

# MATLAB EXPO

## 将基于仿真的数字工程技术应用于智能制造

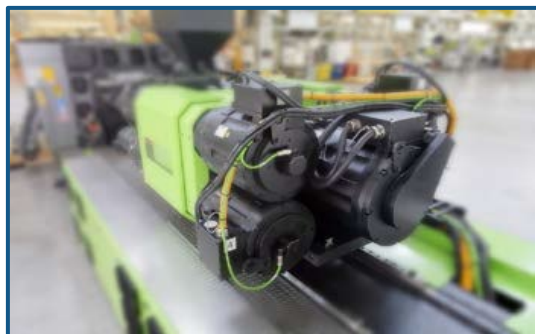
宋胜凯, MathWorks



# 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



Vintec 多轴收割机  
整个收割机控制系统在3个PLC上实现



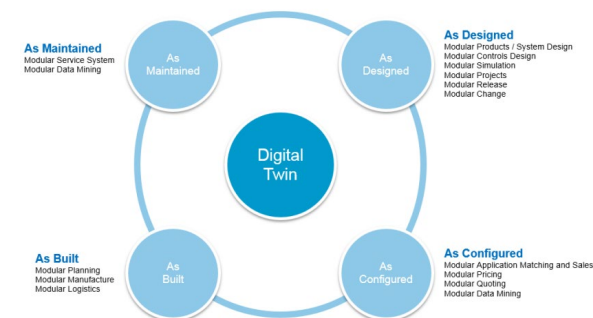
贝克休斯：装有容积泵的卡车



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

# 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  
一个注射单元由四个同步驱动器驱动

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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

