MATLAB EXPO

将基于仿真的数字工程技术应用于智能制造

宋胜凯, MathWorks

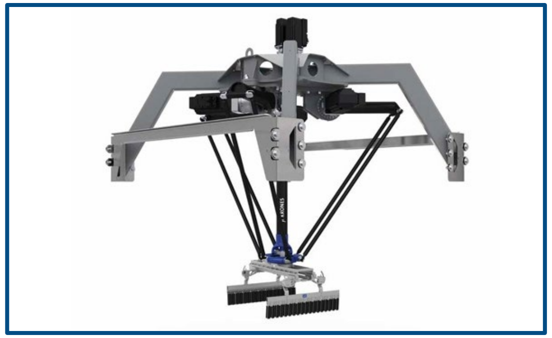
MathWorks

Agenda

- MATLAB/Simulink 在工业自动化和装备领域的应用案例
- 智能制造的两个支柱——自动化和智能运维
- 应用数字化工程技术：系统化的使用模型与数据
- 数字化工程技术的关键——应用仿真
- 总结和展望

MATLAB/Simulink 在工业自动化和装备领域的应用

恩格尔 ENGEL 注塑机
一个注射单元由四个同步驱动器驱动



克朗斯 Krones 罐装&包装设备
Robobox T-GM 型包装搬运机器人

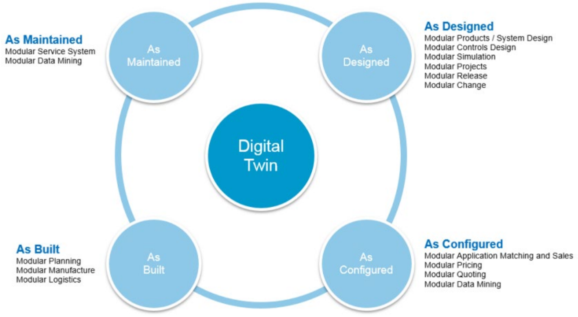
三菱重工开发用于清除核燃料碎片的机械臂
长7米、承载高达2000公斤反作用力

Vintecc 多轴收割机
整个收割机控制系统在3个PLC上实现

贝克休斯：装有容积泵的卡车

蒙迪 Mondi Gronau 塑料生产设备
年产1800万吨塑料和薄膜产品.

STIWA的车间管理系统, 基于MATLAB、
AMS ZPoint-CI和AMS Analysis-CI。



阿特拉斯·科普柯利用将仿真与数据分析集
成在一起的数字孪生将拥有成本最小化

[Company - User Stories - MATLAB & Simulink (mathworks.com)](https://www.mathworks.com)

MATLAB/Simulink 在工业自动化和装备领域的应用

研发
Development

组件/分系统 → 系统/设备

恩格尔ENGEL 注塑机
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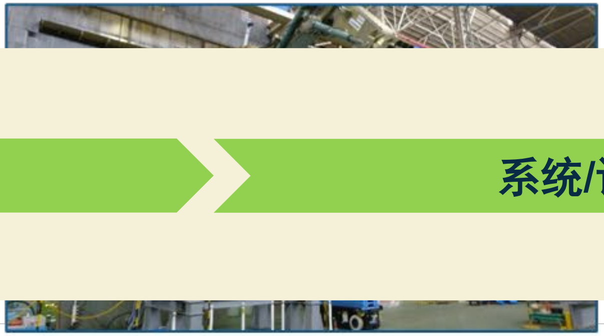

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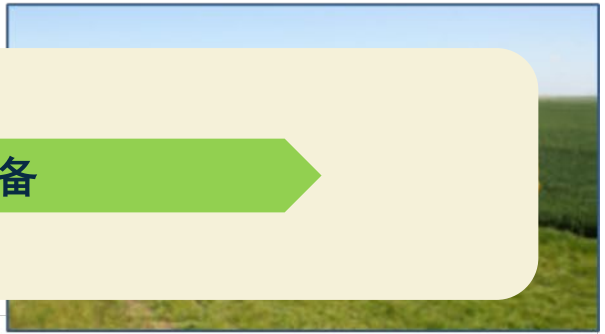
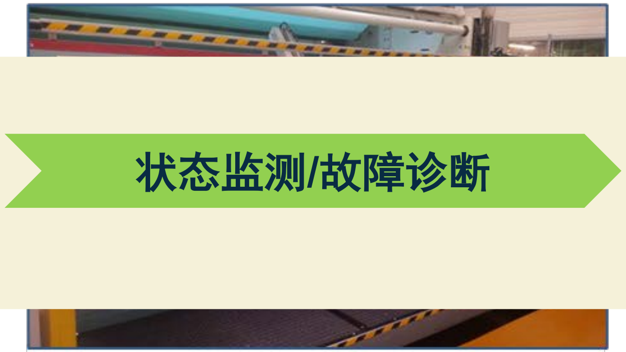


Vintecc 多轴收割机
整个收割机控制系统在3个PLC上实现

运维
Operation & Maintenance

状态监测/故障诊断 → 预测性维护 → 数字孪生

贝克休斯：装有容积泵的卡车



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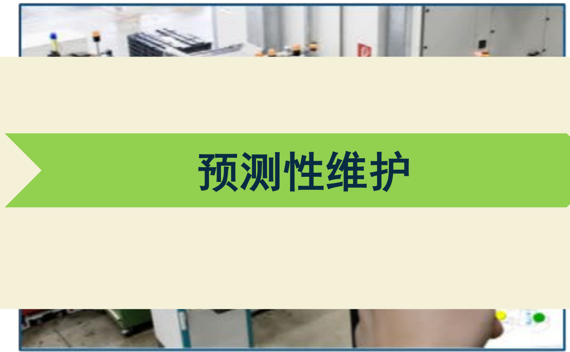

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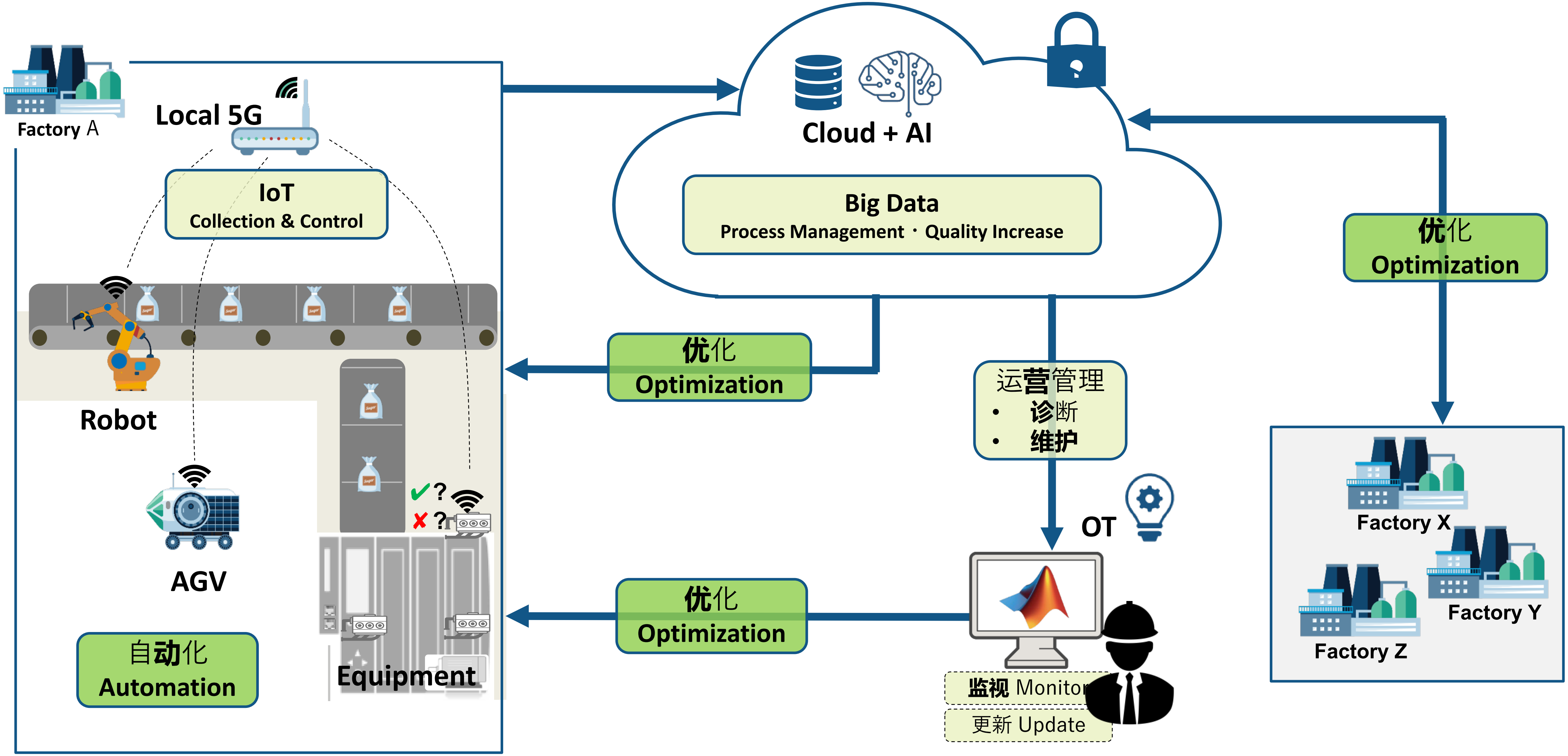
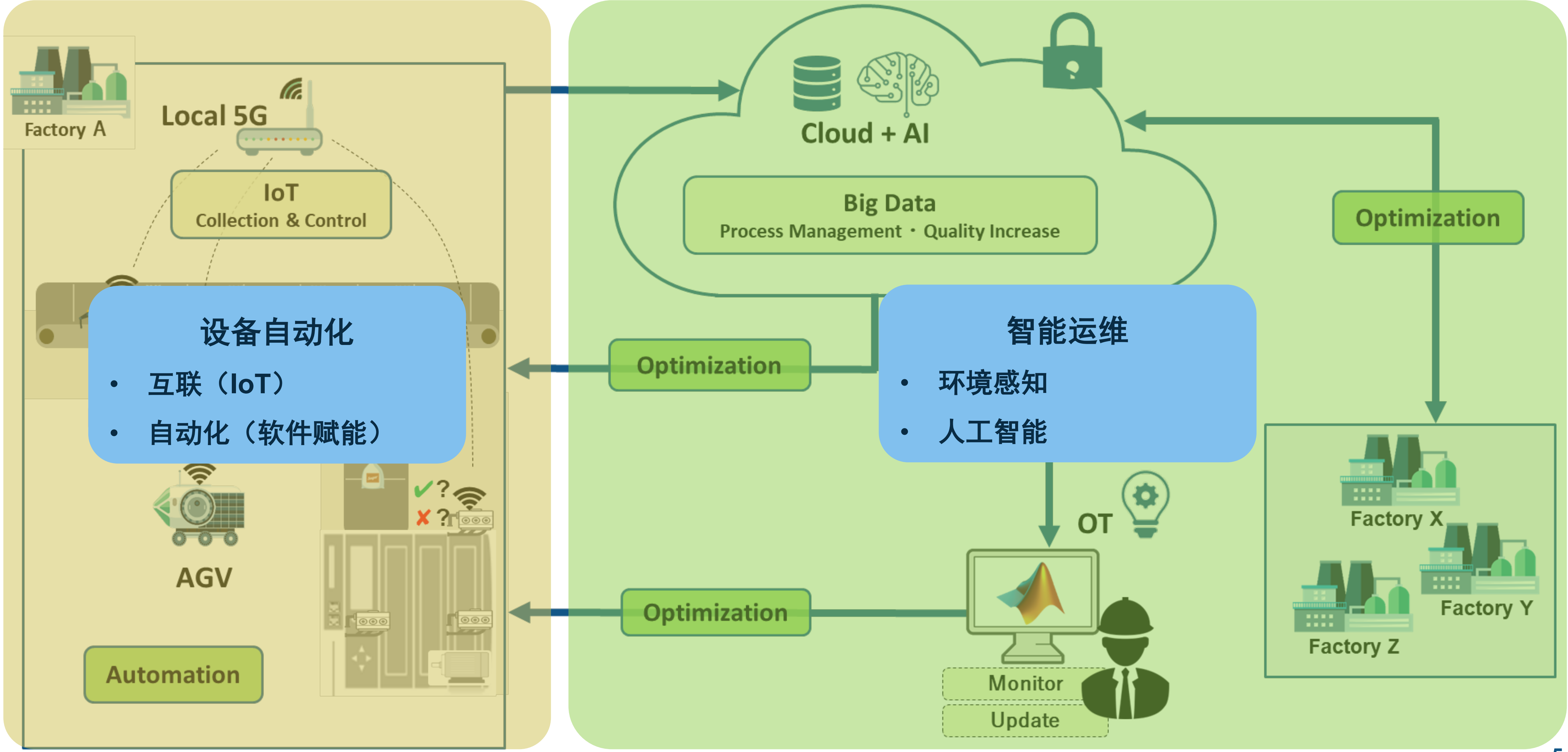
[Company - User Stories - MATLAB & Simulink (mathworks.com)]

