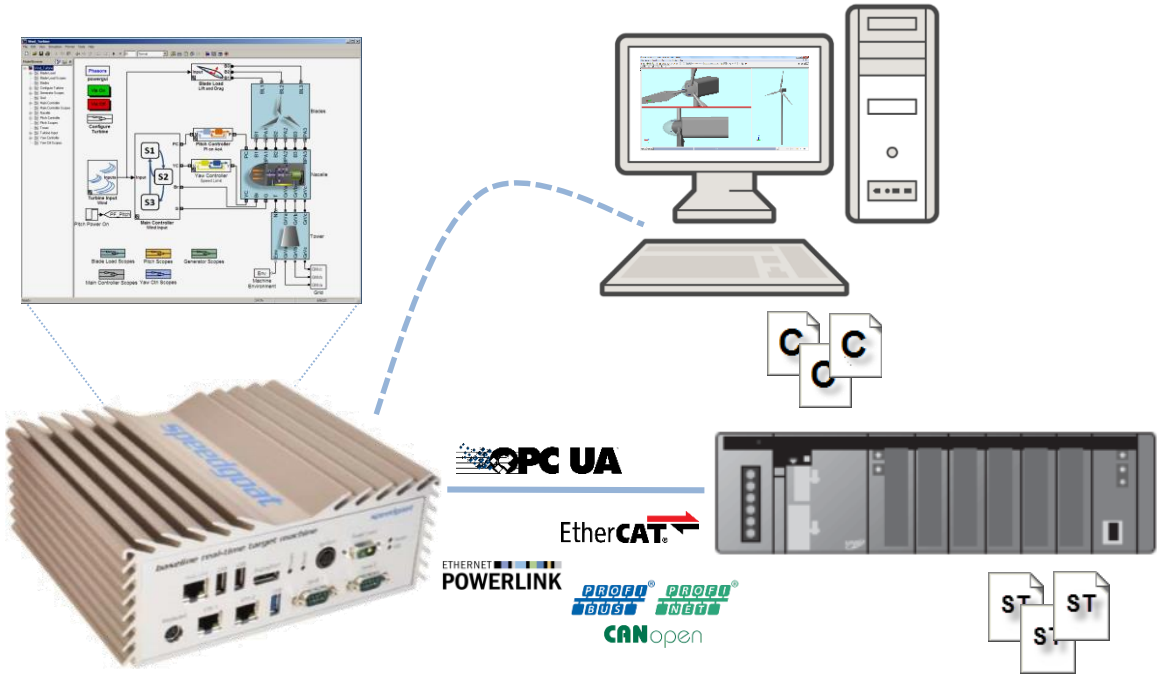
- Model your plant (mechanics, hydraulics, etc.) and controls (PID, state machine, etc.) in one single environment
- Use component libraries offered by MathWorks and 3rd party vendors
- Reuse CAD drawings through import for dynamic mechatronic simulations
- Identify your system behavior from measured data

Step 2: Desktop Simulation



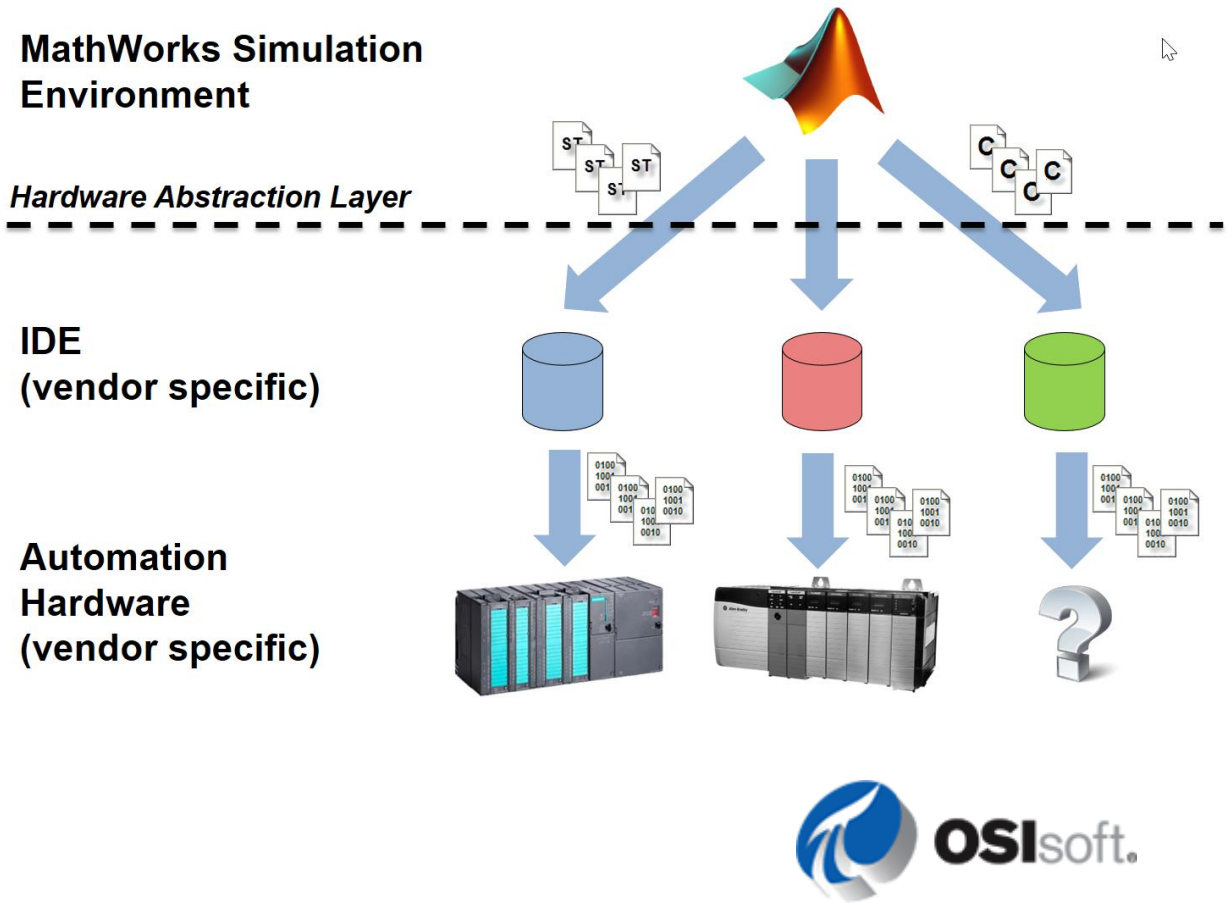
- Prototype new functionality and combine with existing code
- Perform automated system tests that would not be feasible outside of simulation and introduce faults
- Find optimal parameters and size components correctly
- Optimize product or process performance early in the project

Step 3: Hardware in the Loop Simulation



- Emulate the behavior of the physical system (plant model) in real-time
- Connect the virtual plant to your PLC or industrial PC (e.g. over an industrial fieldbus or OPC UA)

Step 4: Production Deployment



- Design and test functionality independently from hardware

Vendor	IDE	IEC 61131-3	C/C++	Connections Partner
3S - Smart Software Solutions	CODESYS	✓		✓
B&R Industrial Automation	Automation Studio	✓	✓	✓
Bachmann Electronic	SolutionCenter	✓	✓	✓
Beckhoff Automation	TwinCAT	✓	✓	✓
Bosch Rexroth	IndraWorks	✓	✓	✓
Mitsubishi Electric	CW Workbench		✓	✓
Ingeteam	Ingesys IC3		✓	✓
Omron	Sysmac Studio	✓		✓
Phoenix Contact	PC WORX	✓	✓	✓
Rockwell Automation	RSLogix / Studio 5000	✓		✓
Schneider Electric	Unity Pro	✓		
Siemens	TIA Portal / STEP 7	✓	✓	✓

Step 5: Use In Operations

- Use models for health monitoring and predictive maintenance
- Reproduce errors from field data
- Train operators on new systems

What are the major components of *Industry 4.0*

Growing complexity of **Software**

Increasing amount of **Data**

Increasing amount of Data

Increasing amount of Data

- Business Data & Engineering Data
- Industrial IoT, M2M communication
- Cheaper sensors, more computing power and data storage
- Powerful algorithms for signal processing and for statistics (e.g. machine learning, deep learning)
- Applications: Machine health monitoring, predictive maintenance, production & process optimization

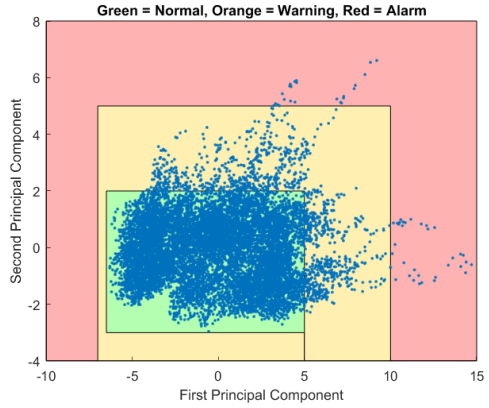
Increasing amount of Data

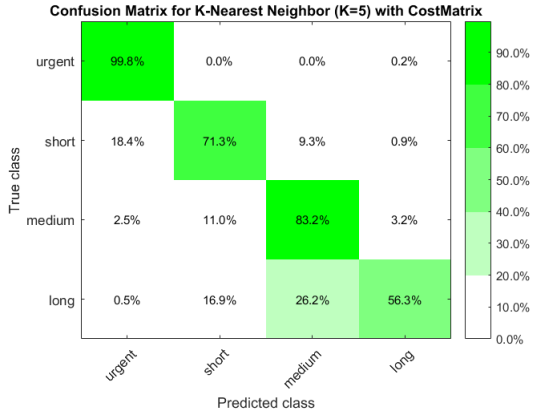
Increasing amount of Data

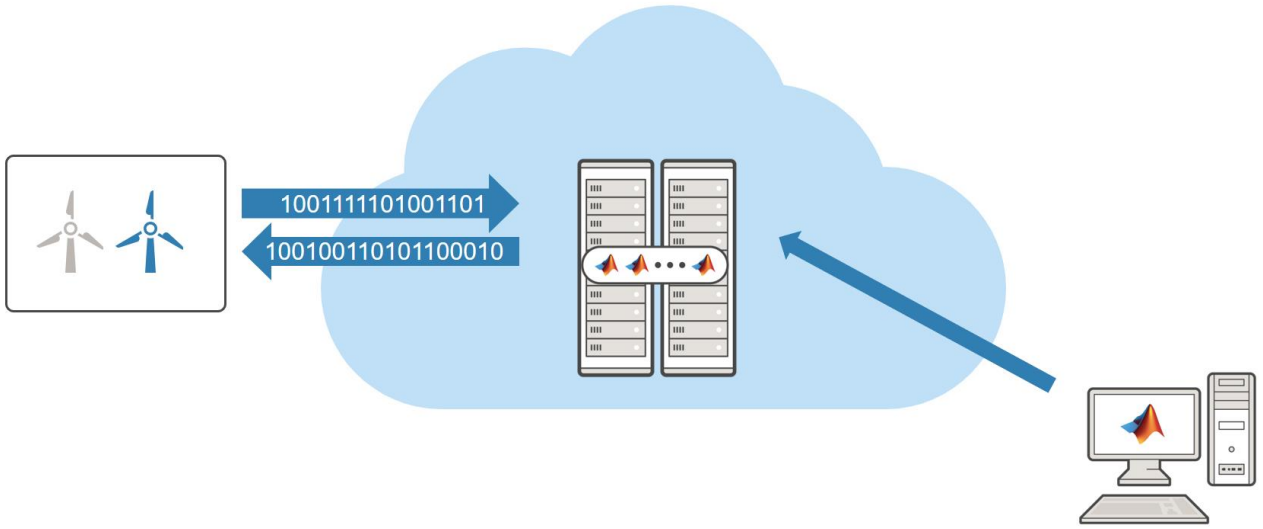
+

Powerful analytics Algorithms

…enable new (service based) Business Models.