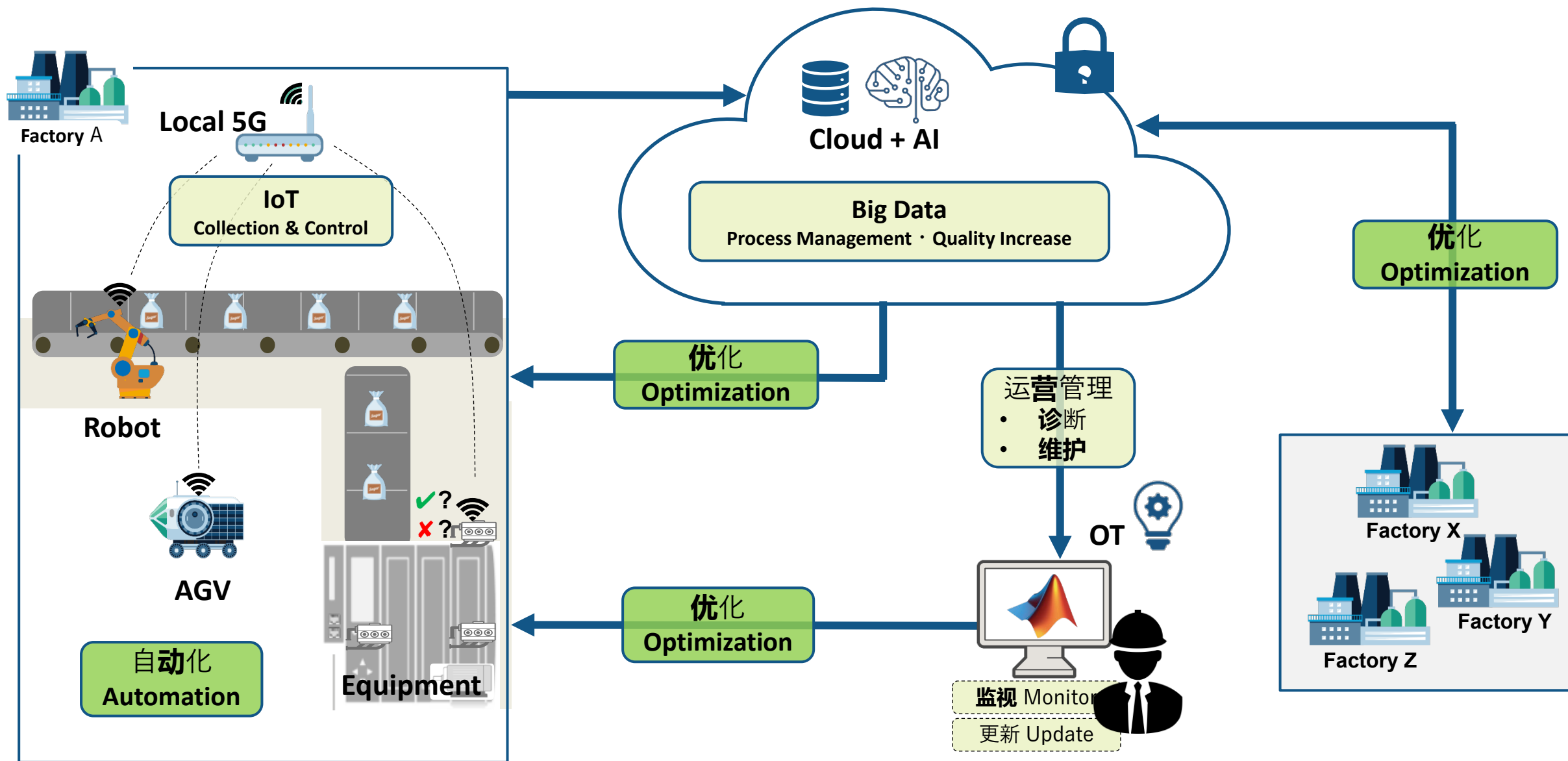
贝克休斯: 装有容积泵的卡车

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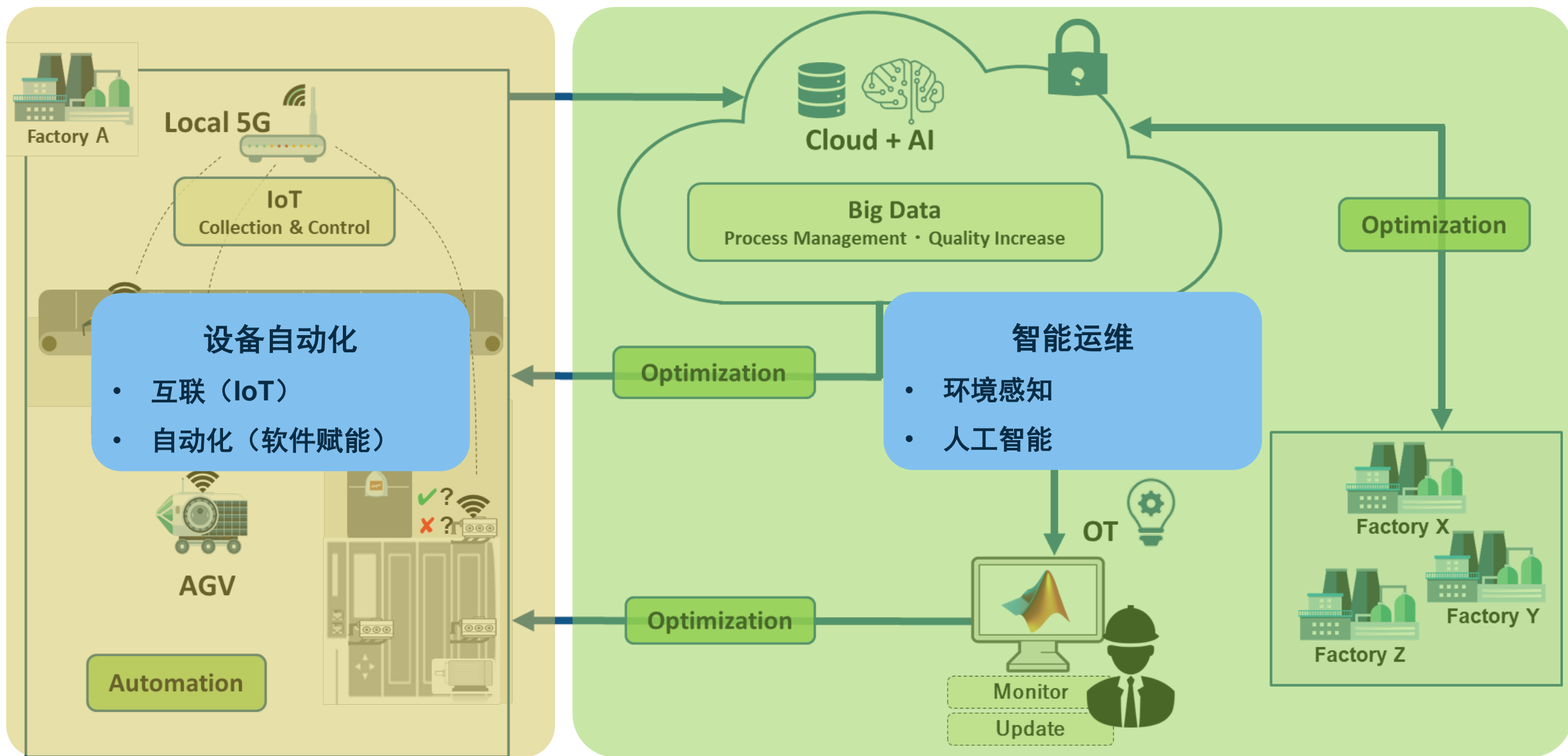
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# 典型的智能制造场景



# 智能制造的两个支柱——设备自动化和智能运维



# 应用数字化工程技术：系统化的使用模型与数据



# 应用数字化工程技术：基于仿真开展各项工程活动

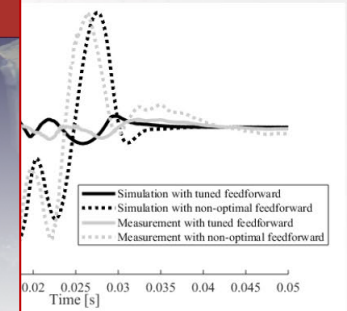
- 基于仿真开展的工程活动
  - 需求确认 —— “完整” + “一致”
  - 权衡分析 —— 可选方案的择优
  - 原型设计 —— 快速的样机展示
  - 详细设计 —— 图形化设计
  - 系统验证 —— 系统指标的符合性测试
  - 交付验证 —— 交付场景下的系统运行
  - 运行优化 —— 优化的组件与运行参数
  - 预测性维护 —— 数据驱动的智能维护
  - ...





## Accurate Match Between Control Simulations and Measurements

- High predictive accuracy of control simulations.



Slide 12

# 仿真：用于产品开发

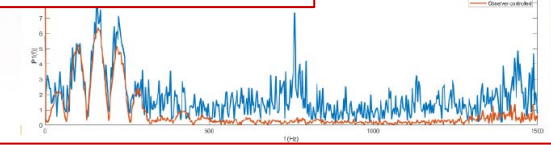
## Concluding Remarks

- 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.