典型的智能制造场景



Factory A
Local 5G
IoT
Collection & Control
Robot
AGV
自动化
Automation
Equipment
Cloud + AI
Big Data
Process Management・Quality Increase
优化
Optimization
优化
Optimization
优化
Optimization
运营管理
• 诊断
• 维护
OT
监视 Monitor
更新 Update
Factory X
Factory Y
Factory Z

智能制造的两个支柱——设备自动化和智能运维



设备自动化

- 互联（IoT）
- 自动化（软件赋能）

智能运维

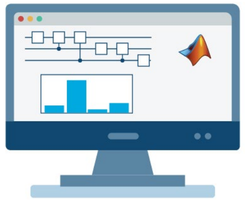
- 环境感知
- 人工智能

应用数字化工程技术：系统化的使用模型与数据

应用数字化工程技术：基于仿真开展各项工程活动

- 基于仿真开展的工程活动
  - 需求确认 —— “完整” + “一致”
  - 权衡分析 —— 可选方案的择优
  - 原型设计 —— 快速的样机展示
  - 详细设计 —— 图形化设计
  - 系统验证 —— 系统指标的符合性测试
  - 交付验证 —— 交付场景下的系统运行
  - 运行优化 —— 优化的组件与运行参数
  - 预测性维护 —— 数据驱动的智能维护
  - …

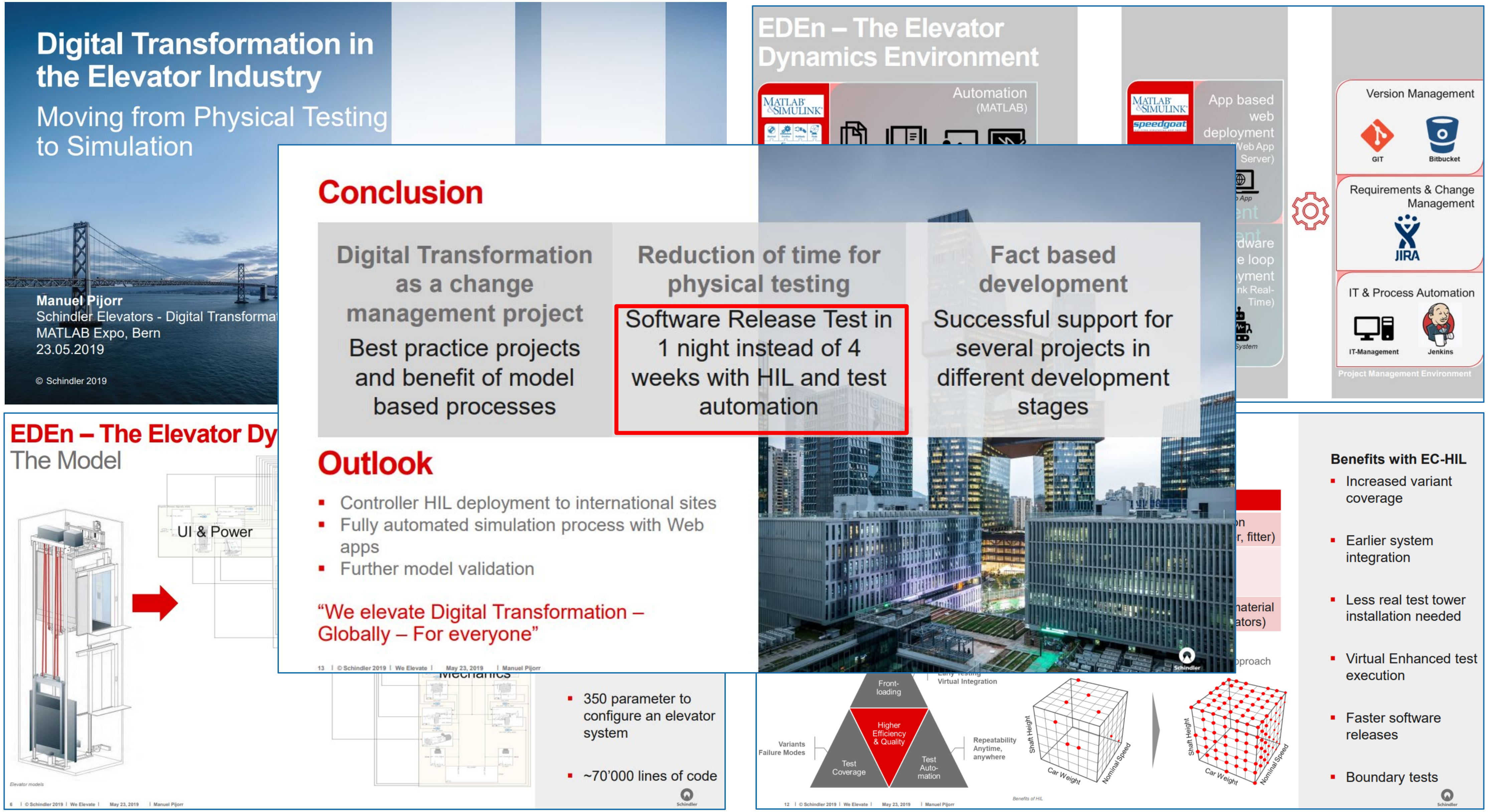
仿 真



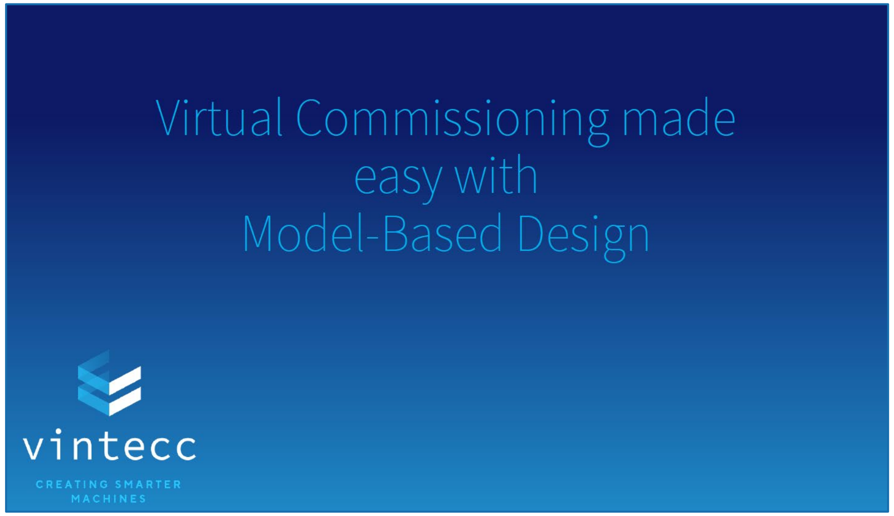
仿真：用于产品开发

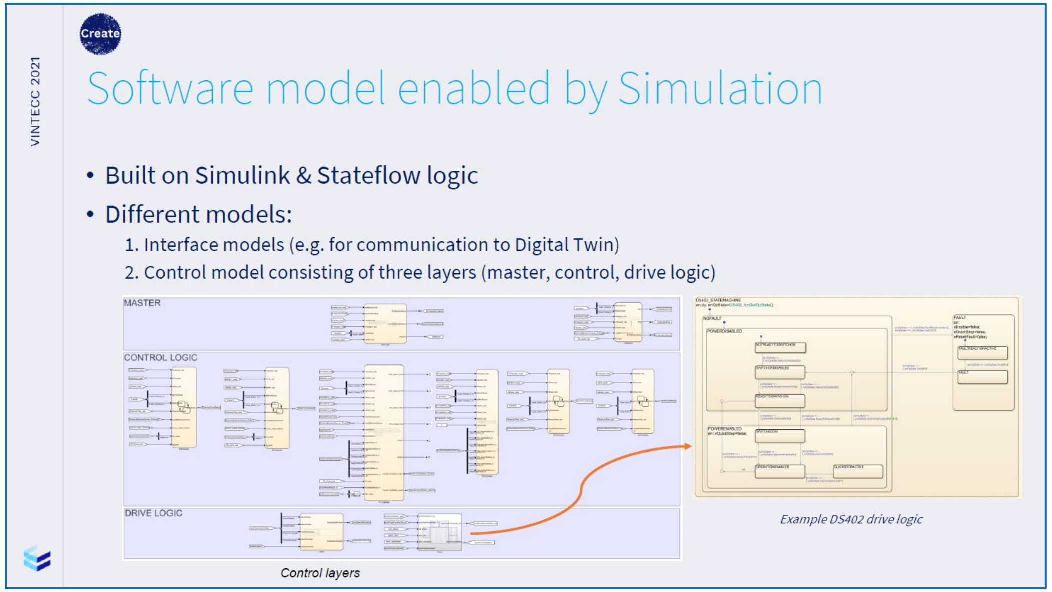

ENABLING THE DIGITAL WORLD
ASM Pacific Technology
Accurate Match Between Control Simulations and Measurements
High predictive accuracy of control simulations.
Simulation with tuned feedforward
Simulation with non-optimal feedforward
Measurement with tuned feedforward
Measurement with non-optimal feedforward
Time [s]
Slide 12
ASM太平洋
ENABLING THE DIGITAL WORLD
ASM Pacific Technology
Concluding Remarks
Building an integral model and performing dynamical analysis of high-tech semiconductor machines is possible and demonstrated with realistic case-studies.
Creating and Configuring Digital Twin models through high levels of modelling automation:
reduces occurrence of modelling errors,
enables non-experts to create fidelity models for design optimizations, root-cause analysis and troubleshooting of performance and reliability issues.
Next milestones:
automated parameter tuning (to further speed-up modelling process),
modelling structurally deformable parts,
deploy a Digital Twin for online machine condition monitoring, health diagnostics and remaining useful life estimation.
www.asmpacific.com
Digital Twin
Slide 15
ENABLING THE DIGITAL WORLD
Integral Model-ba
Integral multi-physics c
User-friendly model bu
high level of modellin
Time-efficient simulatio
Add Joints that represent Springs/Dampers
CAD Software Onshape Solidwork
Reassemble Reassign material
CAD Software Solid Edge
Matlab/Simulink
Ability to run e.g. servo control simulations, test design changes, ...
www.asmpacific.com
Digital Twin
Slide 9
ASM Pacific Technology
n and Control
www.asmpacific.com
Slide 14