Engineering Data Analytics for Predictive Maintenance

Mondi Implements Statistics-Based Health Monitoring and Predictive Maintenance for Manufacturing Processes with Machine Learning

One of Mondi Gronau's plastic production machines, which deliver about 18 million tons of plastic and thin film products annually.

Challenge

Reduce waste and machine downtime in plastics manufacturing plants

Solution

> "MathWorks Consulting's support is among the best I've seen; the consultants are fast and exceptionally knowledgeable. We've already seen a positive return on investment from cost savings, and now we have more budget and time to complete more machine learning projects that will provide similar benefits."
>
> Dr. Michael Kohlert
> Mondi

Link to user story

Link to video

Baker Hughes Develops Predictive Maintenance Software for Gas and Oil Extraction Equipment Using Data Analytics and Machine Learning

Truck with positive displacement pump.

Challenge

Develop a predictive maintenance system to reduce pump equipment costs and downtime

Solution

Use MATLAB to **analyze nearly one terabyte of data and create a neural network that can predict machine failures before they occur**

Results

- Savings of more than $10 million projected
- Development time reduced tenfold
- Multiple types of data easily accessed

"MATLAB gave us the ability to convert previously unreadable data into a usable format; automate filtering, spectral analysis, and transform steps for multiple trucks and regions; and ultimately, apply machine learning techniques in real time to predict the ideal time to perform maintenance."

Gulshan Singh
Baker Hughes

Link to user story

Data Analytics for Predictive Maintenance

Example: Mondi

Equipment Operators

Care about:
- Increased uptime
- Having in-house knowledge of operating machinery
- Ownership of data

Business model:
- Build in-house Predictive Maintenance solution to increase uptime and minimize unplanned / unnecessary maintenance

MathWorks / Opti-Num role:
- Analyze your field data, recommend algorithms and help integrate into IT infrastructure

Example: Baker Hughes

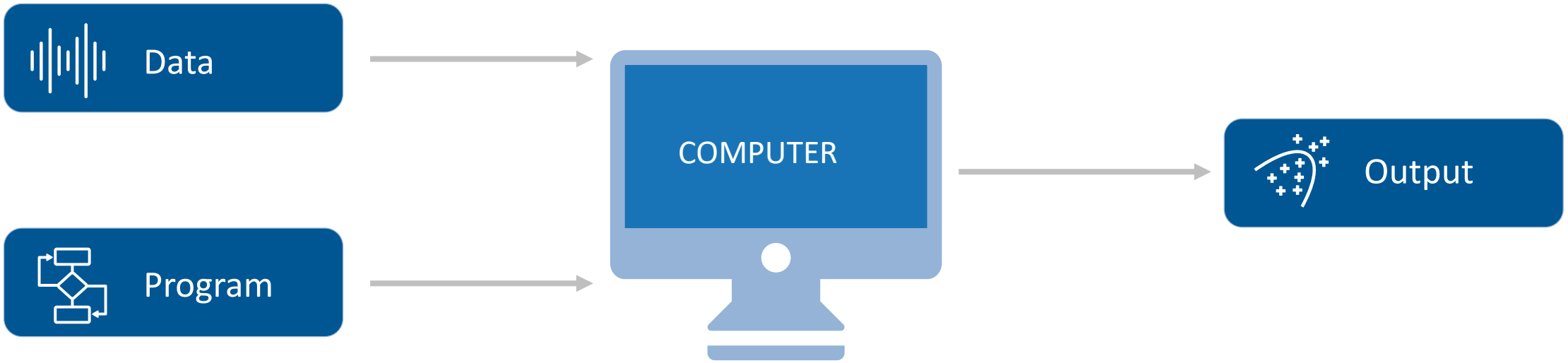
Equipment Builders

Care about:
- Differentiating from other equipment builders
- New business models for a more continuous revenue stream
- Increasing services side of business

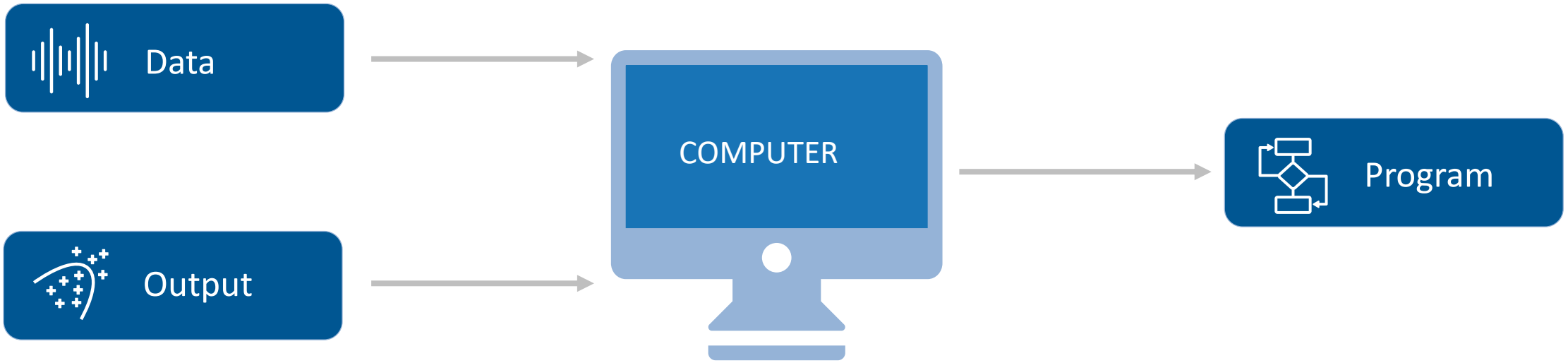
Business model:
- Offer Predictive Maintenance solution and according service contract to Equipment Operators (their customers)

MathWorks / Opti-Num role:
- Support building algorithms based on test data and help build packaged solution as part of product portfolio