## n and Control



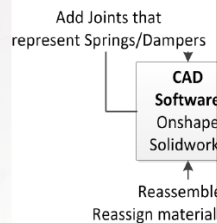
Slide 15



Slide 14

## Integral Model-based

- Integral multi-physics control
- User-friendly model building
  - high level of modelling automation
- Time-efficient simulation



## Digital Twin

**Matlab/Simulink**  
Ability to run e.g. servo control simulations, test design changes, ...

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

## Digital Transformation in the Elevator Industry

### Moving from Physical Testing to Simulation



Manuel Pijorr  
Schindler Elevators - Digital Transformation  
MATLAB Expo, Bern  
23.05.2019

© Schindler 2019

## EDEn – The Elevator Dynamics Environment

Automation (MATLAB)

App based web deployment (Web App Server)

Version Management  
GIT Bitbucket

Requirements & Change Management  
JIRA

IT & Process Automation  
IT-Management Jenkins

Project Management Environment

## Conclusion

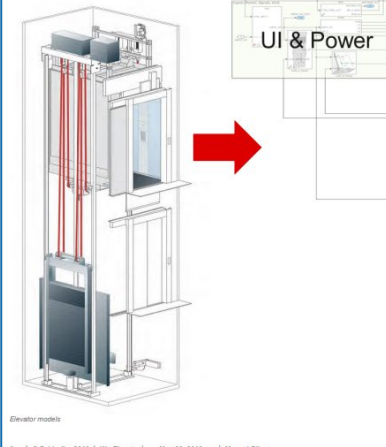
Digital Transformation as a change management project  
Best practice projects and benefit of model based processes

Reduction of time for physical testing  
Software Release Test in 1 night instead of 4 weeks with HIL and test automation

Fact based development  
Successful support for several projects in different development stages

## EDEn – The Elevator Dynamics Environment

### The Model



UI & Power


© Schindler 2019 | We Elevate | May 23, 2019 | Manuel Pijorr

## Outlook

- Controller HIL deployment to international sites
- Fully automated simulation process with Web apps
- Further model validation

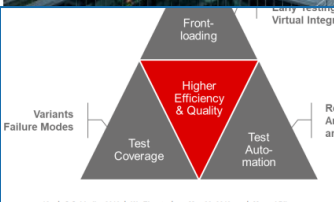
“We elevate Digital Transformation – Globally – For everyone”

- 350 parameter to configure an elevator system
- ~70'000 lines of code



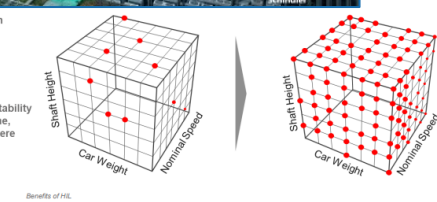
## Benefits with EC-HIL

- Increased variant coverage
- Earlier system integration
- Less real test tower installation needed
- Virtual Enhanced test execution
- Faster software releases
- Boundary tests



Front-loading  
Virtual Integration

Repeatability Anytime, anywhere



Shaft Height  
Car Weight  
Nominal Speed

© Schindler 2019 | We Elevate | May 23, 2019 | Manuel Pijorr

# 仿真：虚拟交付 VC (Virtual Commissioning)

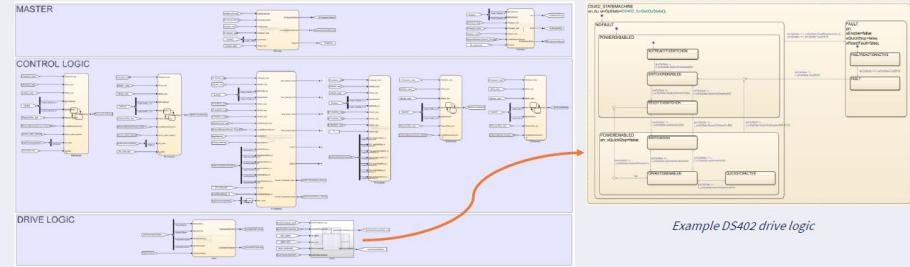
Virtual Commissioning made easy with Model-Based Design



**Create**

## Software model enabled by Simulation

- Built on Simulink & Stateflow logic
- Different models:
  - Interface models (e.g. for communication to Digital Twin)
  - Control model consisting of three layers (master, control, drive logic)



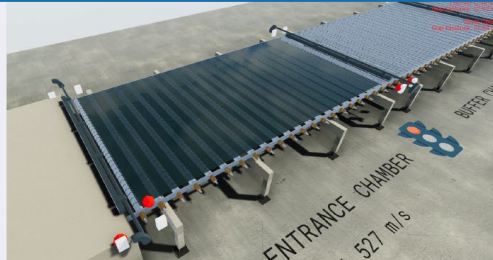
Control layers

Example DS402 drive logic

**Build**

## Building the Digital Twin

- Starting from 3D CAD models
- Adding necessary sensors/actuators
- Add object constraints & kinematics
  - Idealised simulation: no dynamic behaviour such as torque & friction
- Simulation update:



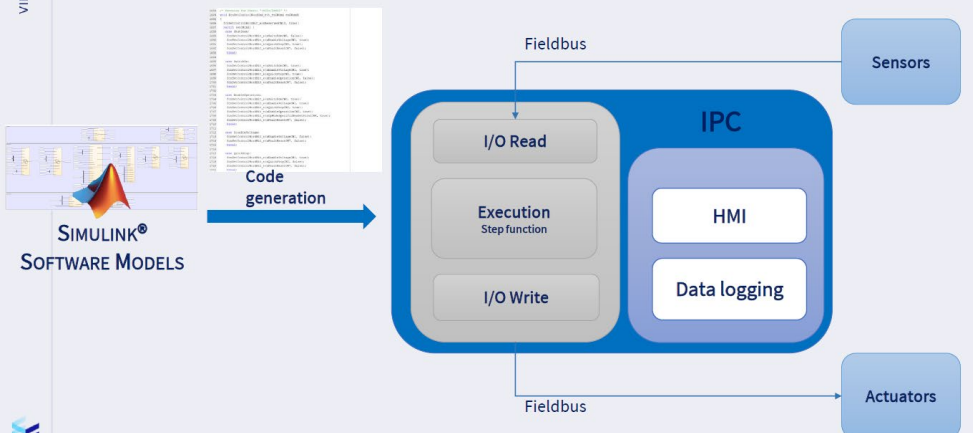
```

    graph LR
        A[Control input read] --> B[Simulation step]
        subgraph B [Simulation step]
            B1[Apply actuation]
            B2[Object update]
            B3[Sensor simulation]
        end
        B --> C[Status write]
    
```