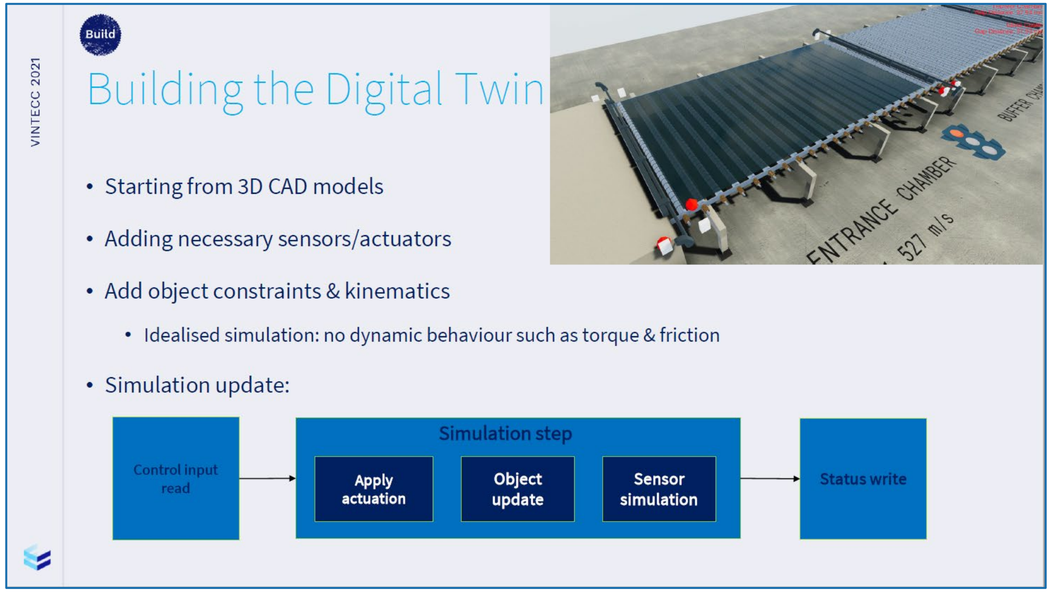
仿真：开展硬件在环测试 HIL（Hardware In Loop）User story link

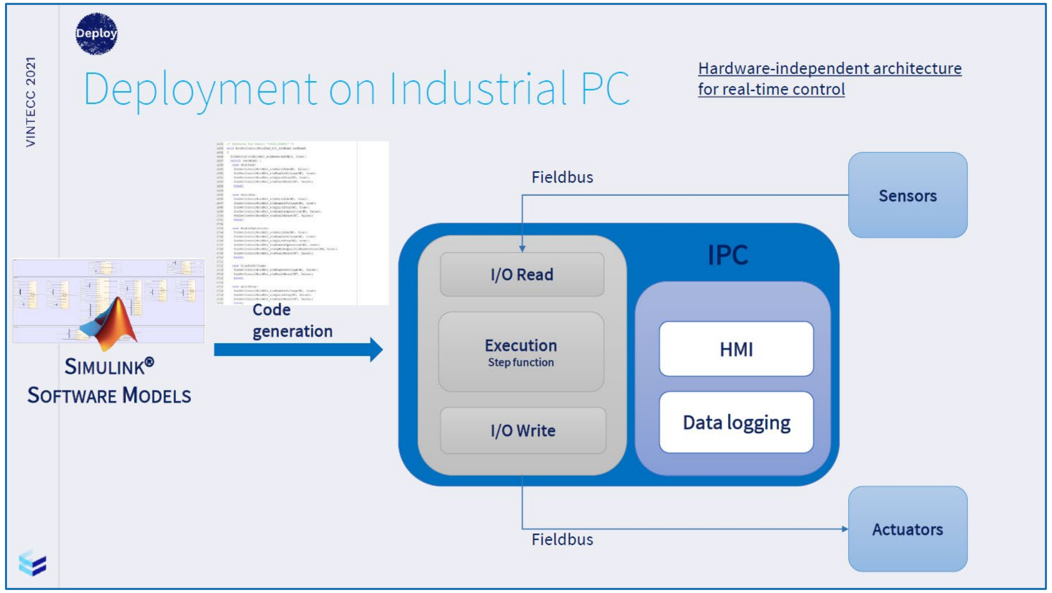


仿真：虚拟交付 VC（Virtual Commissioning)









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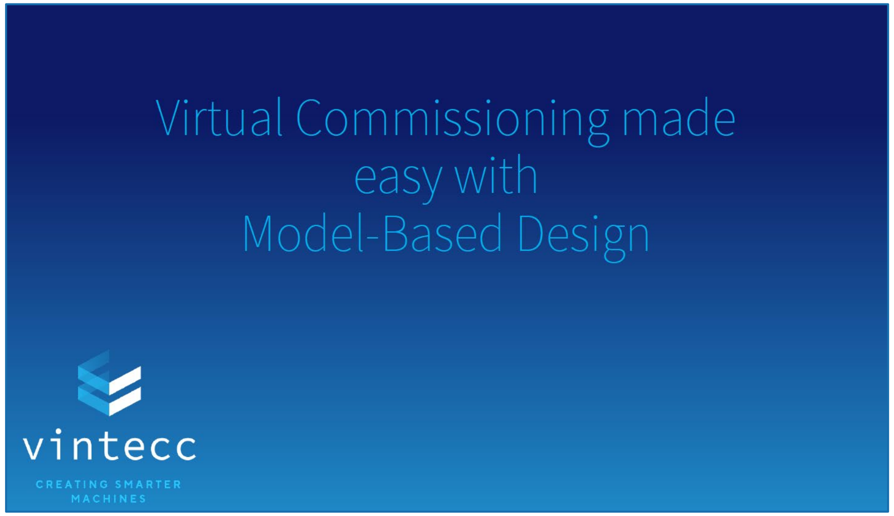
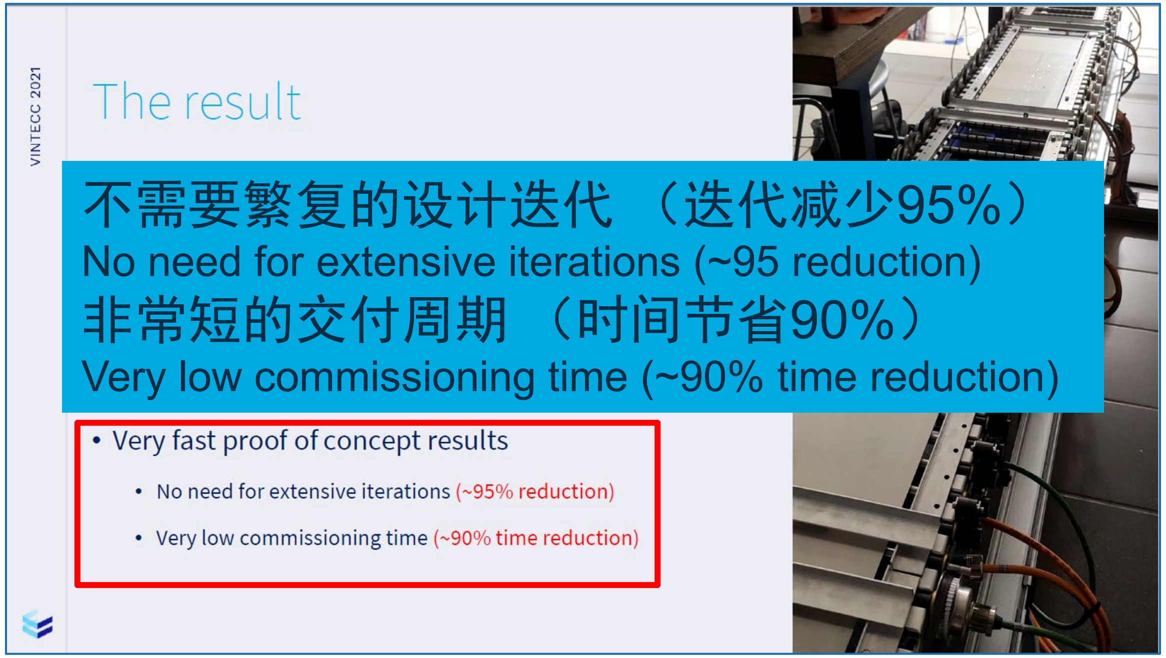
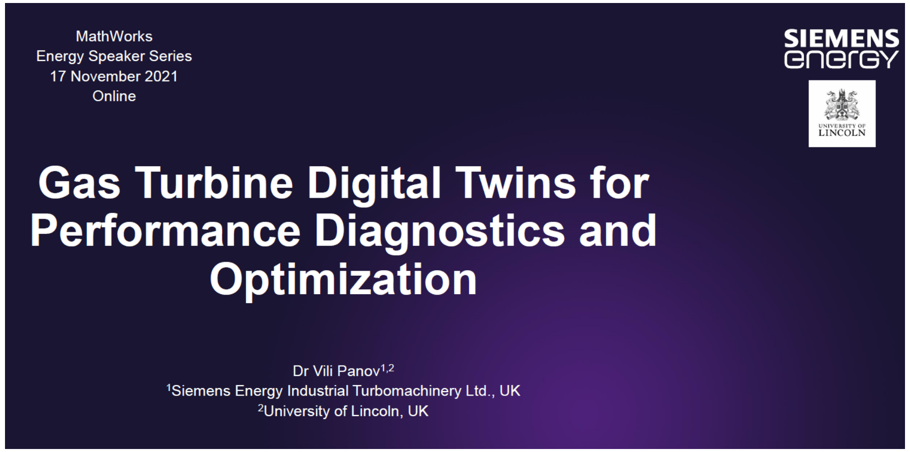