How does Machine Learning work

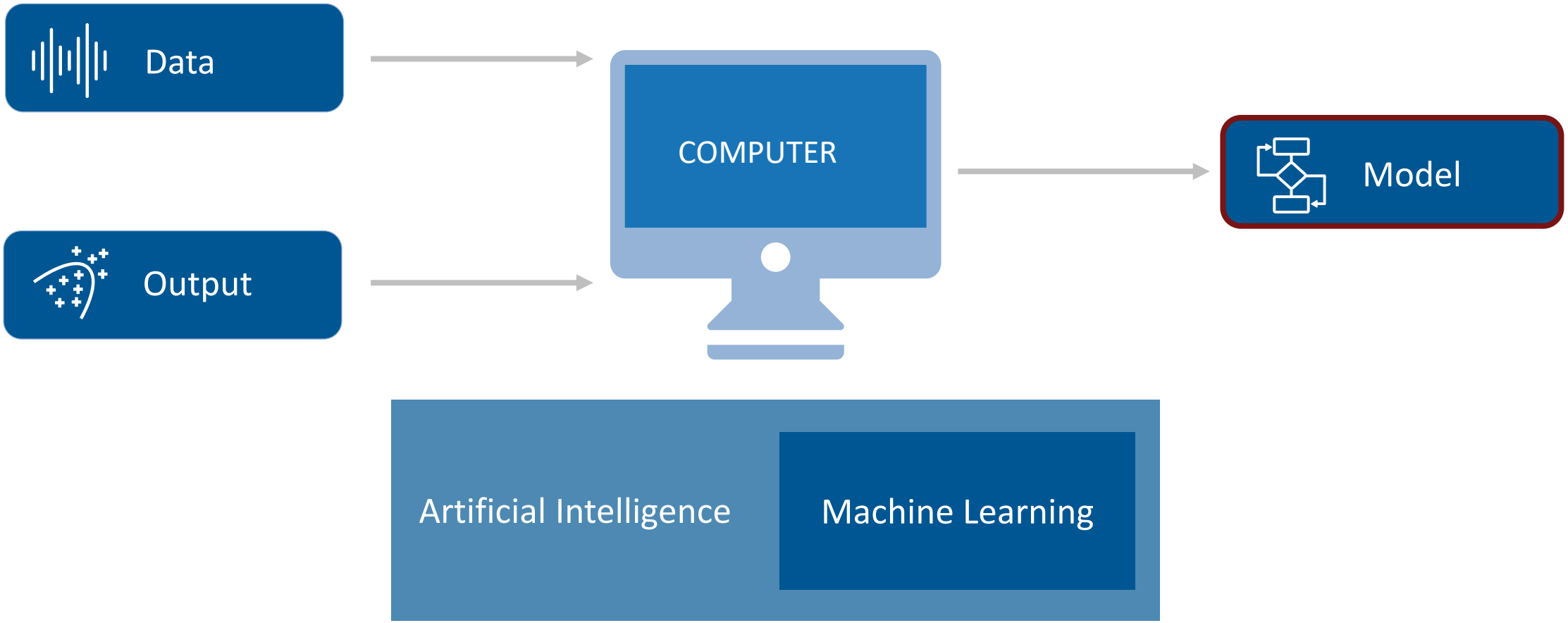


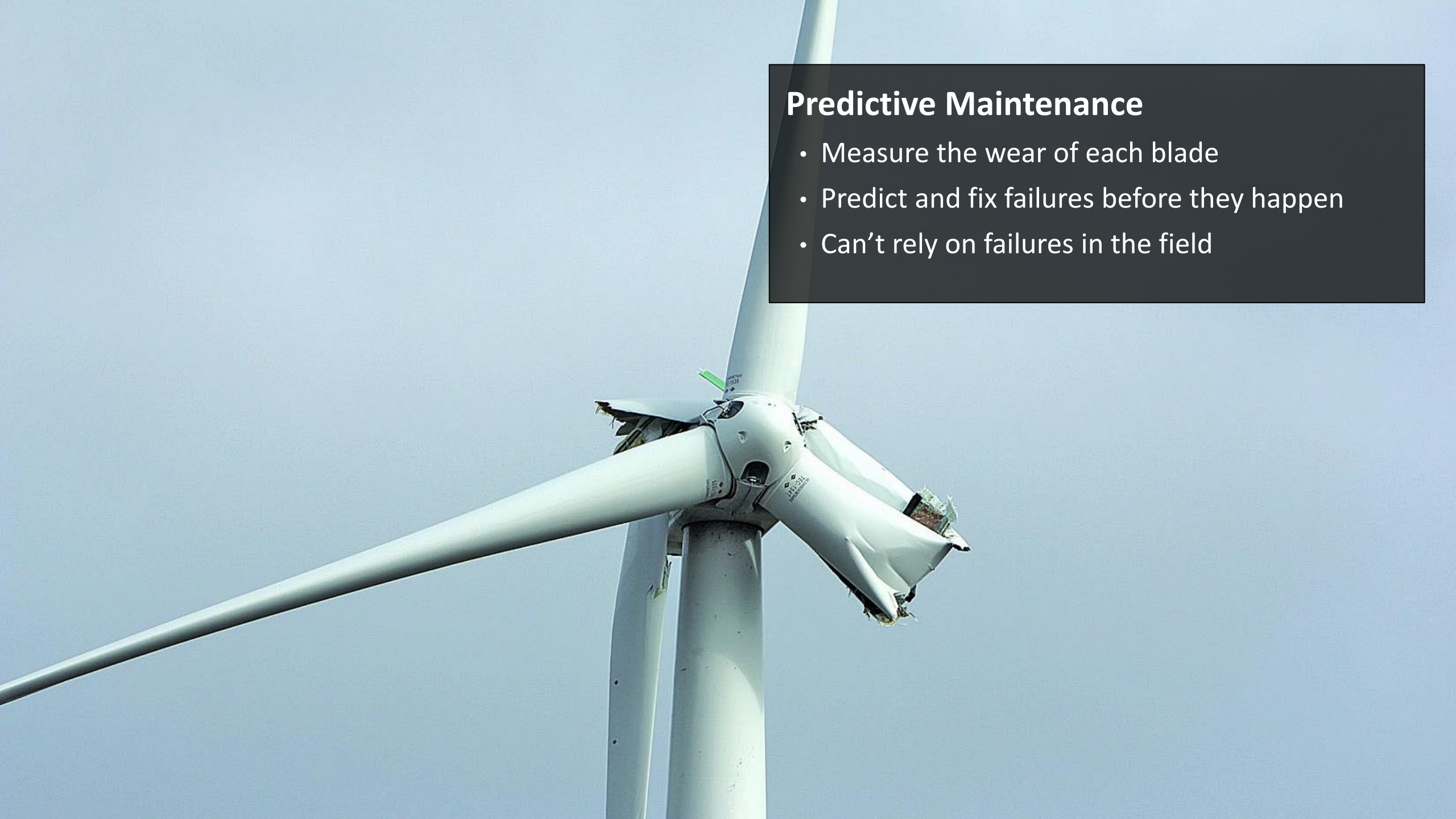
How does Machine Learning work



How does Machine Learning work

What if you don't have enough (failure) data to train your model?

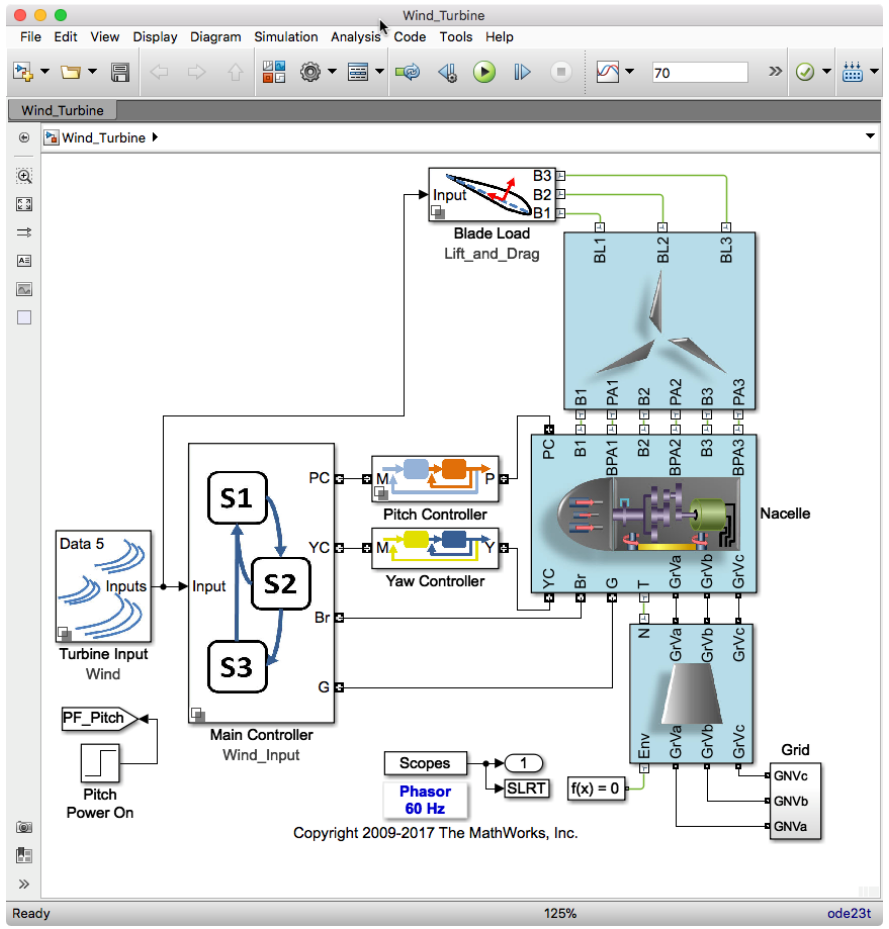


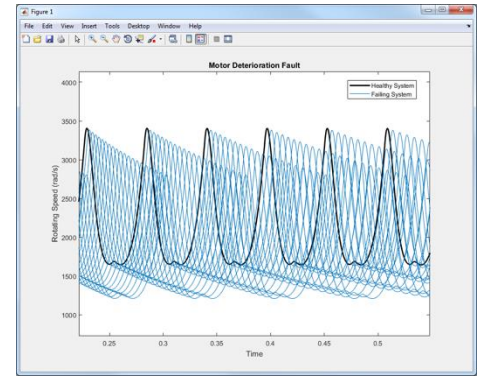


Predictive Maintenance

- Measure the wear of each blade
- Predict and fix failures before they happen
- Can’t rely on failures in the field