**Deploy**

## Deployment on Industrial PC

Hardware-independent architecture for real-time control



SIMULINK® SOFTWARE MODELS

Code generation

Fieldbus

Sensors

IPC

I/O Read

Execution Step function

I/O Write

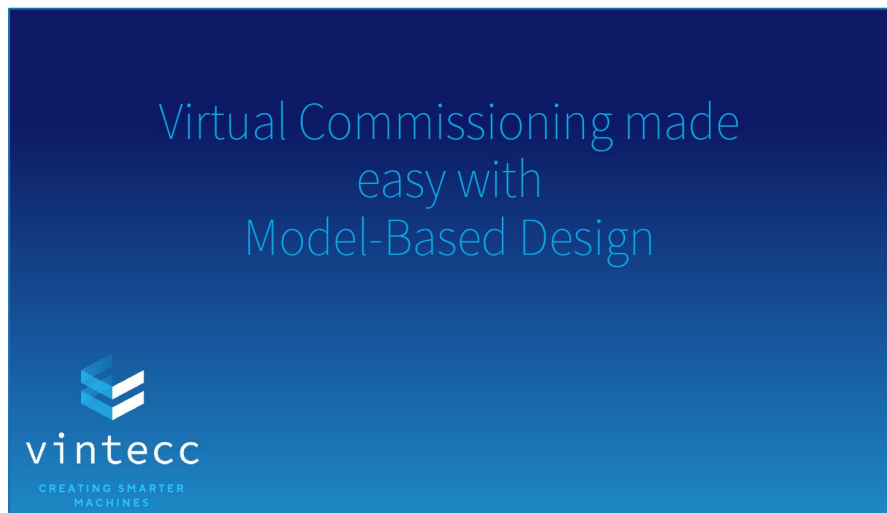
HMI

Data logging

Fieldbus

Actuators

# 仿真：虚拟交付 VC (Virtual Commissioning)



## ■ 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

THE RESULT

不需要繁复的设计迭代 (迭代减少95%)  
No need for extensive iterations (~95 reduction)  
非常短的交付周期 (时间节省90%)  
Very low commissioning time (~90% time reduction)

- Very fast proof of concept results
  - No need for extensive iterations (~95% reduction)
  - Very low commissioning time (~90% time reduction)

Key takeaways

- Every design is a trade-off between these three forces:
  - Complexity
  - Time-to-Market
  - Resources
- Virtual Commissioning optimally combines all of them
- Applying the right tools and cooperating with the right people accelerate this process

# 仿真：运行优化 Optimization [User Story Link](#)

MathWorks  
Energy Speaker Series  
17 November 2021  
Online

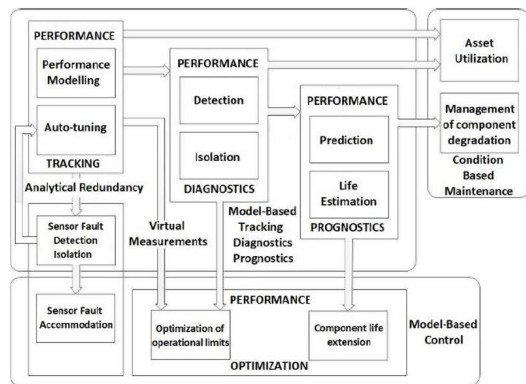
**SIEMENS ENERGY**

**UNIVERSITY OF LINCOLN**

## Gas Turbine Digital Twins for Performance Diagnostics and Optimization

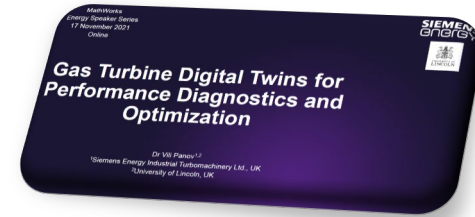
Dr Vili Panov<sup>1,2</sup>  
<sup>1</sup>Siemens Energy Industrial Turbomachinery Ltd., UK  
<sup>2</sup>University of Lincoln, UK

### Performance Digital Twin

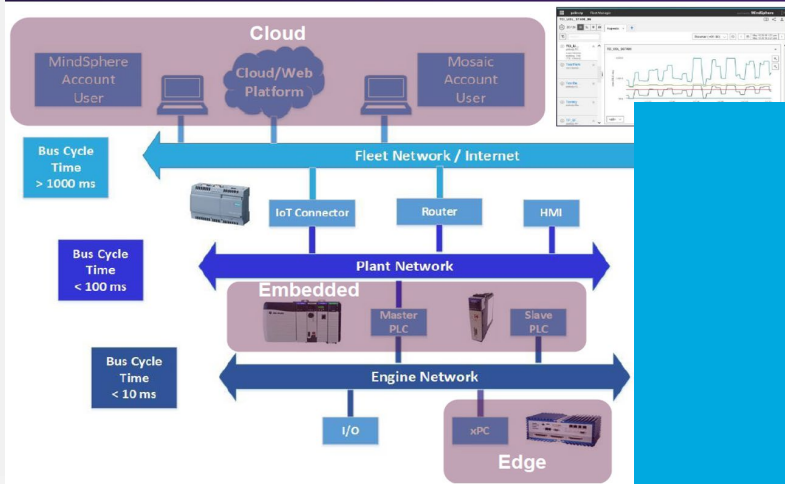


- **Tracking**
  - Accounting for engine-to-engine variation and engine deterioration based on alignment of DT
- **Diagnostics**
  - Diagnosing typical gas path degradation and fault modes based on health parameters generated by DT
- **Prognostics**
  - Estimation of remaining useful life of gas path 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](#)