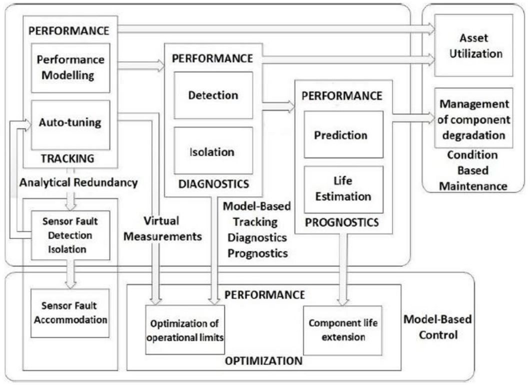
- 关键信息
  - 每个设计任务都是在以下这三种要素间进行权衡:
    - 系统复杂度
    - 产品上市时间
    - 资源
  - “虚拟交付”综合考虑到了这些要素
  - 使用正确的工具、与正确的人协作可以加速这一过程

仿真：运行优化 Optimization

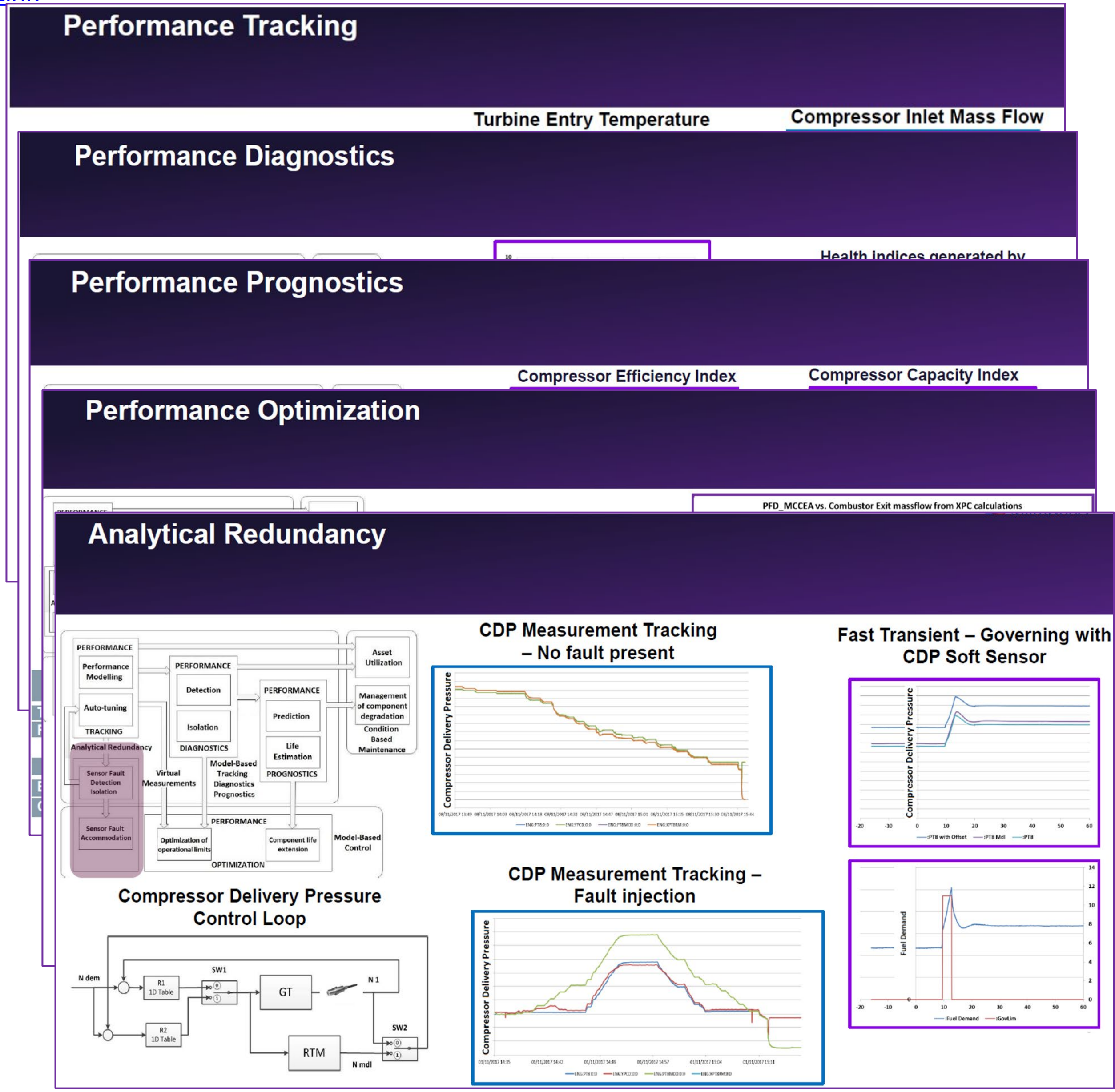
User Story Link



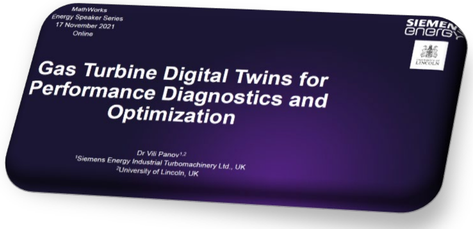
Performance Digital Twin

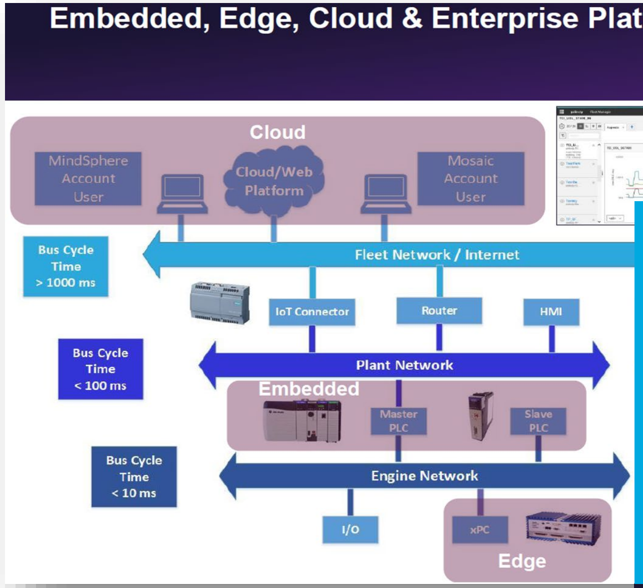


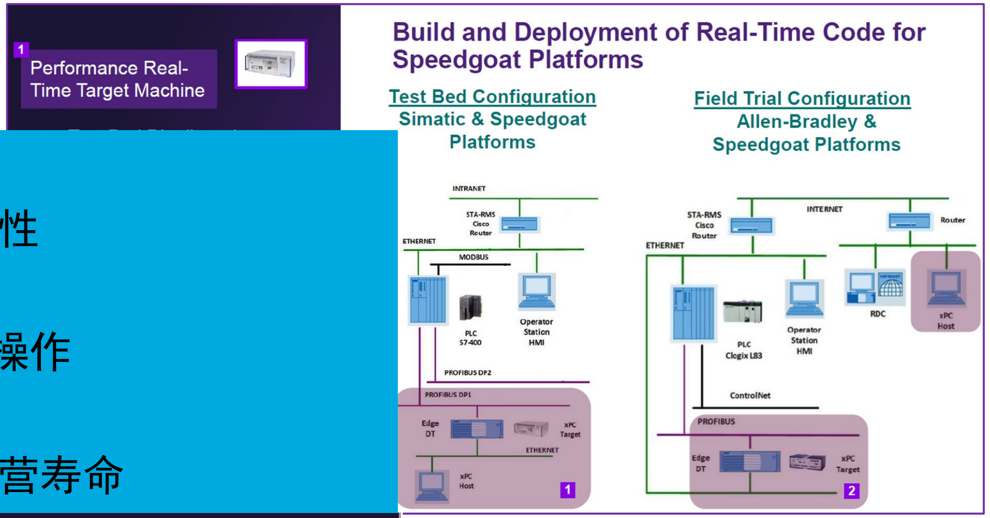
- **Tracking**
  - Accounting for engine-to-engine variation and engine deterioration based on alignment of DT
- **Diagnostics**
  - Diagnosing typical gas path degradation and fault modes based on health parameters generated by DT
- **Prognostics**
  - Estimation of remaining useful life of gas path components based on regression modelling of health indices deduced by DT
- **Optimization**
  - Performance optimization based on model-based control strategies utilizing DT virtual sensors
- **Analytical Redundancy**
  - Reduction of gas path related trips based on analytical sensor redundancy provided by DT



仿真：运行优化 Optimization [User Story Link]