Predictive Maintenance with synthetic failure data from simulation

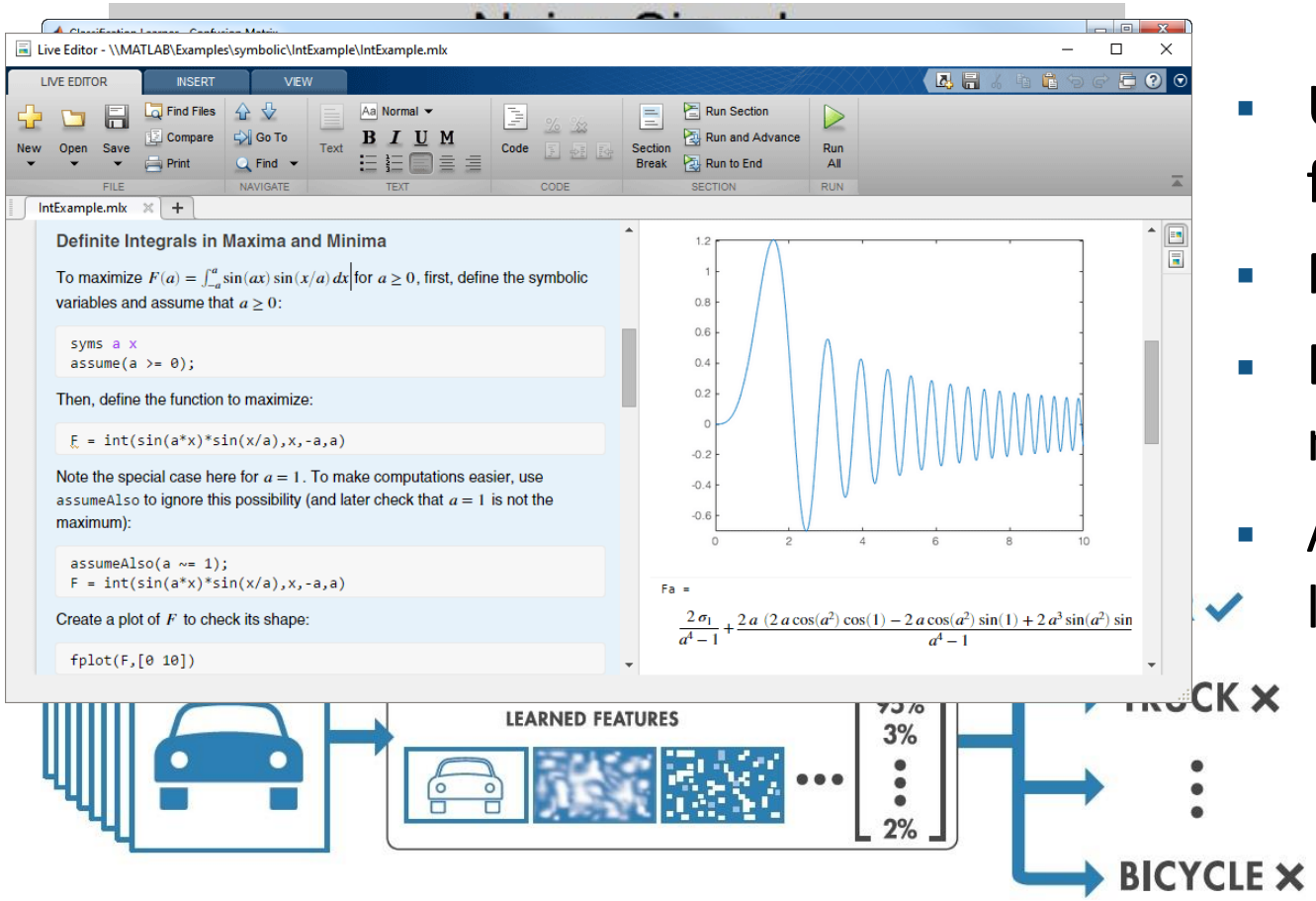




Step 1: Import Data

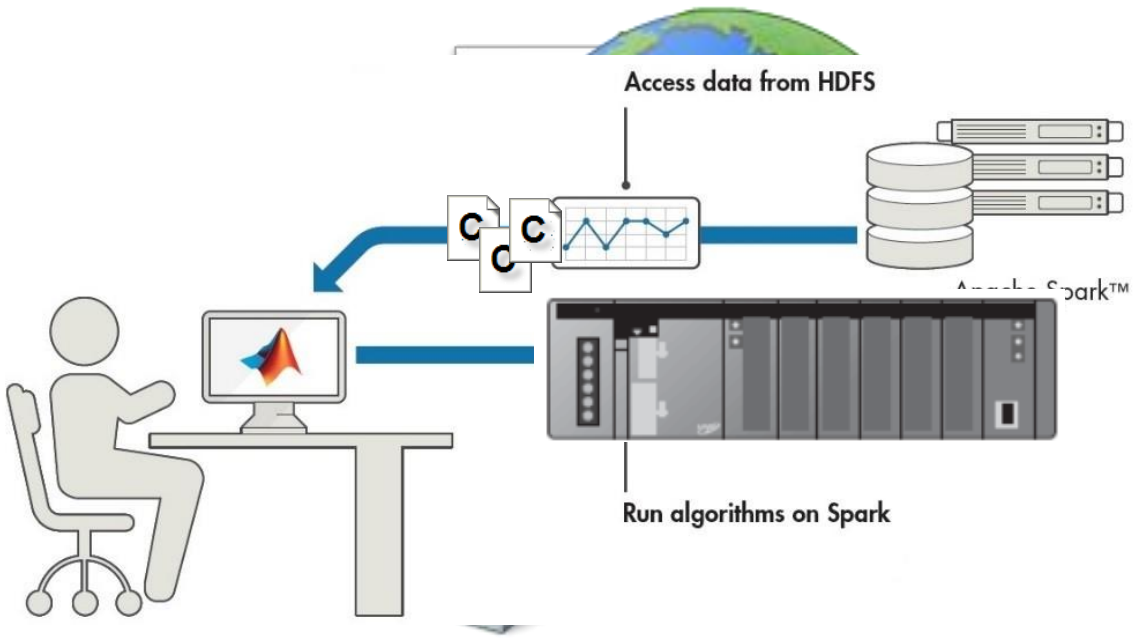
- From files (e.g. csv)
- Directly from hardware (e.g. OPC UA)
- From data bases (SQL and non SQL) or data historians
- Hadoop and Spark support for Big Data (out of memory data)

Step 2: Analyze Data



- Use signal processing methods (e.g. for filtering)
- Machine Learning
- Deep Learning including pre-trained networks
- Automate analytics scripts in MATLAB language

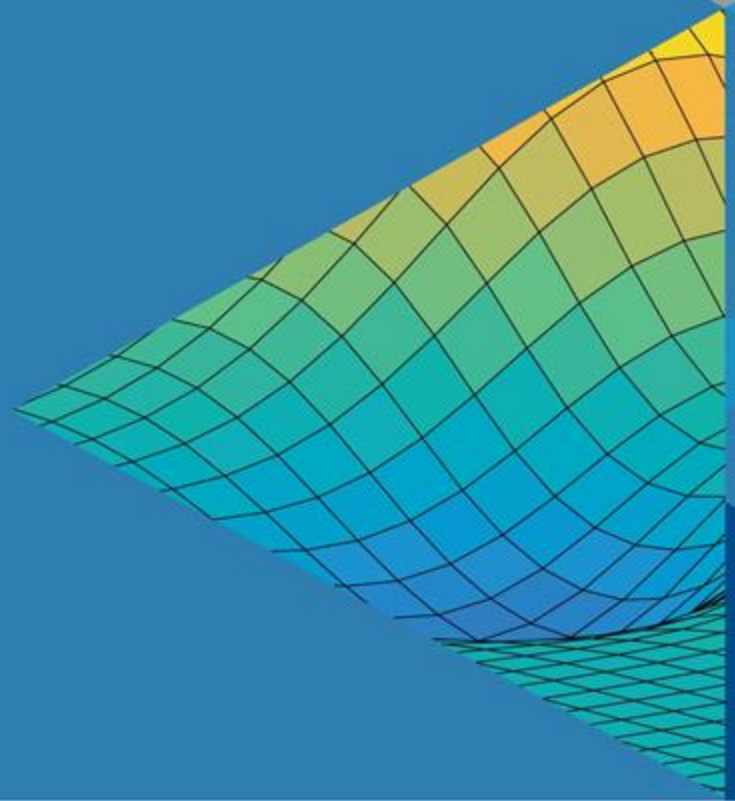
Step 3: Deploy Algorithms



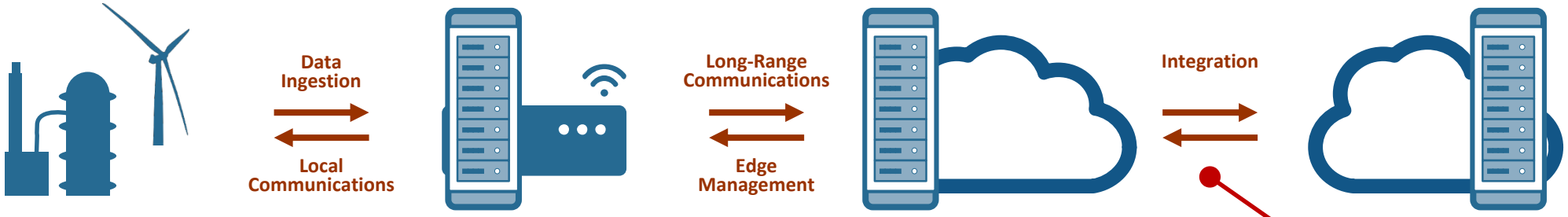
- Create stand alone applications
- Integrate into existing IT/OT system
- Generate real-time C/C++ or PLC (IEC 61131-3) code
- Hadoop and Spark support for Big Data (out of memory data)

Where does Industry 4.0 live

How does Industry 4.0 fit into your IT/OT infrastructure and how does it relate to Digital Twins and IIoT?



Industrial Internet of Things (IIoT): Systems of physical assets in operation



- Added value from services (e.g. for energy forecasting or predictive maintenance)
- Software in everything plus connectivity allows remote monitoring and optimization
- Assets can be heavily sensored at low cost

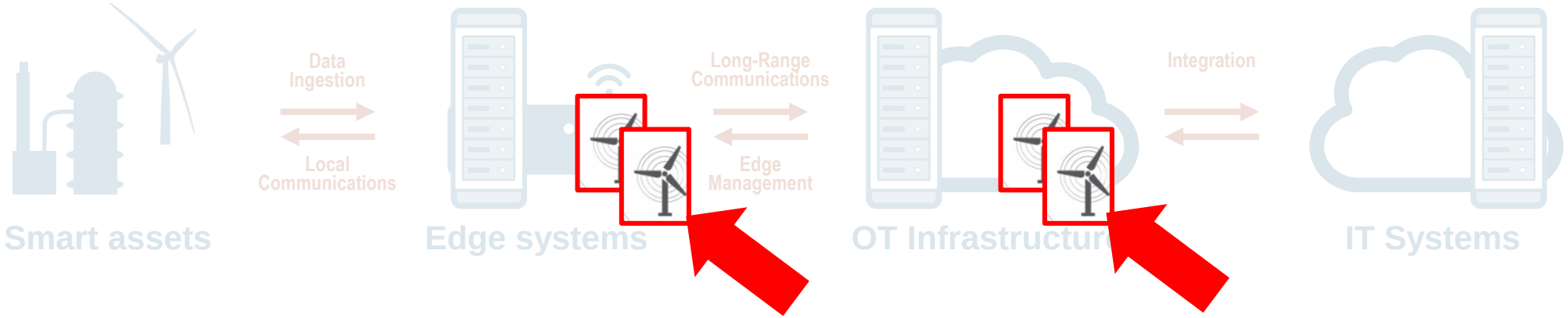
- Assets pervasively connected
- Increase of local computing and monitoring systems not on the asset

- Data transport protocols
- Transition to web technology

- Big data and increased comfort driving cloud use; IP, reliability, etc. pushing on-prem
- Hybrid (both cloud and on-prem)

- Operational Technology teams managing systems to support assets and services (instead of product teams)
- Focus to optimize across operations and business boundaries

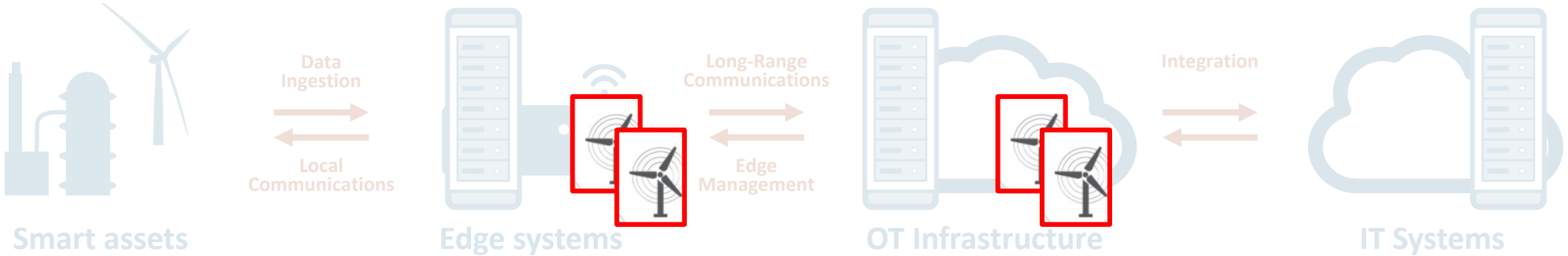
Digital Twins in operation



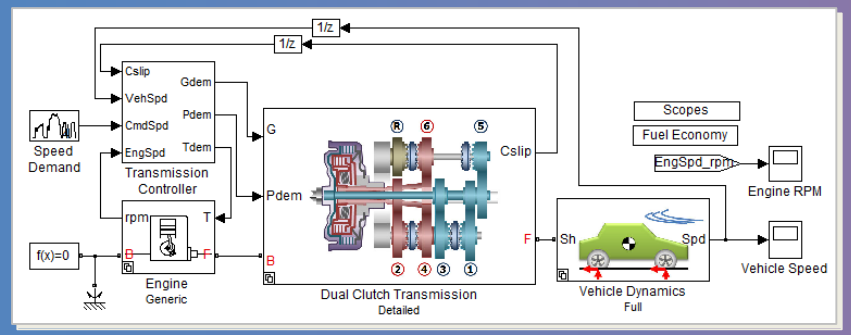
- Faithful, up-to-date **representation of asset** (current, past, or future state)

- Composite of modelled behaviors using any number of modeling approaches – **data or physics**
  This can be hierarchical and include **multiple levels of fidelity**