## Embedded, Edge, Cloud & Enterprise Platforms



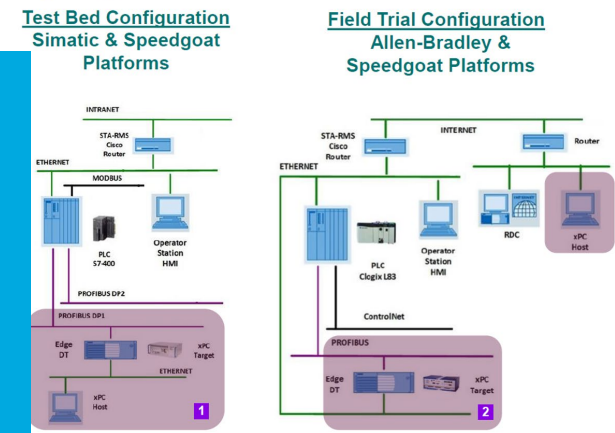
- 改进资产鲁棒性
- 提高可用性 & 可靠性
- 提升资产的灵活性
- 无人值守的运行与操作
- 减少运营成本
- 提升效率 & 延长运营寿命

### Business / Customer Benefits

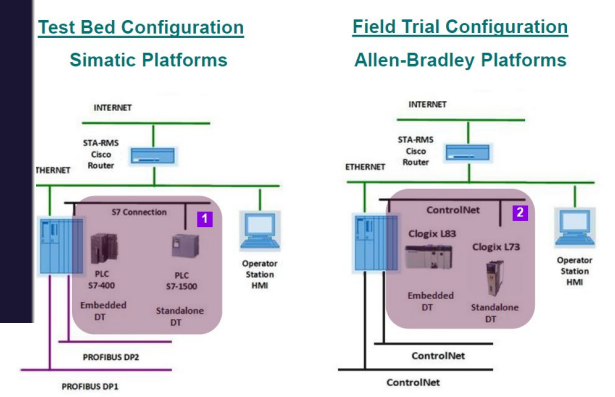
- Improved robustness of assets:
  - Availability & Reliability
- Increased flexibility of assets:
  - Unmanned operation & Operability
- Operational cost reduction:
  - Improved efficiency & Extended operational life

1 Performance Real-Time Target Machine

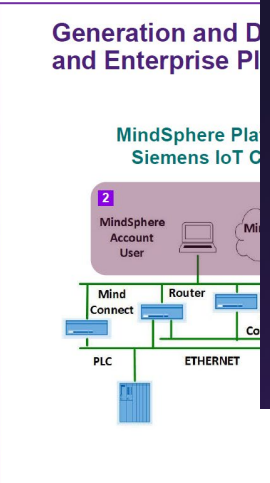
## Build and Deployment of Real-Time Code for Speedgoat Platforms



## Generation and Deployment of Code for PLC Platforms



- 1 AWS IoT Core
  - Mosaic
- 2 Siemens IoT Core
  - MindSphere
- 3 STA-RMS
  - DMA Platform



Remote Monitoring System DMA Platform

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



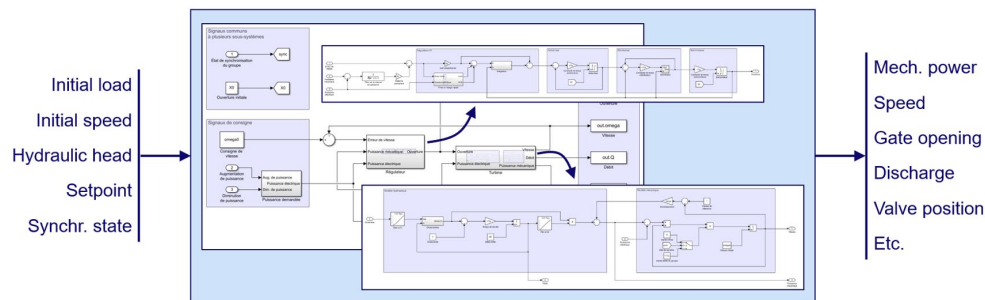
## Predictive Maintenance in Hydroelectric Plants – A Digital Twin of a Generating Unit Speed Governor