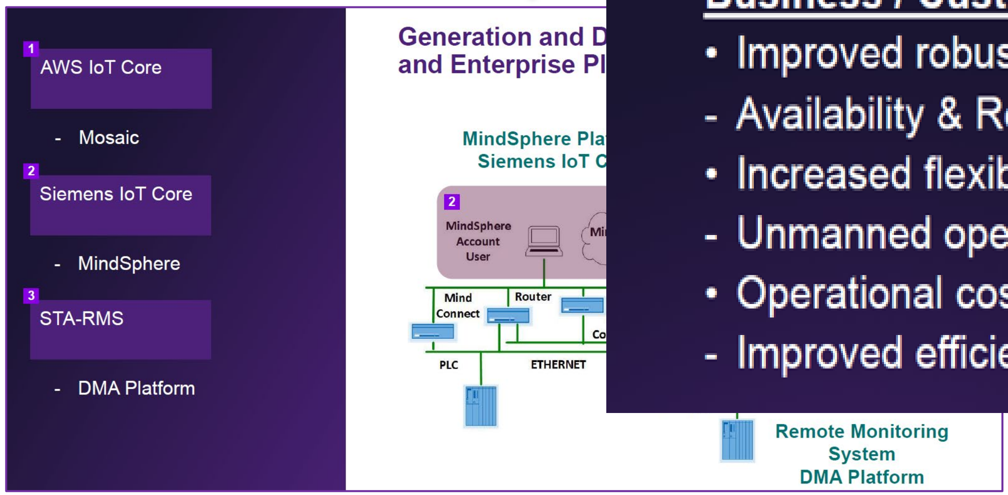


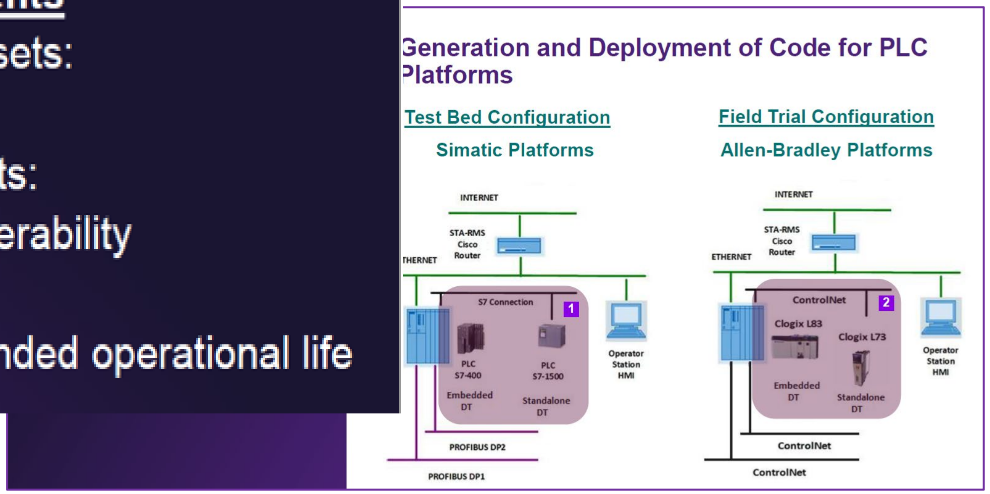


- 改进资产鲁棒性
- 提高可用性 & 可靠性
- 提升资产的灵活性
- 无人值守的运行与操作
- 减少运营成本
- 提升效率 & 延长运营寿命

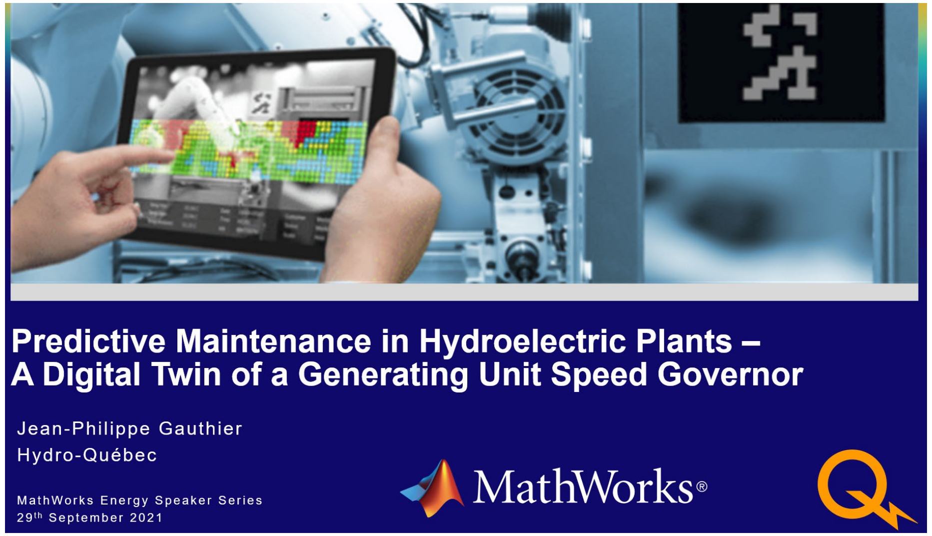
Business / Customer Benefits

- Improved robustness of assets:
- Availability & Reliability
- Increased flexibility of assets:
- Unmanned operation & Operability
- Operational cost reduction:
- Improved efficiency & Extended operational life

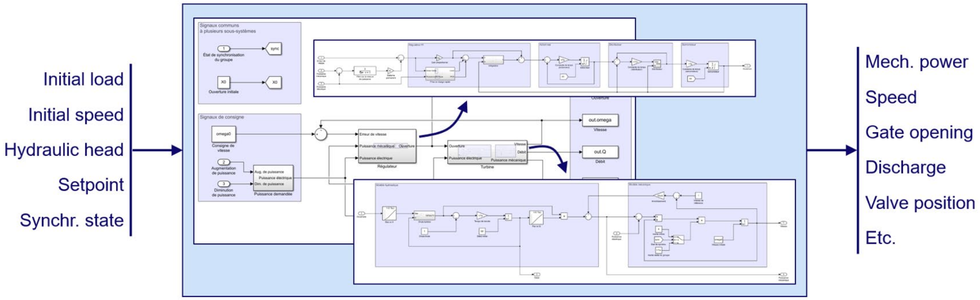




仿真：故障检测与诊断（Fault Detection and Diagnostics） User Story Link



Simulation model

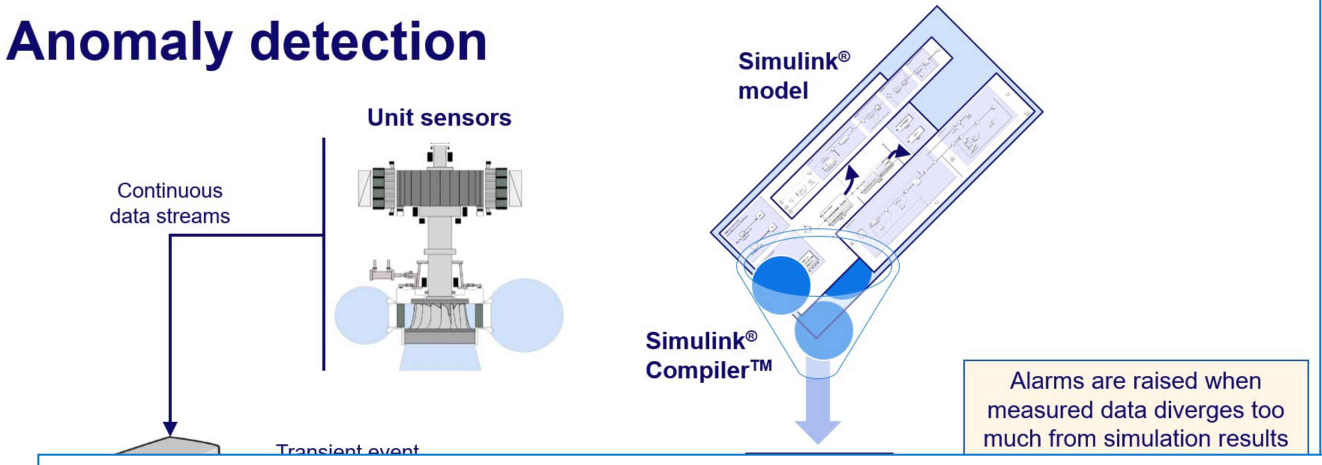


Augmented WEHGOV* model implementation in Simulink®

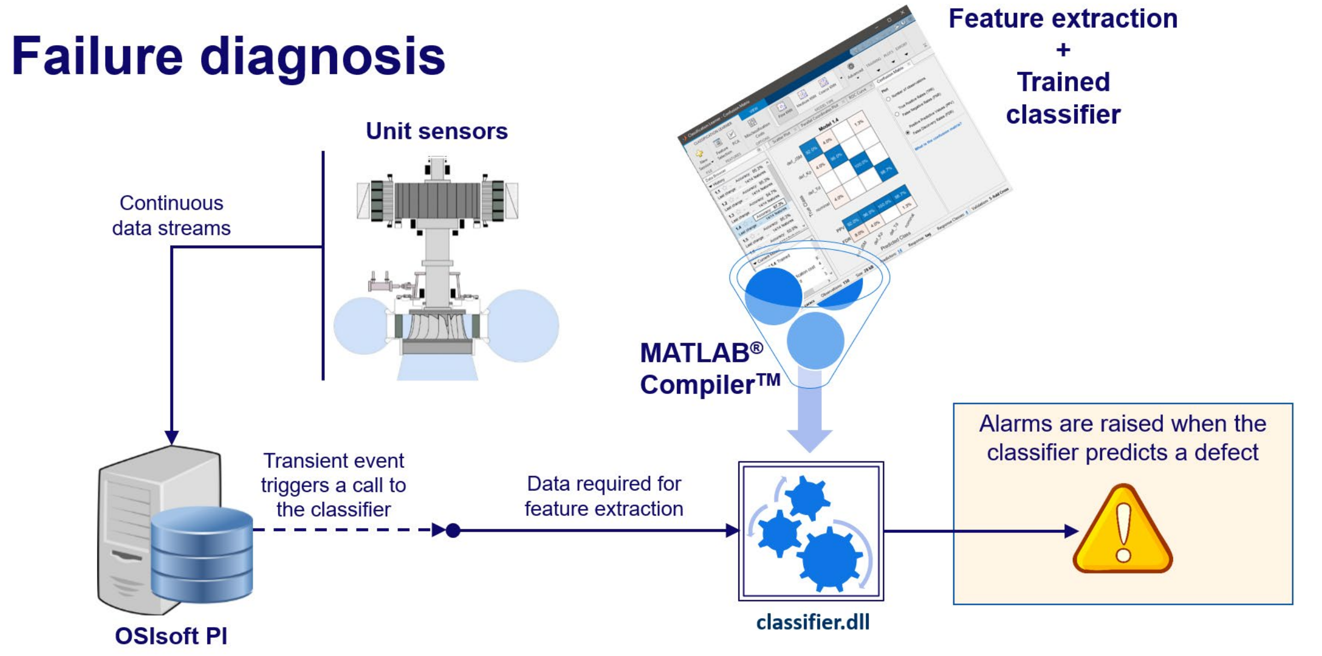
- Basic coupling approach with electrical grid
- Rapid load setpoint adjustment (feed-forward)
- Scaling from nominal to actual hydraulic head

*Woodward Electric Hydro Governor, included in the NERC Library of Standardized Dynamics Models for speed governors

Anomaly detection



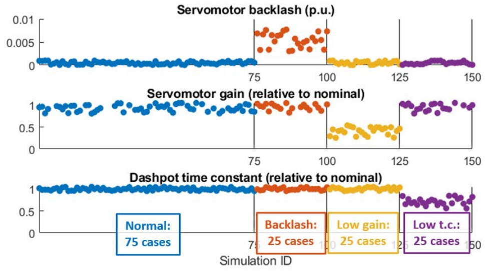
Failure diagnosis

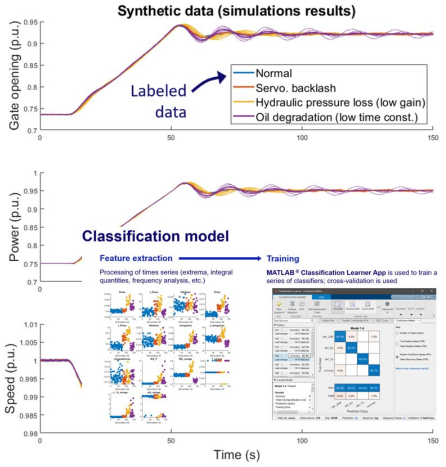


仿真：故障检测与诊断（Fault Detection and Diagnostics） User Story Link

Synthetic data

- Simulation cases are generated by allowing parameters to randomly vary inside a given range, depending on the simulation type (label)
- Randomization mimics variability of the real process
- Each simulation corresponds to a fixed set of parameters