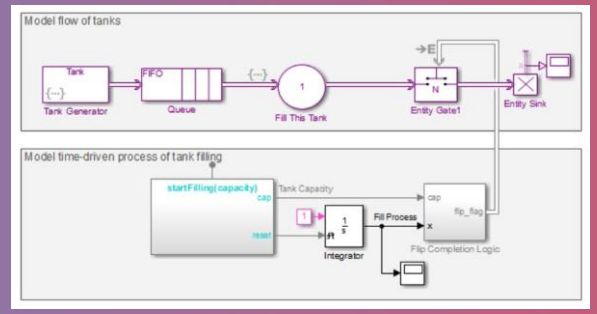
Digital Twins in operation



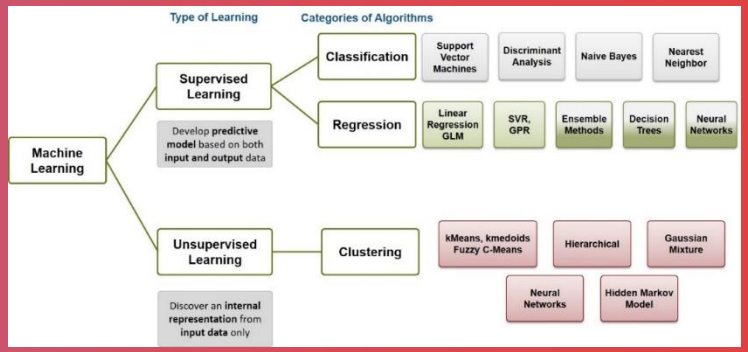
First Principles Modeling



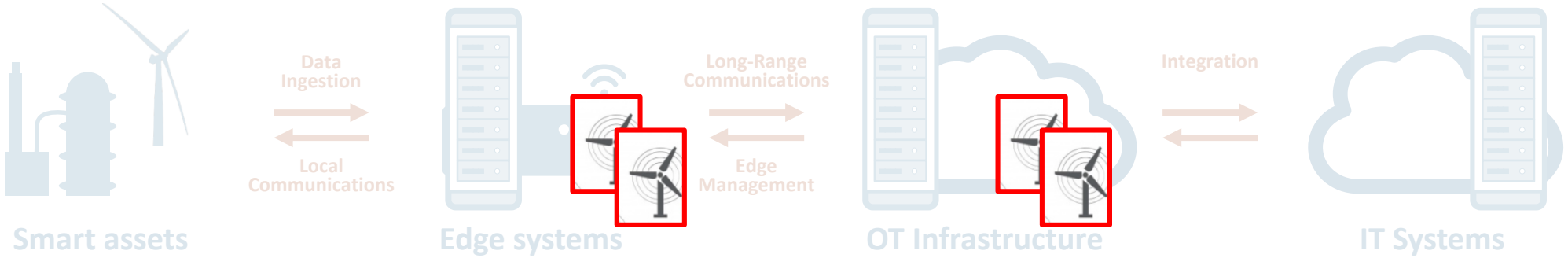
Discrete Event Modeling



Data-Driven Modeling



Applications enabled by Digital Twins



Example Applications in operation
Predictive Maintenance
Asset Performance Management (APM)
Operations Optimization
Business Optimization
Advanced Controls / Edge Computing
Energy Forecasting

Mill Operators' Conference 2018

Paper Number: 27

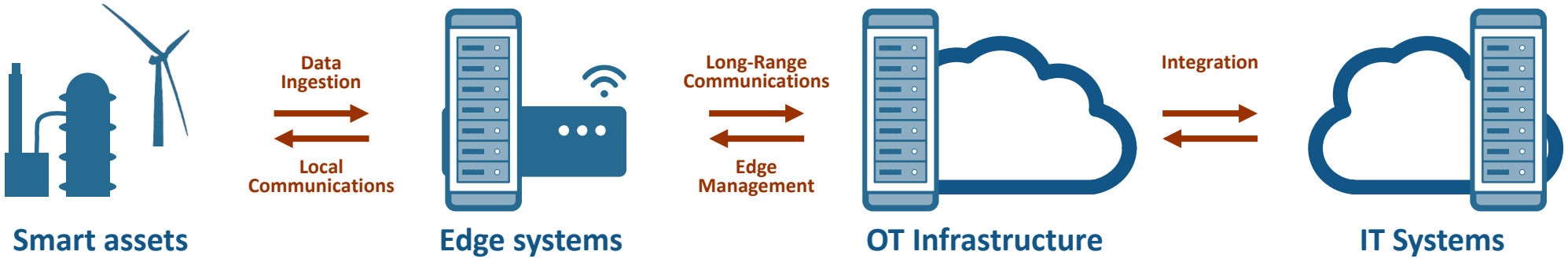
Optimising flotation plant operation by using a "Digital Twin" in the control room

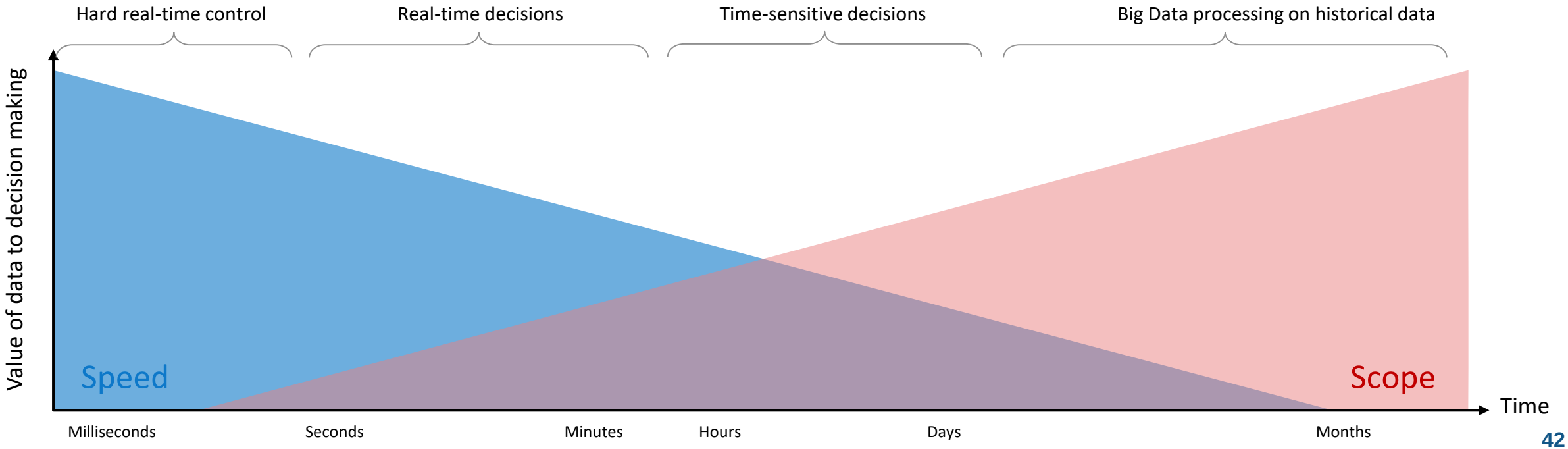
S J Oliver[1], MathWorks

1.
Principal Technical Consultant, MathWorks, Sydney NSW 2067. Email: sam.oliver@mathworks.com.au

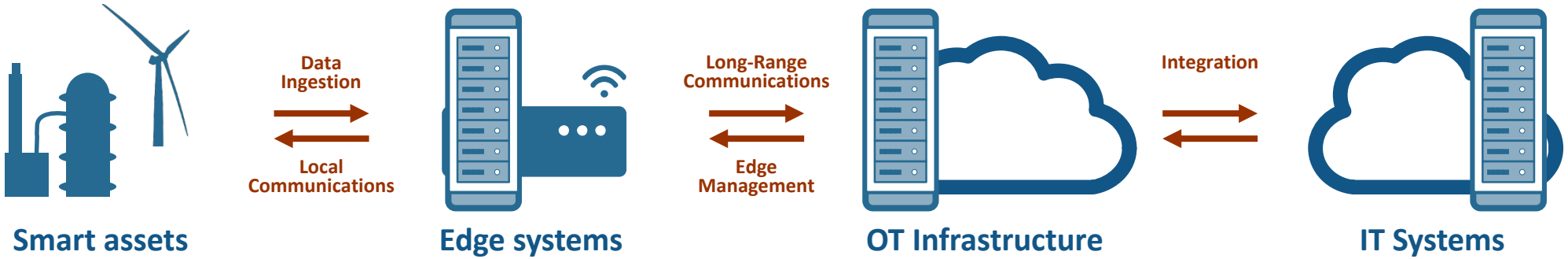
ABSTRACT

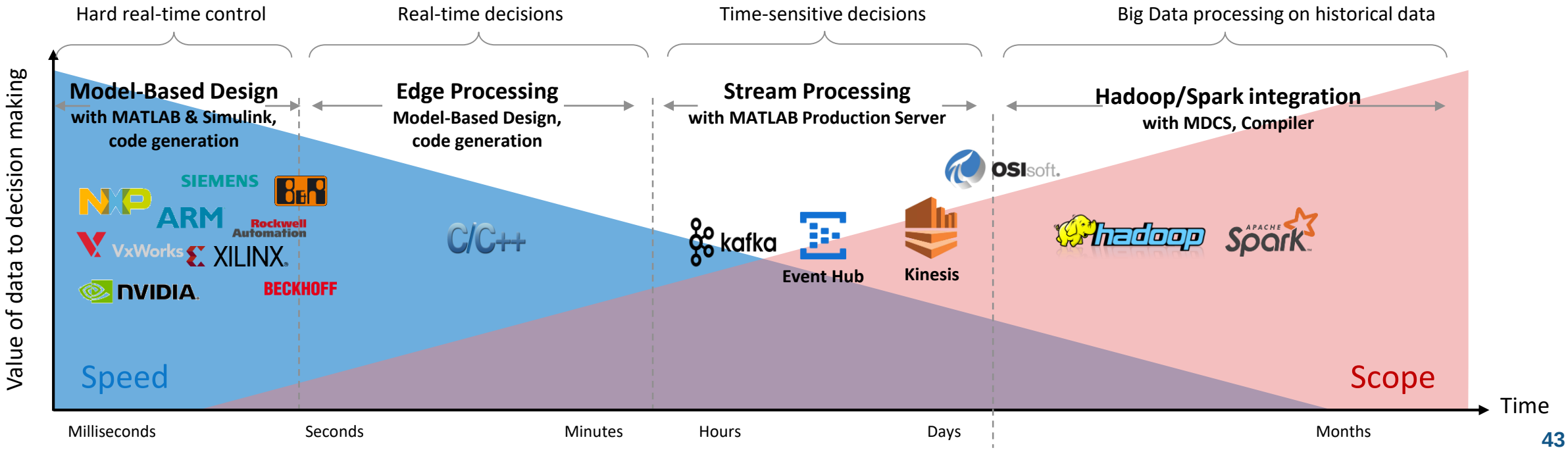
MathWorks support for the design of Digital Twins