Jean-Philippe Gauthier  
Hydro-Québec

MathWorks Energy Speaker Series  
29<sup>th</sup> September 2021



### Simulation model

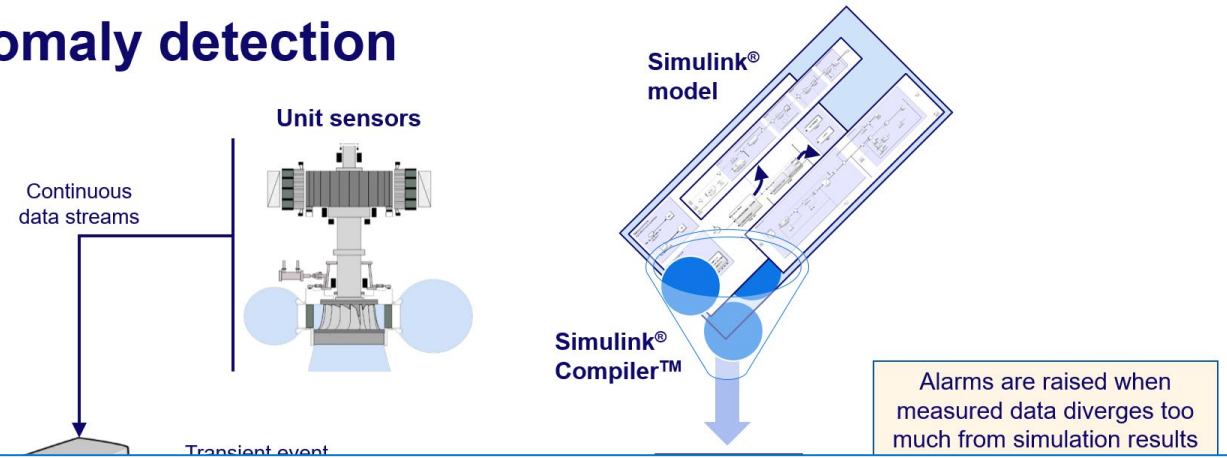


#### Augmented WEHGOV\* model implementation in Simulink®

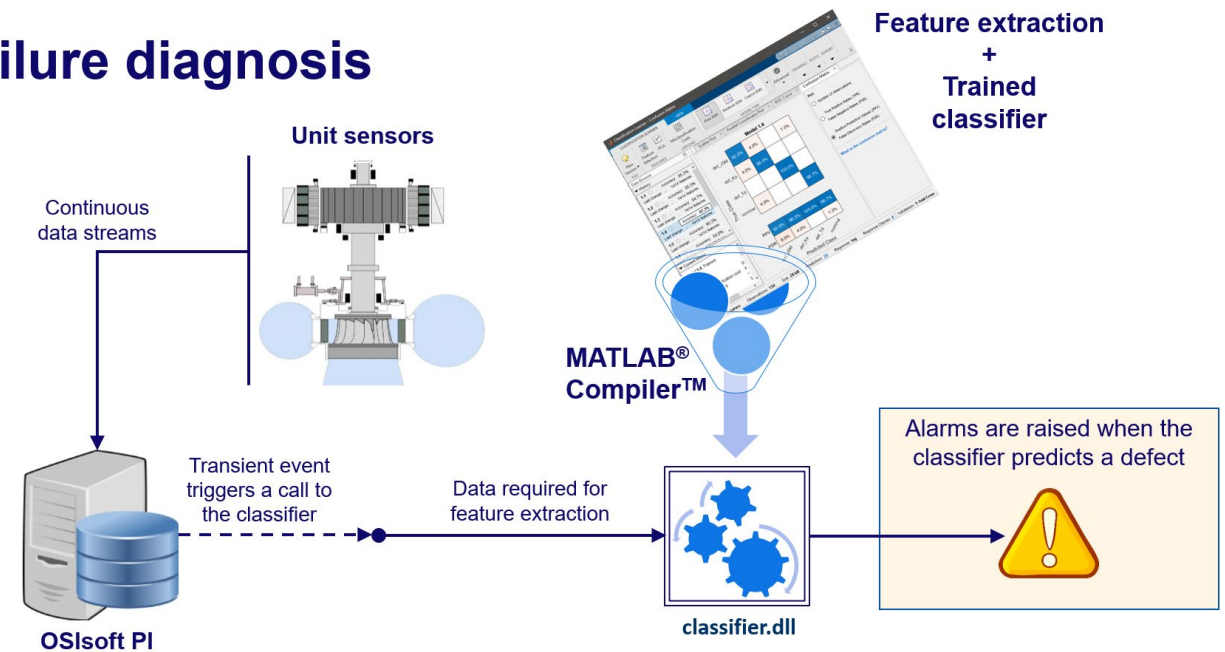
- Basic coupling approach with electrical grid
- Rapid load setpoint adjustment (feed-forward)
- Scaling from nominal to actual hydraulic head

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

### Anomaly detection



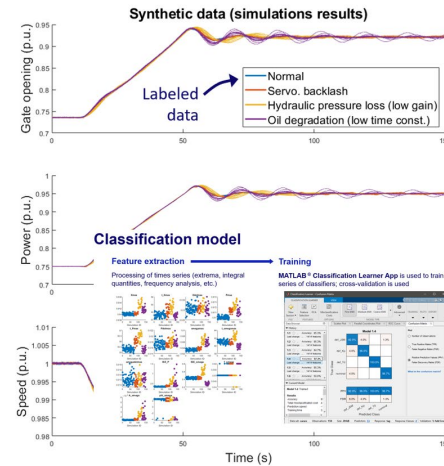
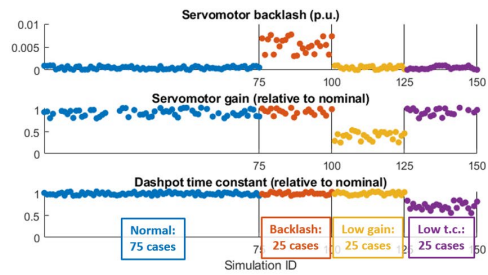
### Failure diagnosis