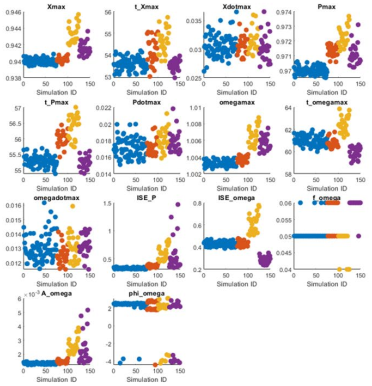
- 利用仿真模型合成数据支持
  - 多种场景
  - 故障注入

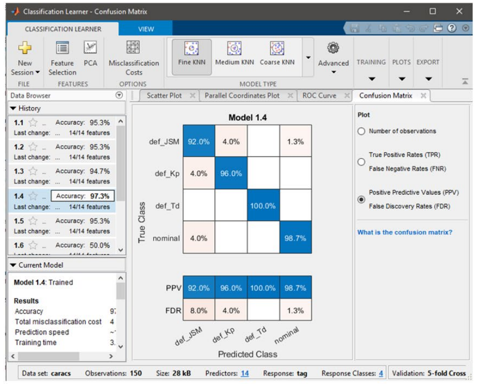
Classification model

Feature extraction → **Training**

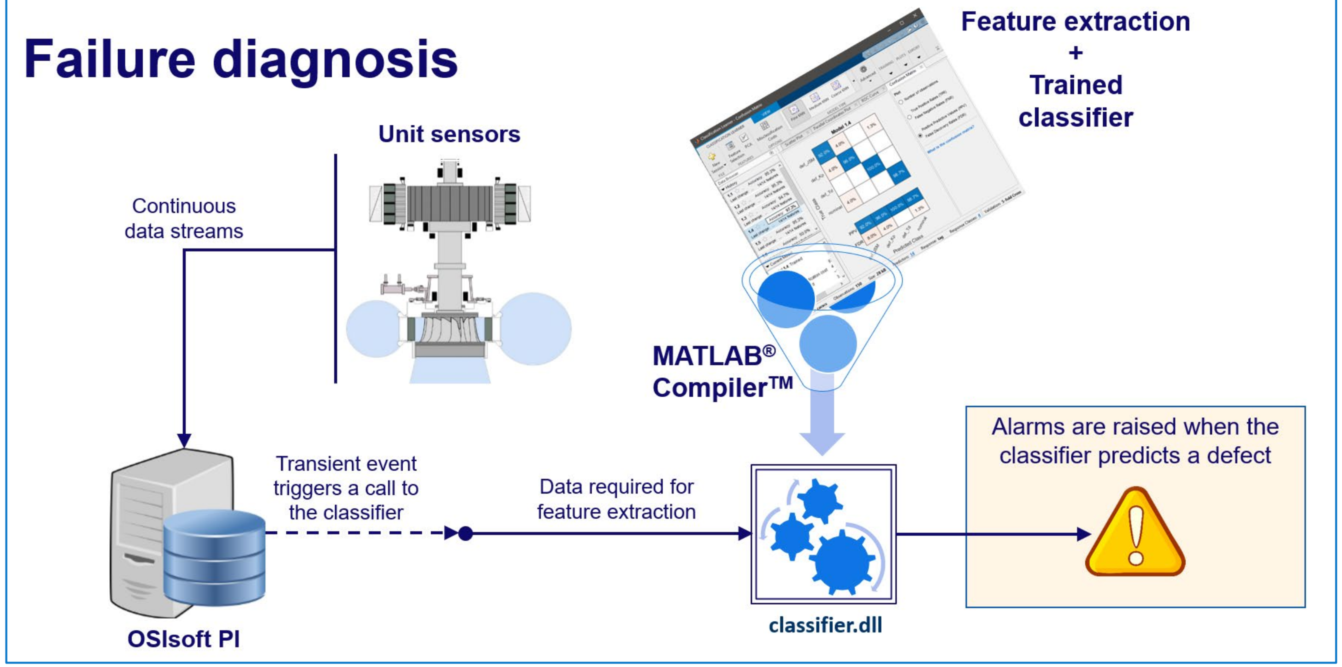
Processing of times series (extrema, integral quantities, frequency analysis, etc.)

MATLAB® **Classification Learner App** is used to train a series of classifiers; cross-validation is used



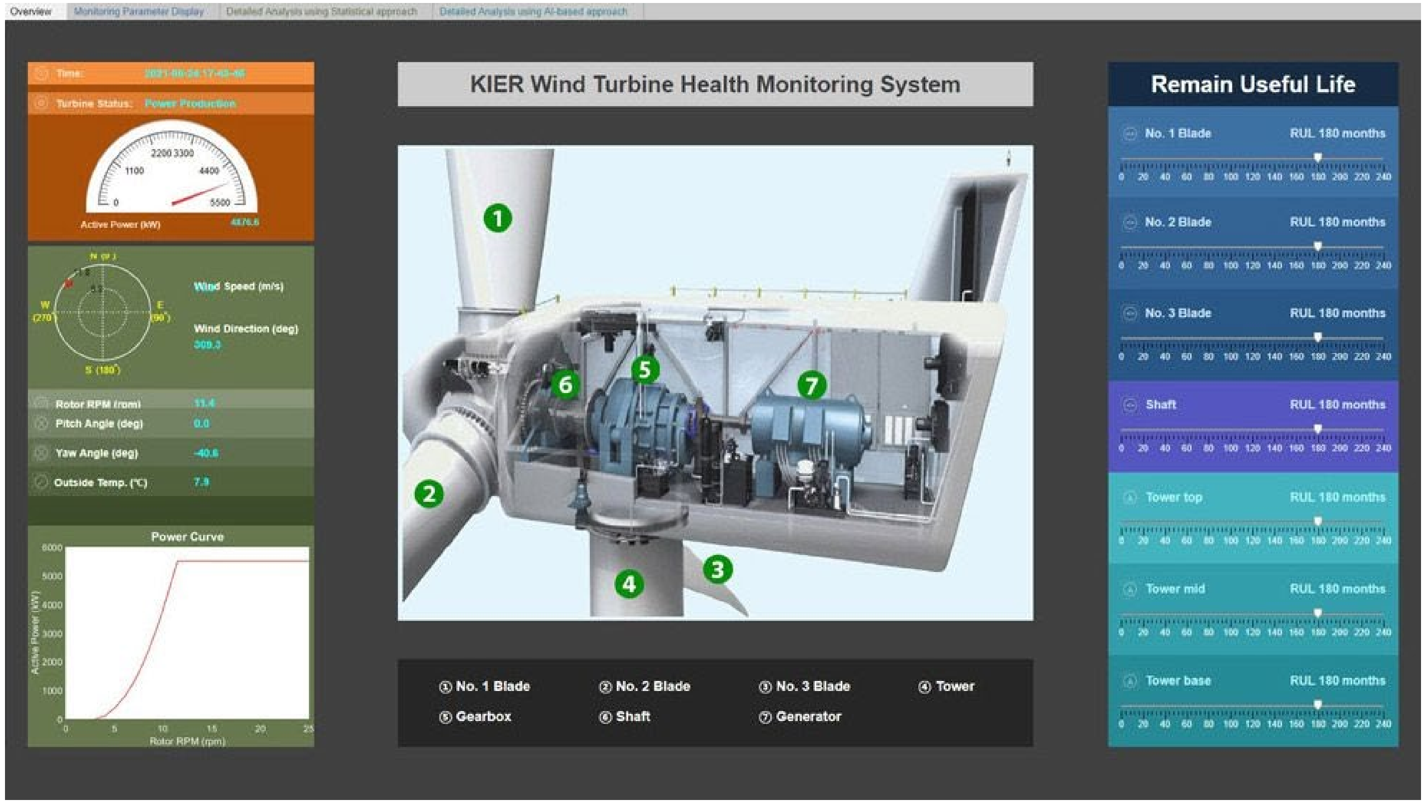


Failure diagnosis



仿真：预测性维护 PdM（Predictive Maintenance) User Story Link

韩国能源技术研究院 (Korea Institute of Energy Research, KIER)
开发了基于人工智能的海上风电预测维护模型



KIER 风机健康监测系统

挑战

通过通过在潜在组件故障发生之前识别故障，防止海上风力涡轮机昂贵的停机时间

解决方案

使用MATLAB开发机器学习和深度学习算法，使用现有的传感器数据来预测可能的故障

结果

- 开发时间缩短了一半
- 达到90%以上的预测精度
- 按期（紧迫）交付

“尽管之前有很少的人工智能的经验，但在有限的预算和紧迫的期限内，我们在MATLAB中完成了一个诊断模型，能够以90%以上的准确率预测风力涡轮机部件故障.”

- Jung Chul Choi, Korea Institute of Energy Research

系统建模与仿真

MATLAB

AI Models
- Machine learning
- Deep learning
- Reinforcement Learning
- Optimization

SIMULINK

Continuous-Time Models
- System dynamics
- Environment

Discrete-Time Models
- Digital control
- DSP
- Computer vision

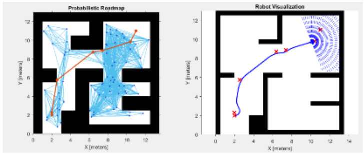
Physical Models
- Electronics
- Mechanics
- Etc.

State Machines
- Control logic
- Mode logic

Discrete-Event Models
- Servers/queues
- Architecture

Components | System | Scenarios | Systems of systems

Perception systems | Autonomous systems

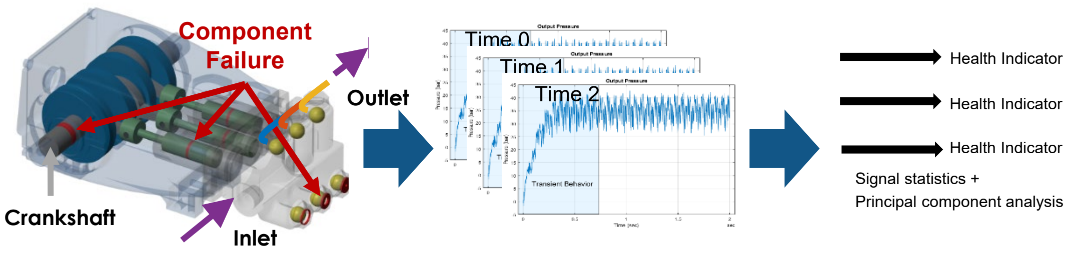


Simulink和MATLAB支持多种仿真机制：连续、离散、状态机、异步事件、物理、数据驱动

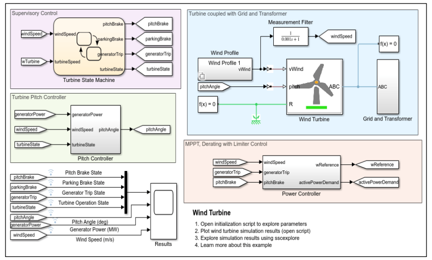
MATLAB EXPO

建模仿真与AI的融合

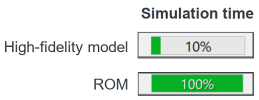
Data synthesis for AI training
- Predictive maintenance