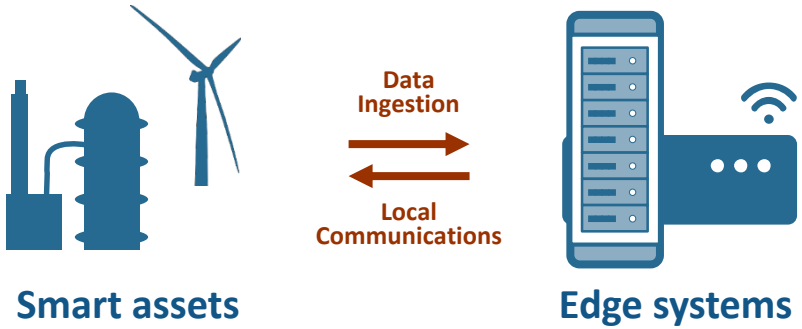


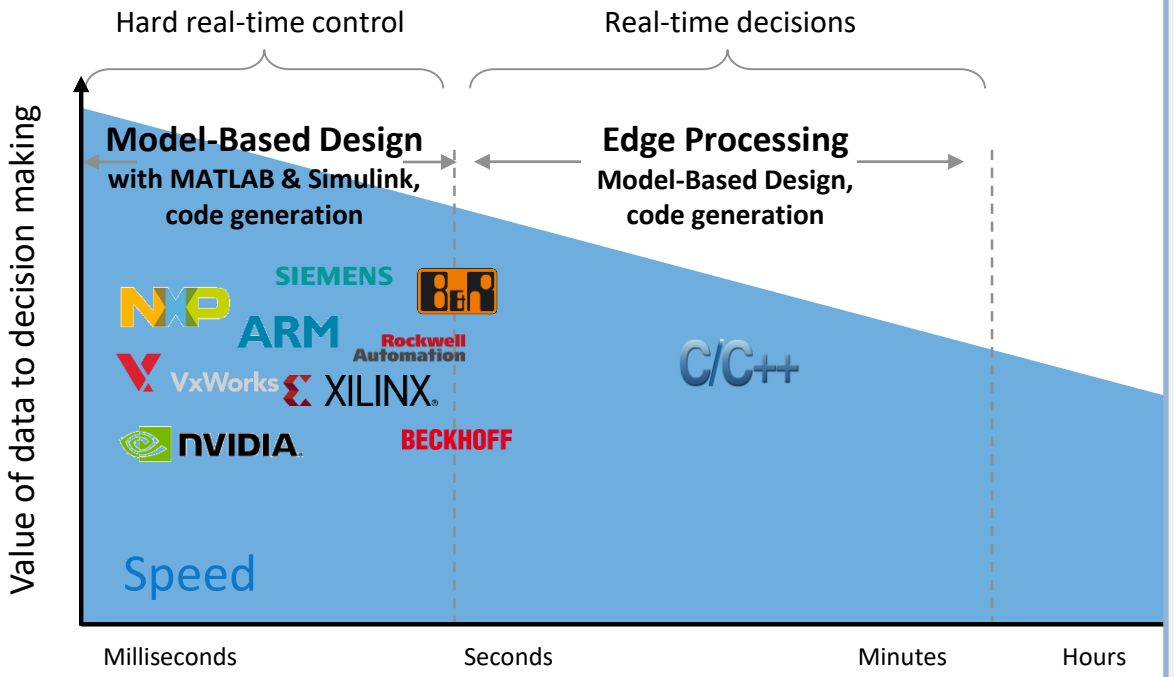
MathWorks support for the design of Digital Twins



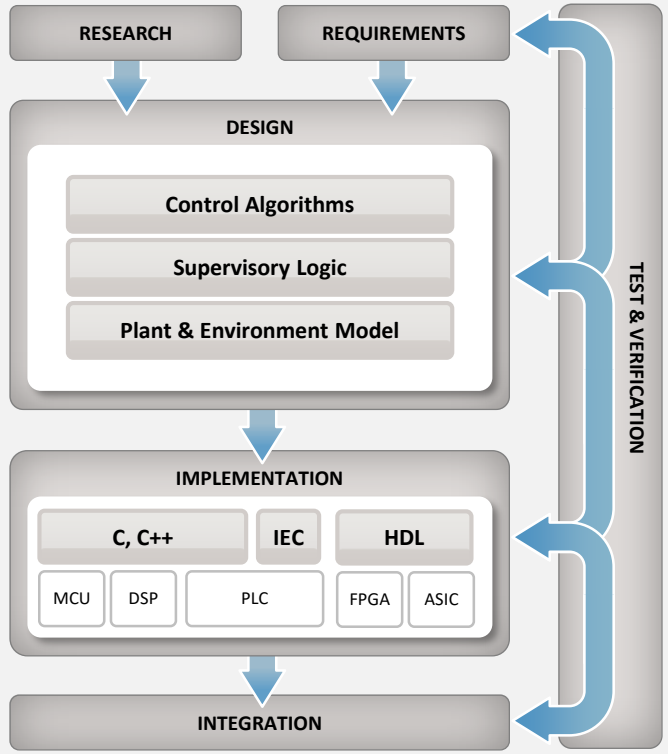


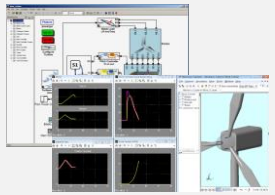
Development for fast and highly-deterministic systems