# 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



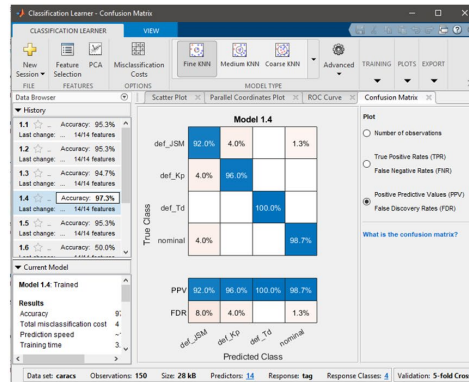
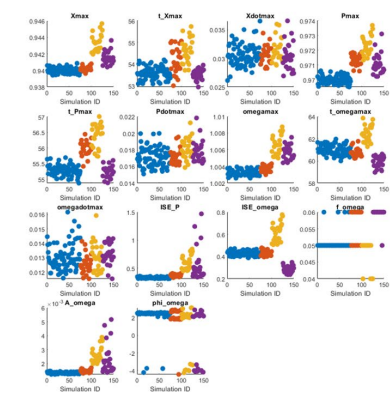
■ 利用仿真模型合成数据支持  
— 多种场景  
— 故障注入

## Classification model

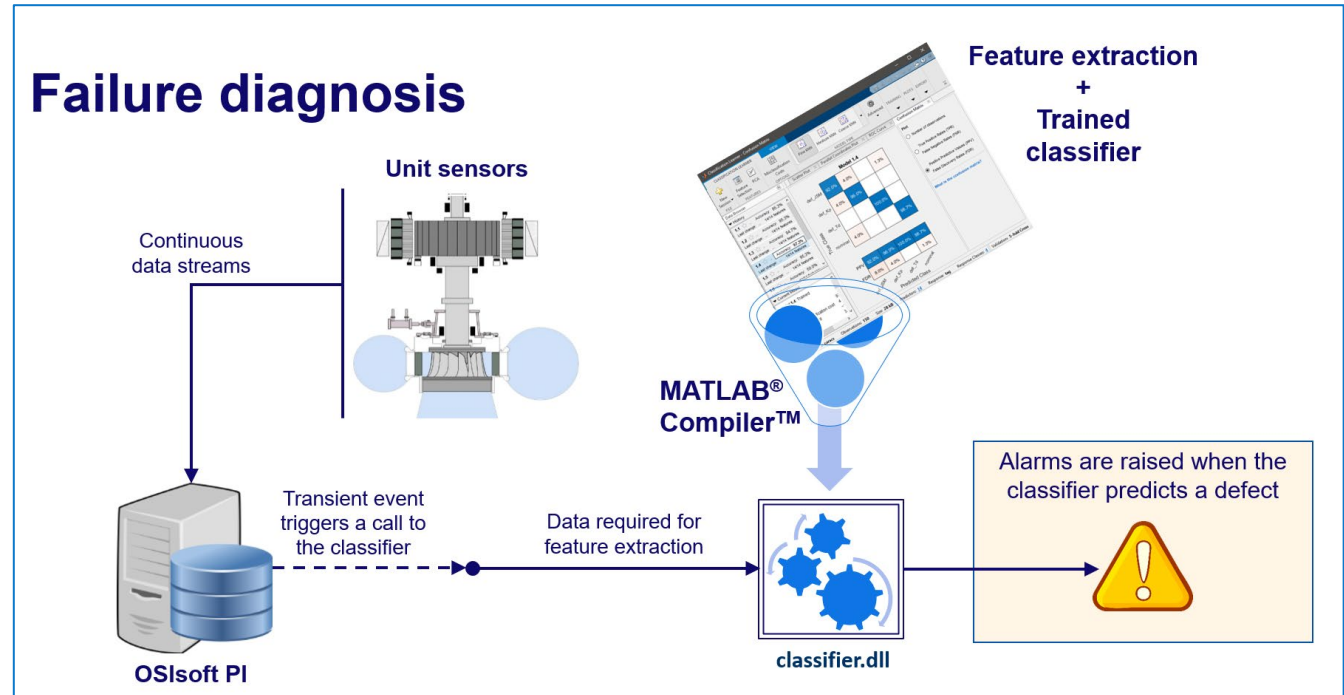
Feature extraction → Training