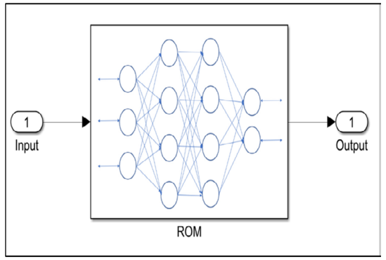


AI for component modeling
- Reduced-order models (ROM)



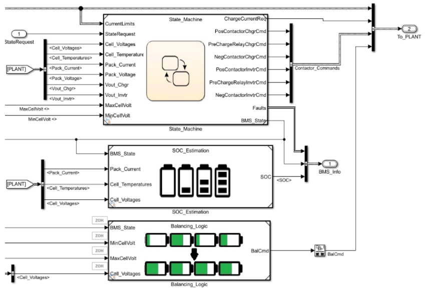
High-Fidelity Model

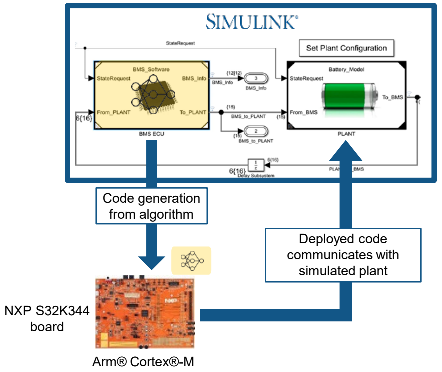




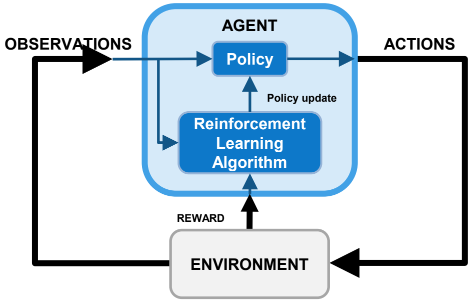
Reduced-Order Model (ROM)

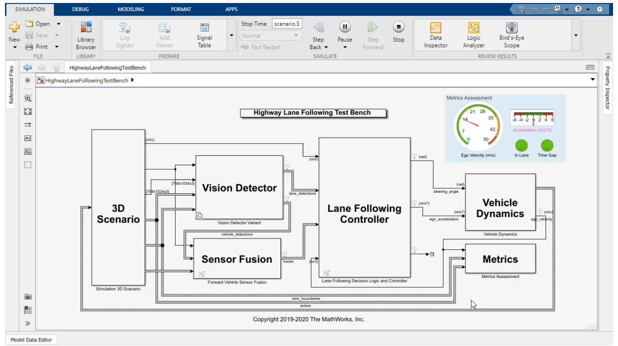
AI for algorithm development
- Virtual sensor modeling
- Sensor fusion
- Object detection





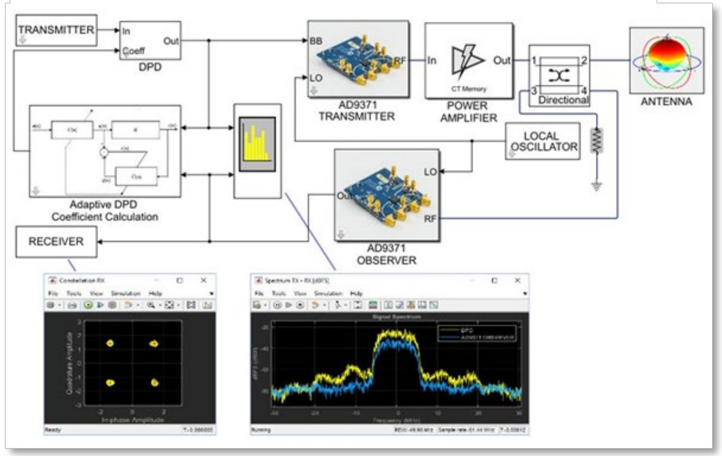
AI for system development
- Reinforcement learning
- AI-driven systems