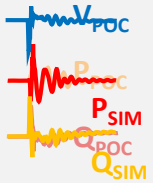


Model-Based Design

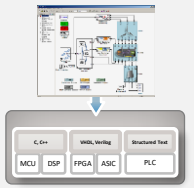




Multi-domain system modeling

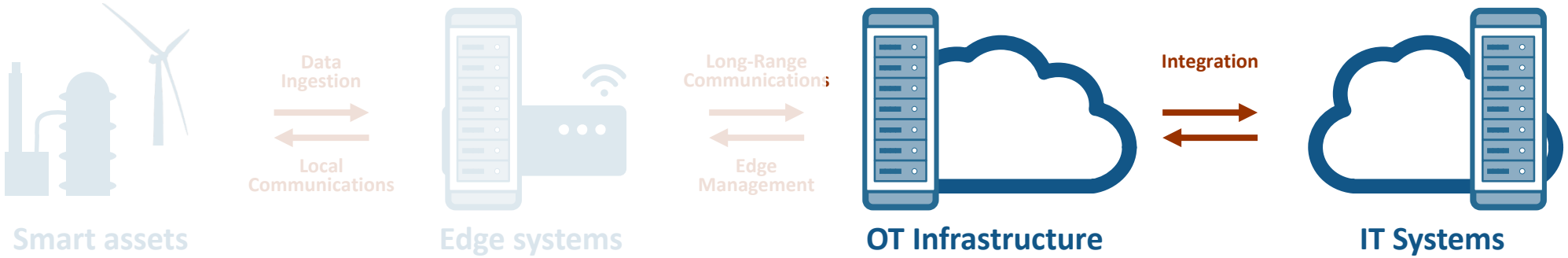


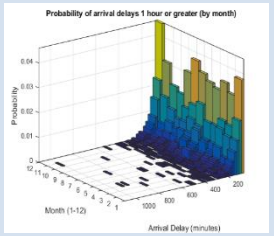
Parameter estimation



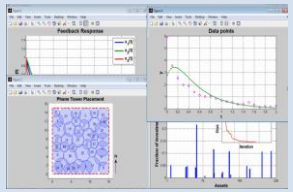
Automatic code generation

Development to OT/IT enterprise infrastructure

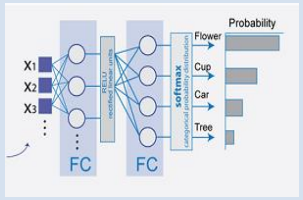




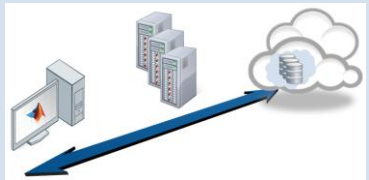
Variety and Volumes of Data



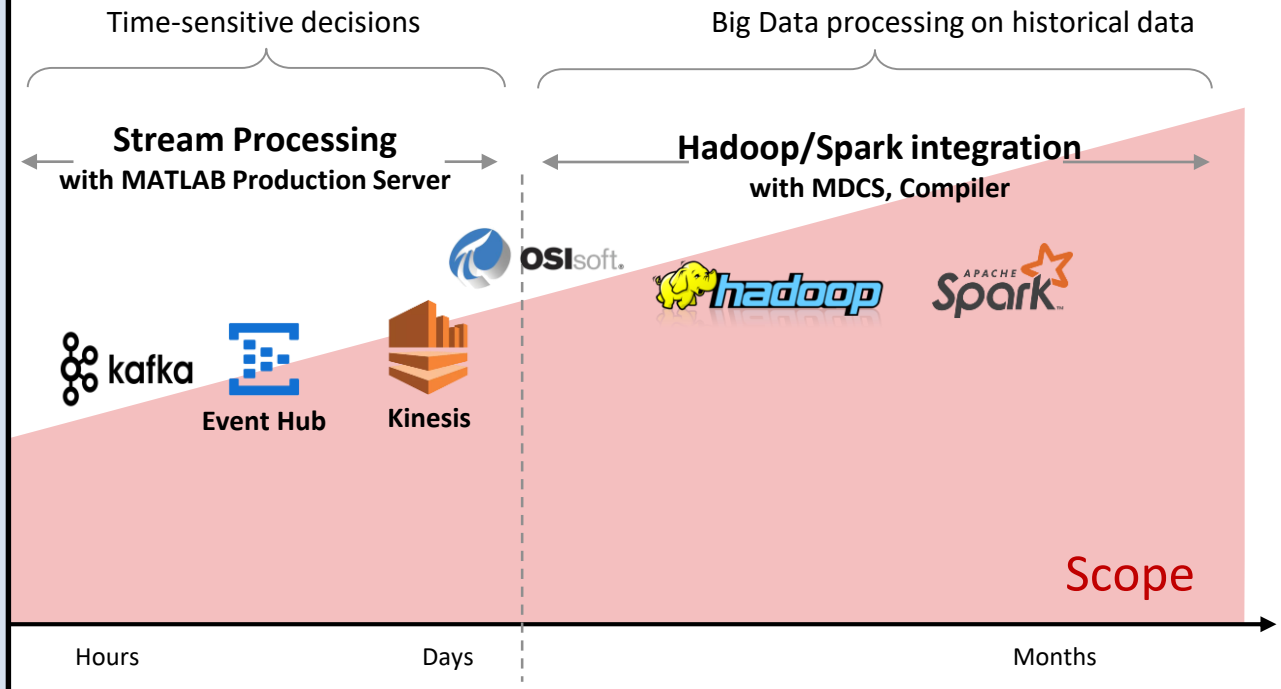
Optimization



Machine Learning and Deep Learning

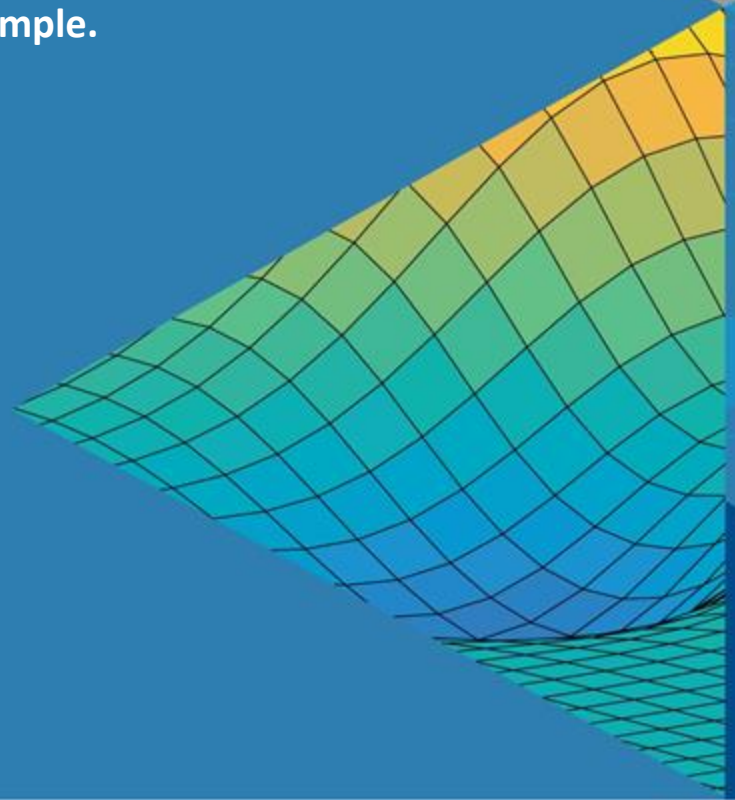


Enterprise system integration, with cluster/cloud execution



The benefits of Industry 4.0

Finally – does Industry 4.0 really pay off? Predictive Maintenance example.




5" 12,000 PSI
5" 12,000 PSI
BAKER HUGHES

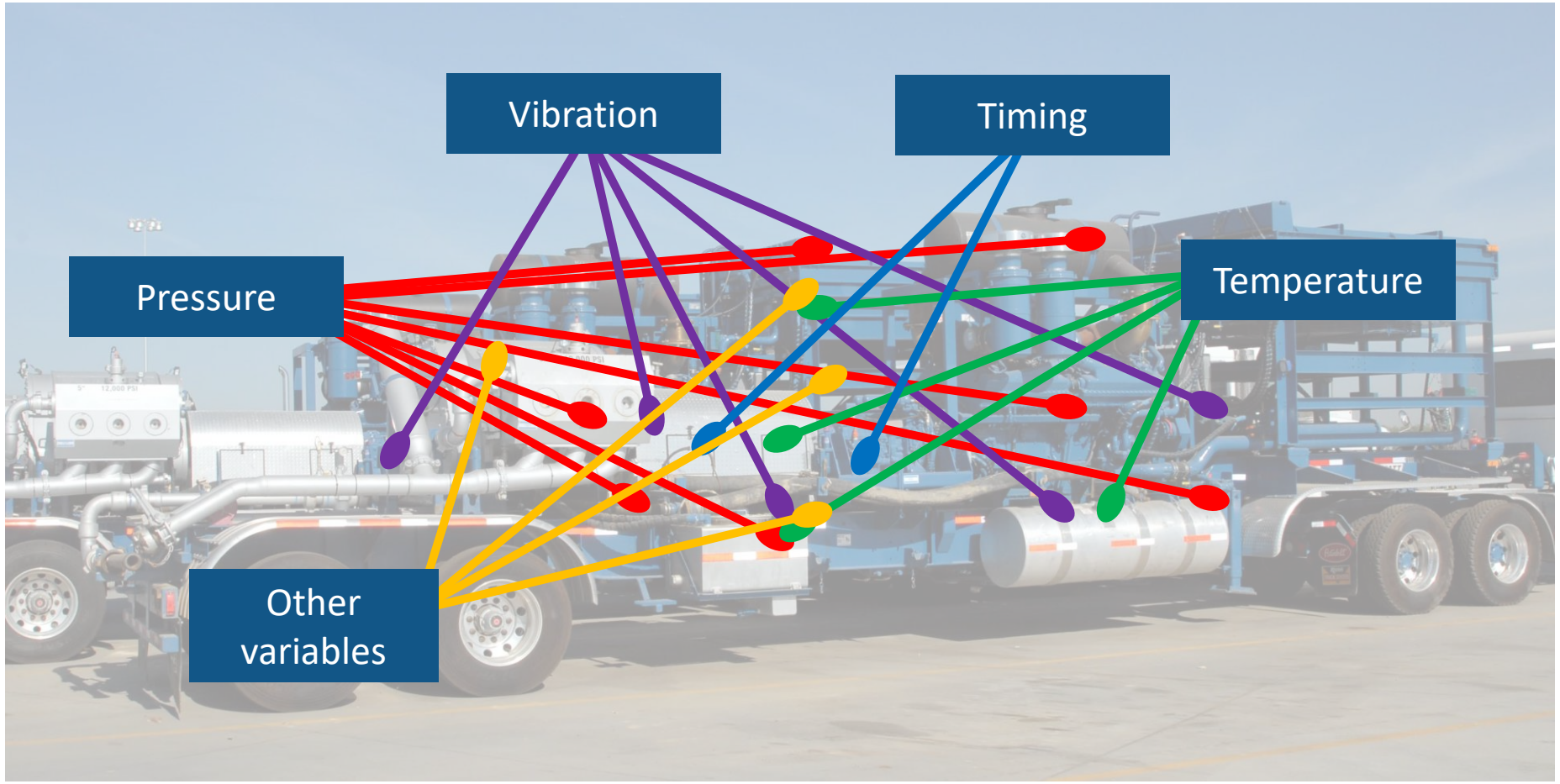

Cost of rig: >$1M
Repair cost: $100,000
Cost of valve: $200
5" 12,000 PSI
5" 12,000 PSI
BAKER HUGHES

Service for Predictive Maintenance

010010
100001
011100
100101

Data & Information

Which sensor values should they use?



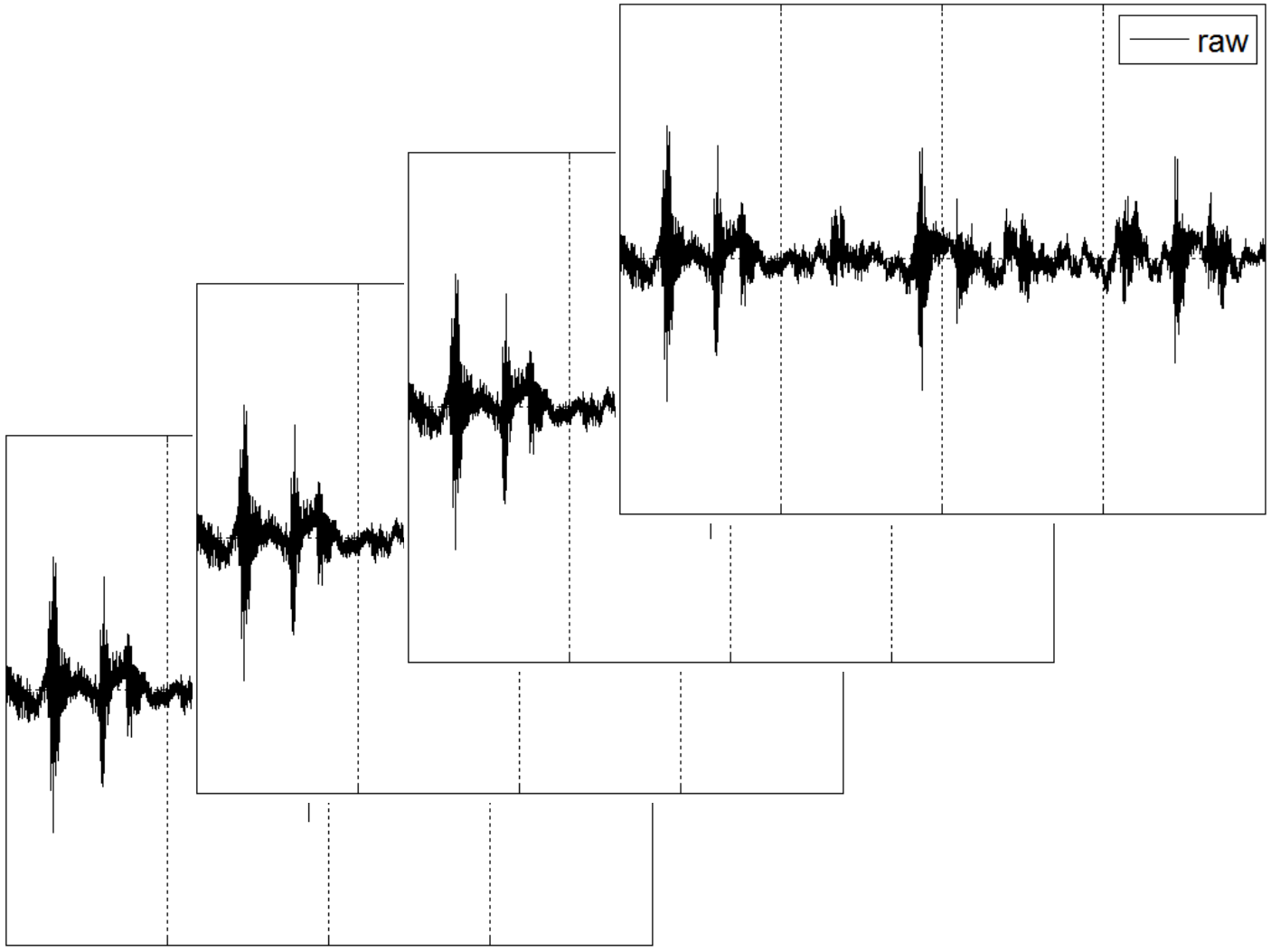
[Link to User Story]