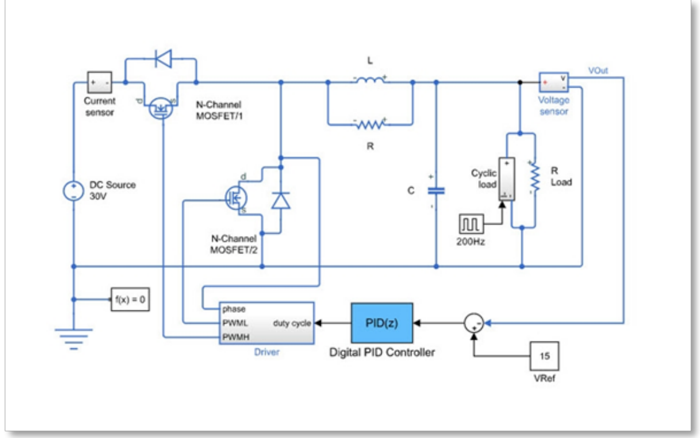


支持多种类型系统的建模与仿真

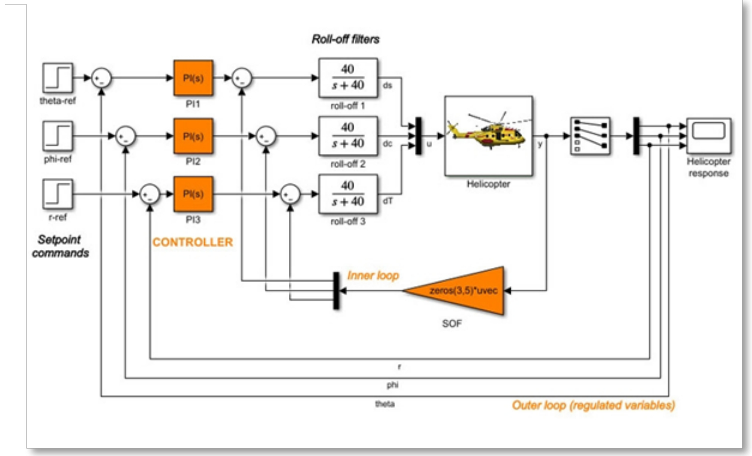
无线通信 Wireless Communication



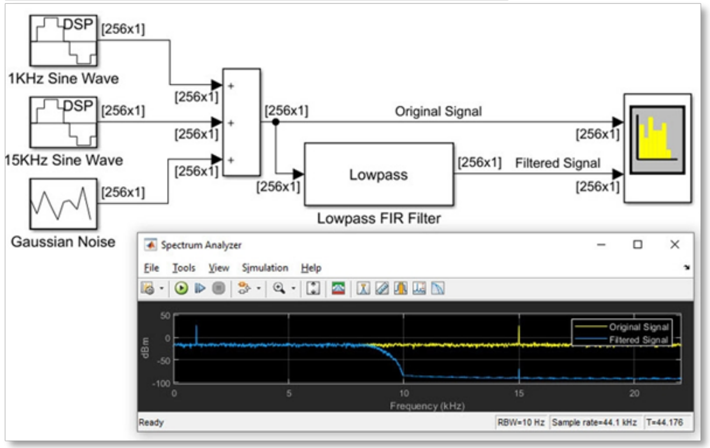
电力电子 Power Electronics



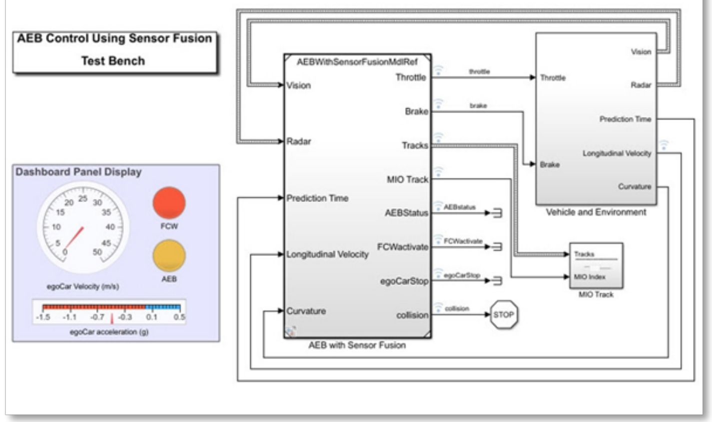
控制系统 Control System



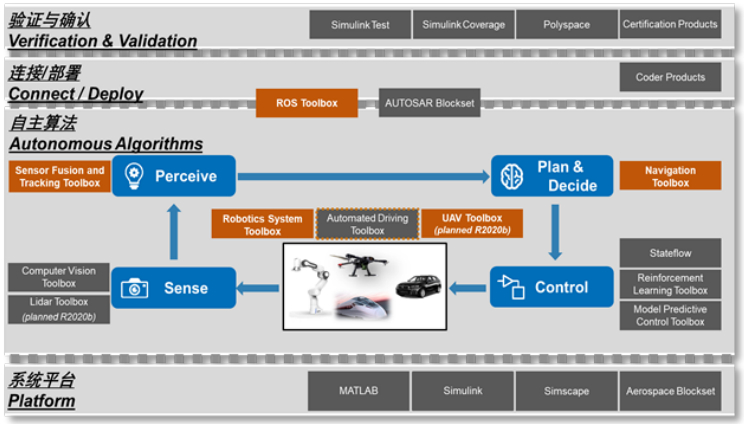
信号处理 Signal Processing



图像/视频处理 Image Processing

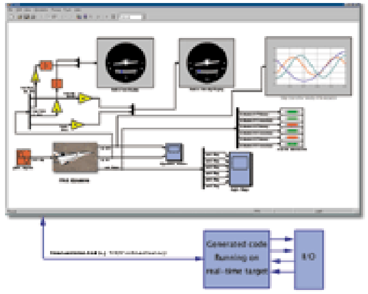


自主系统 Autonomous System

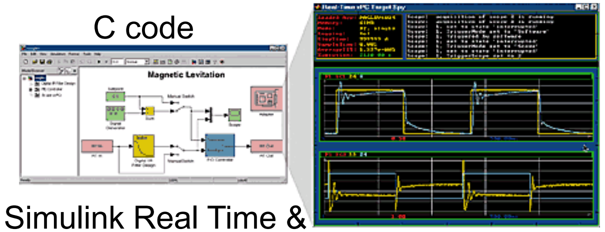


将基于模型的设计应用于工业控制系统的开发

Hardware-in-the-loop



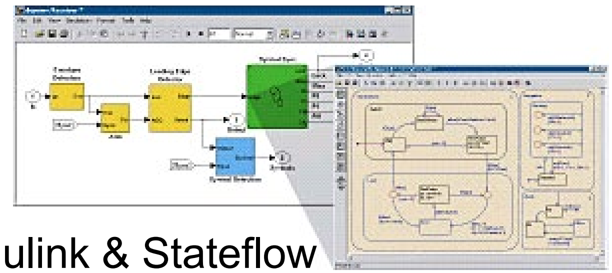
C code



Simulink Real Time & Target Computer

Ethernet Connectivity

对象模型

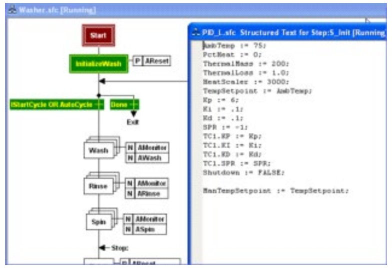


Simulink & Stateflow

基于模型的设计（Model-based Design）
支持工业控制系统的开发

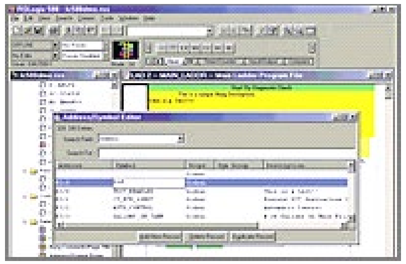
PLC Hardware

控制算法



IEC 61131-3
代码生成

IEC 61131-3 compliant language



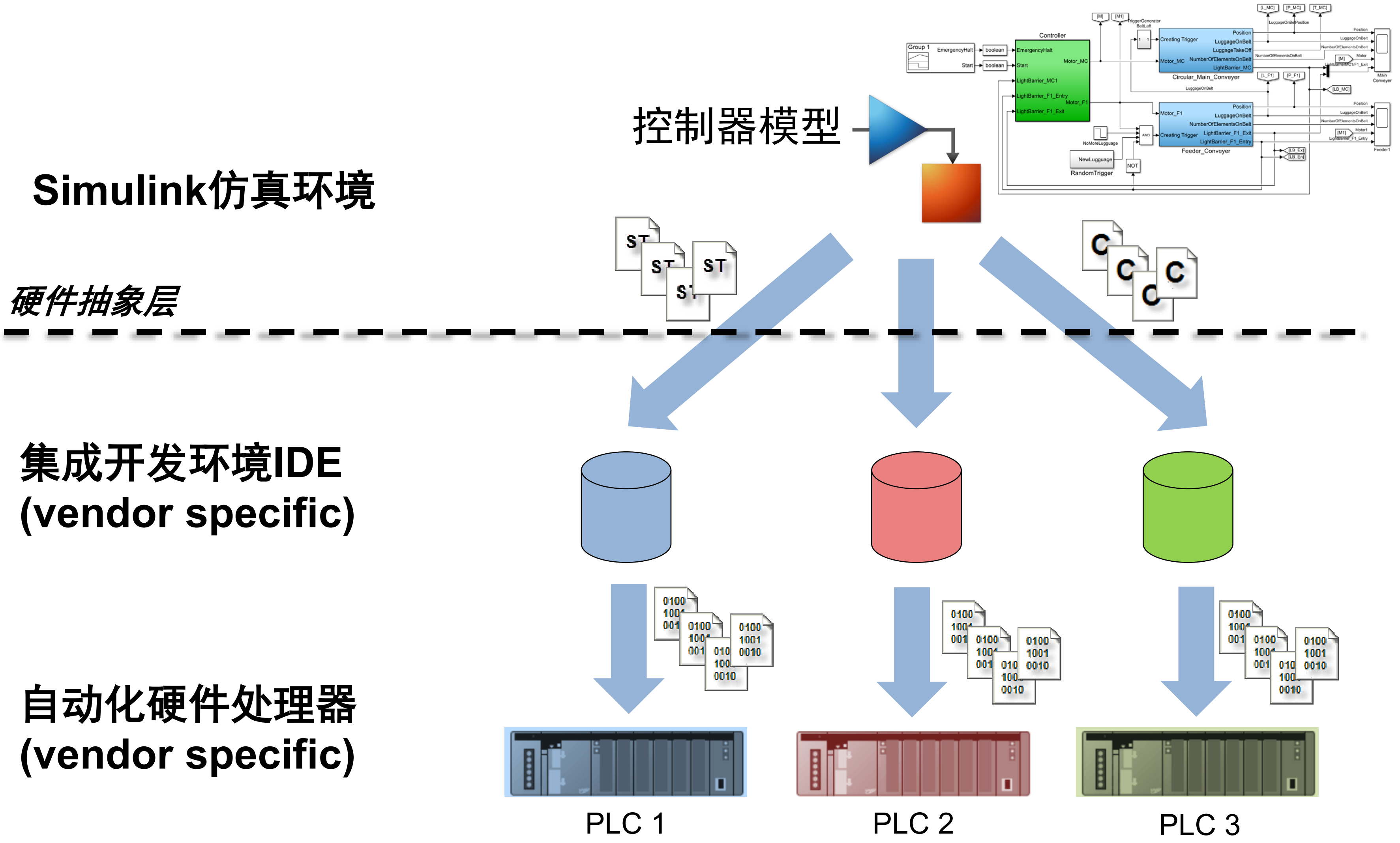
Vendor specific PLC IDE

各种PLC开发平台对MBD的支持

Vendor	IDE	IEC 61131-3 (Simulink PLC Coder)	C/C++ (Simulink Coder)	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	✓	✓	✓

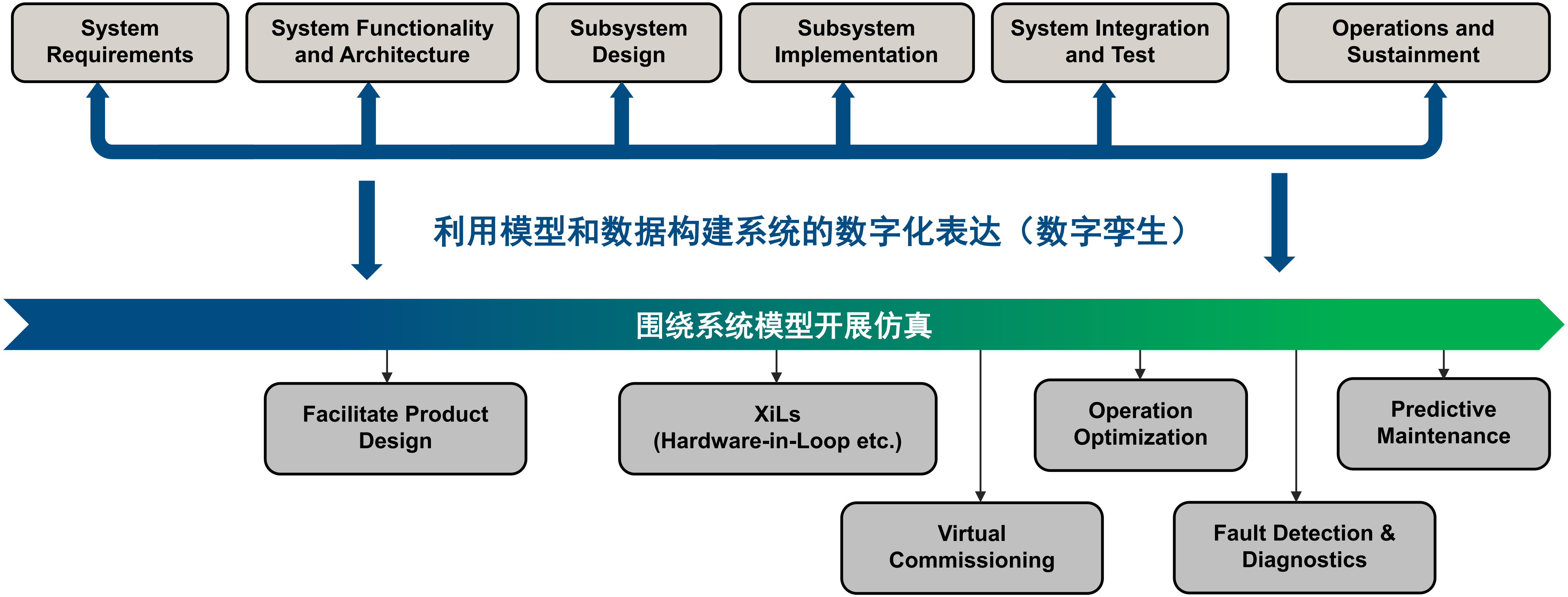
与PLC硬件平台的“解耦”

自动代码生成工具 支持 将经过**充分测试**的源代码部署到常用的自动化平台



总结与展望

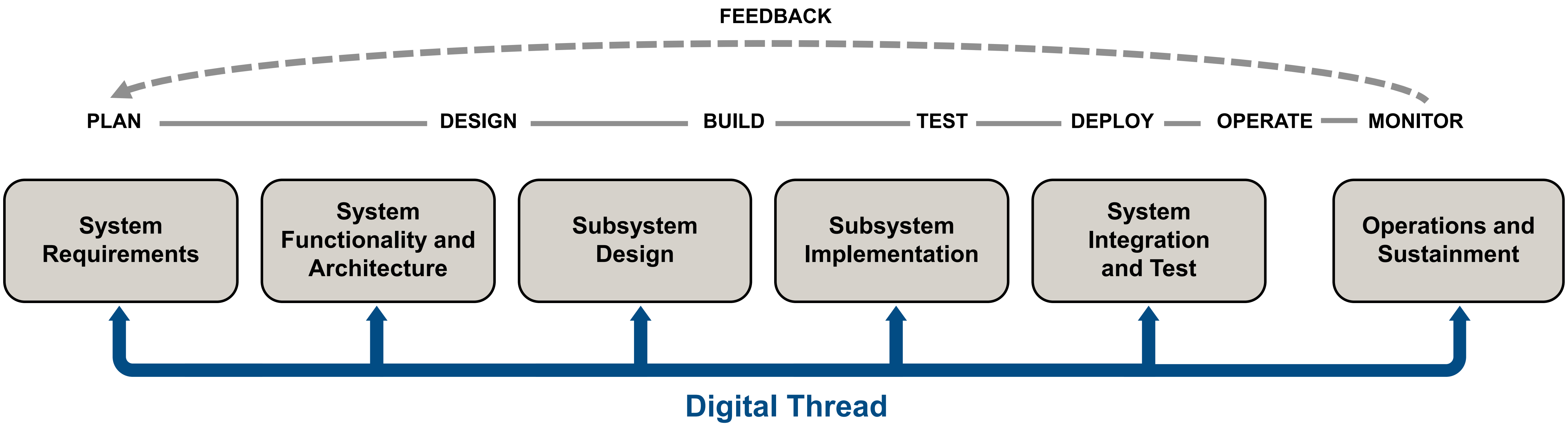
- 总结



System Requirements
System Functionality and Architecture
Subsystem Design
Subsystem Implementation
System Integration and Test
Operations and Sustainment
利用模型和数据构建系统的数字化表达（数字孪生）
围绕系统模型开展仿真
Facilitate Product Design
XiLs (Hardware-in-Loop etc.)
Operation Optimization
Predictive Maintenance
Virtual Commissioning
Fault Detection & Diagnostics

总结与展望

- 展望：在整个产品生命周期中使用模型、开展仿真



Simulate Early & Simulate Often

MATLAB EXPO

Thank you

MathWorks®