Service for Predictive Maintenance

010010
100001
011100
100101

Data & Information

Knowledge



Link to User Story

Service for Predictive Maintenance

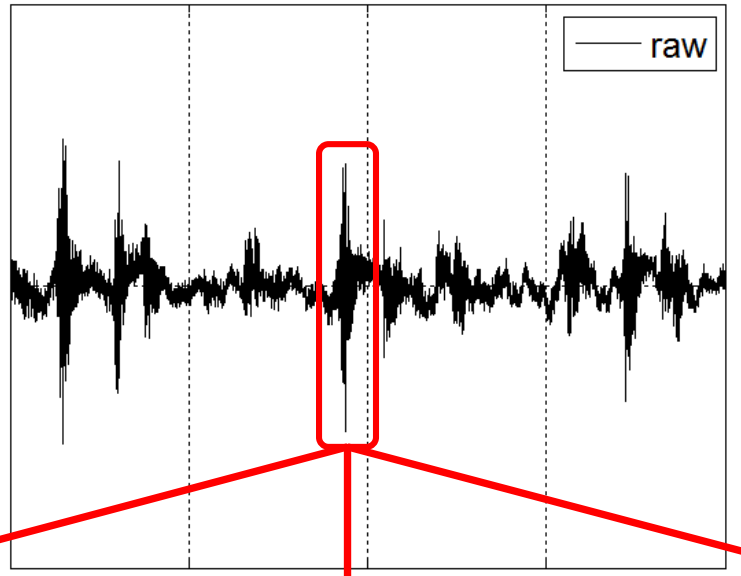
010010
100001
011100
100101

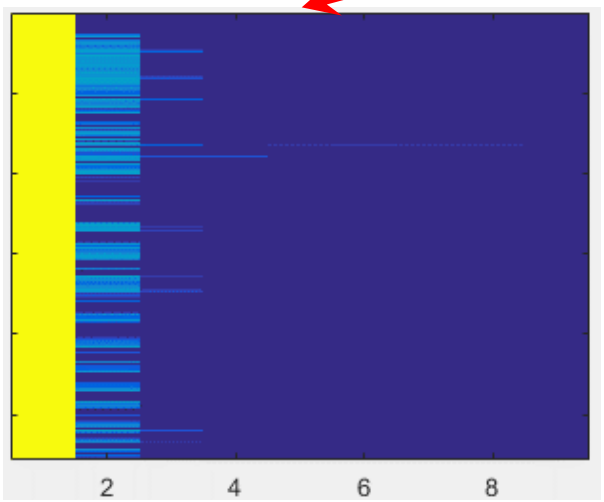
Data & Information

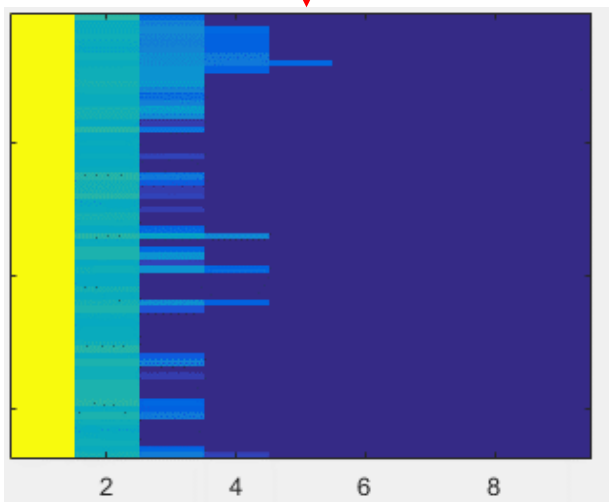
Knowledge

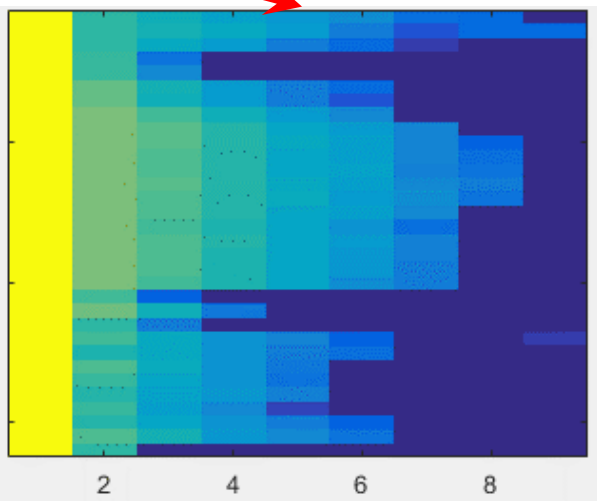
Wisdom

[Link to User Story]









Normal Operation

Monitor Closely

Maintenance Needed

Predictive Maintenance for polymer-based production machines

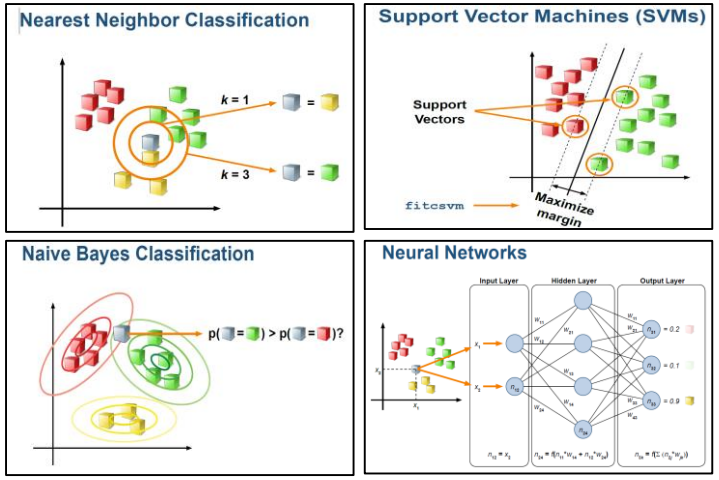
Sensor Data (~1 minute)

10-100 sensors/machine

Quality State (~40 minutes)

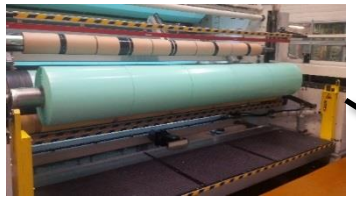
1 TIMESTAMP	2 PARAMETER										3 STATE
2015-07-14 00:49:12.0'	160	160	160	160	1000	7	1000	9	33	32	1
2015-07-14 00:50:12.0'	160	160	160	160	1000	8	1000	10	33	32	1
2015-07-14 00:51:13.0'	160	160	160	160	1000	8	1000	10	33	32	1
2015-07-14 00:52:12.0'	160	160	160	160	1000	8	1000	10	33	32	1
2015-07-14 00:53:12.0'	160	160	160	160	1000	8	1000	11	33	32	2
'2015-07-14 00:54:12.0'	160	160	160	160	1000	8	1000	12	33	32	2
'2015-07-14 00:55:12.0'	160	160	160	160	1000	8	1000	10	33	32	2

Classification using Statistics, Machine Learning, and Neural Networks

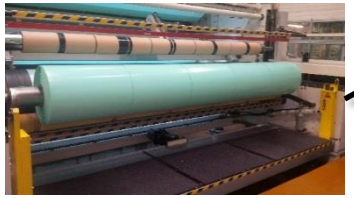


[Link to User Story]

Deployment – a MATLAB App used by machine operators



M153



M157

State NOT OK

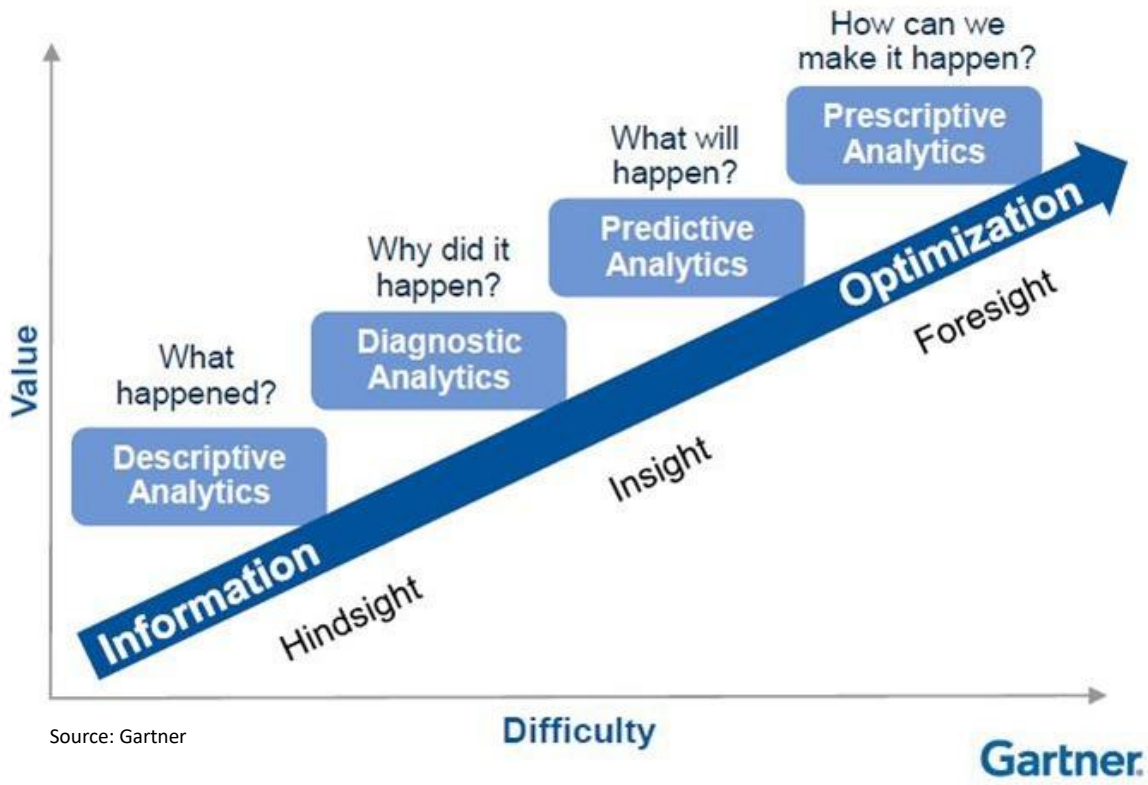
State OK

[Link to User Story]


MathWorks®


MathWorks®

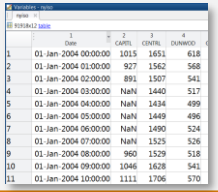
Going One Step Further: Prescriptive Analytics



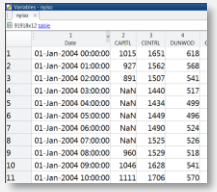
Source: Gartner

Going One Step Further: Prescriptive Analytics

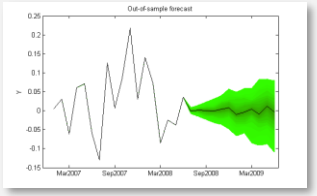
Historical Sensor Data



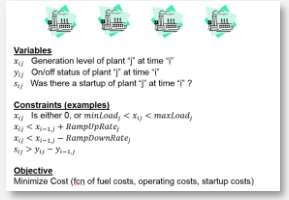
Historical Operations Data



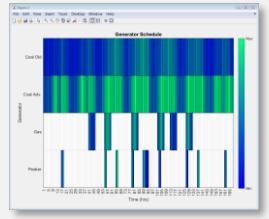
RUL Forecast



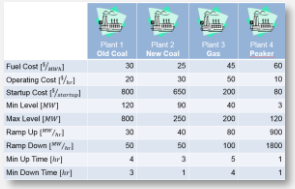
Optimization



Maintenance Schedule



Current Operations Data



Key Takeaway

- Industry 4.0 is real and is already used in practical applications
- There is not “the one” Industry 4.0 application
- Know your business case before implementing your Industry 4.0 application

Talk to us (Terasoft and MathWorks) on how we can support you!