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



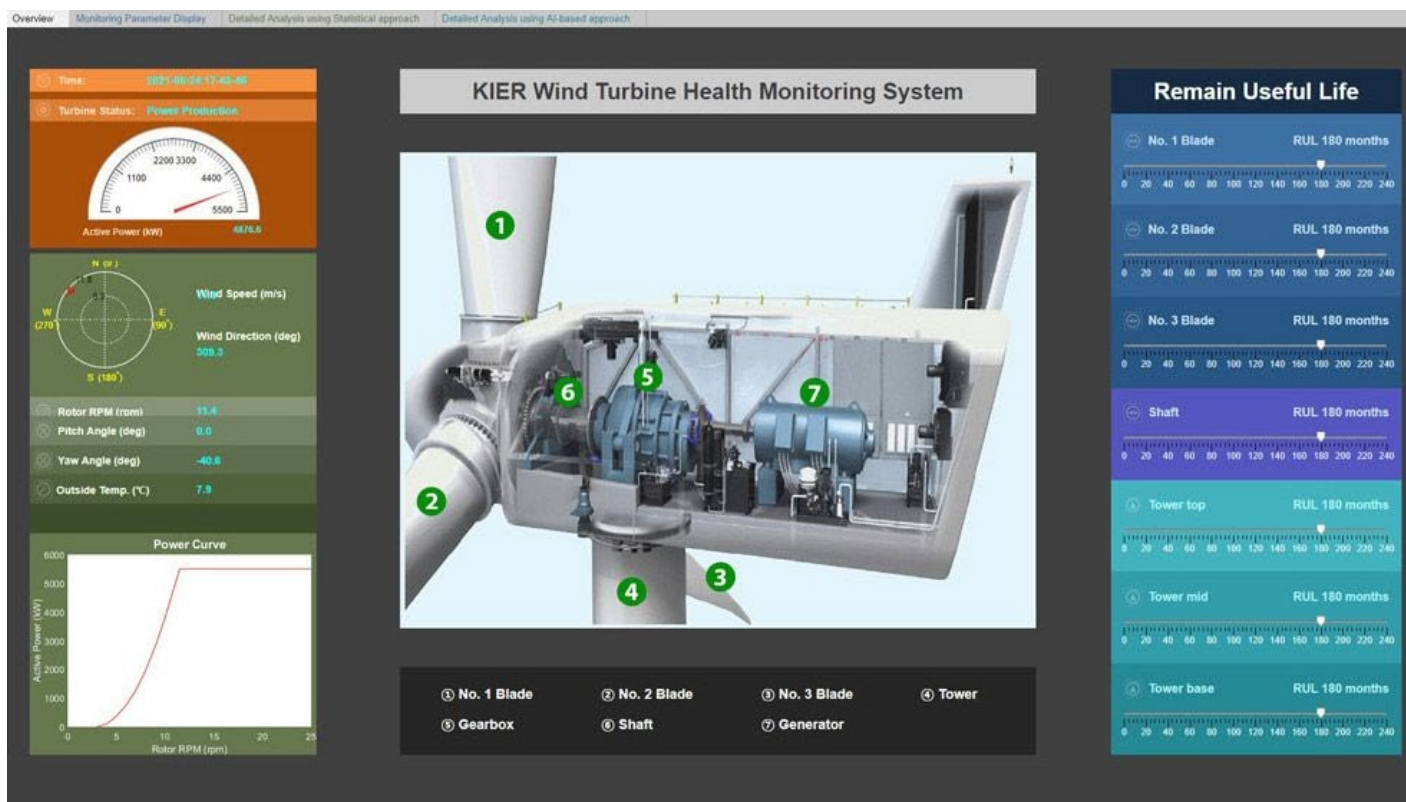
## Failure diagnosis





# 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

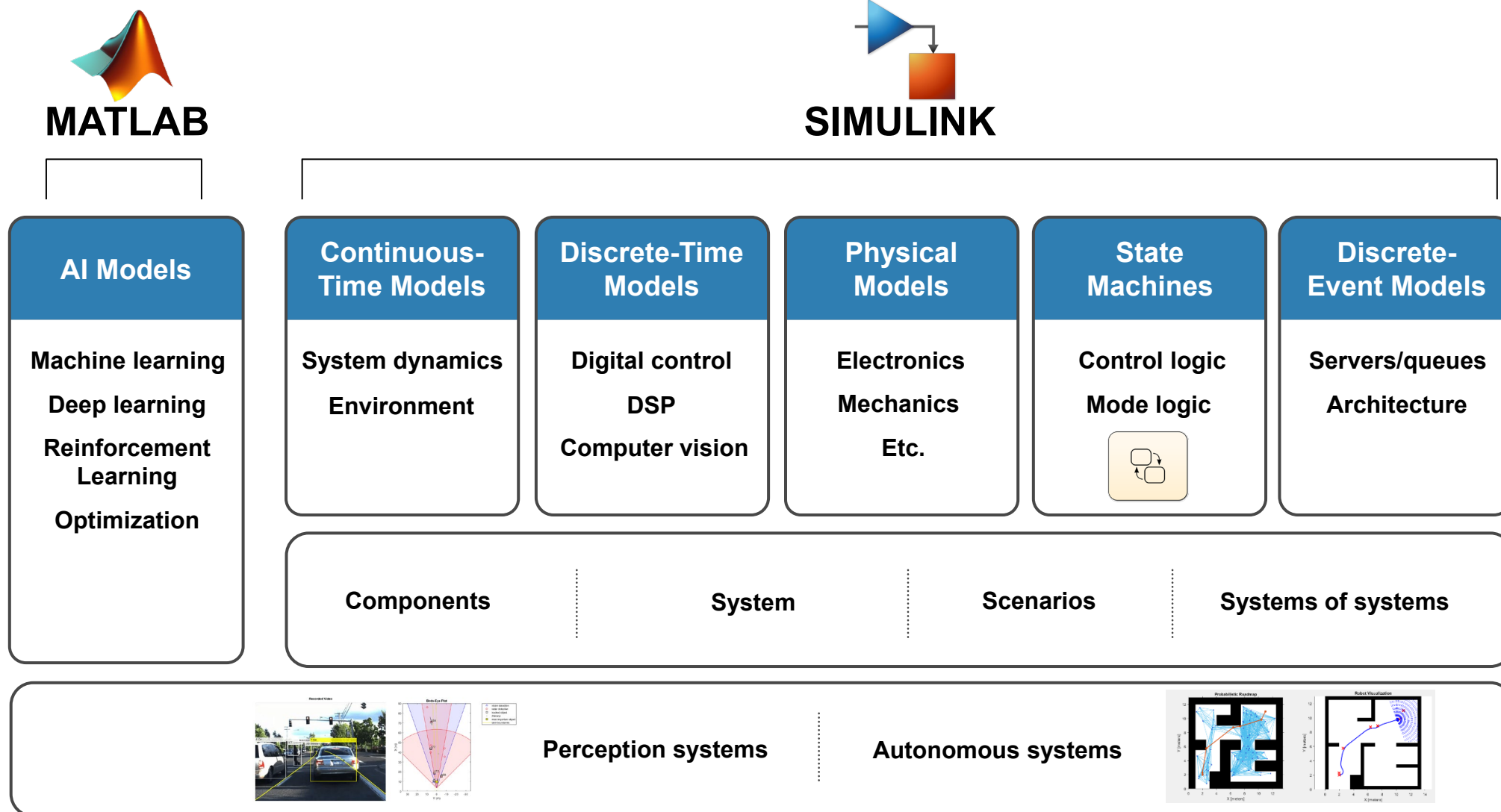
## 结果

- 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

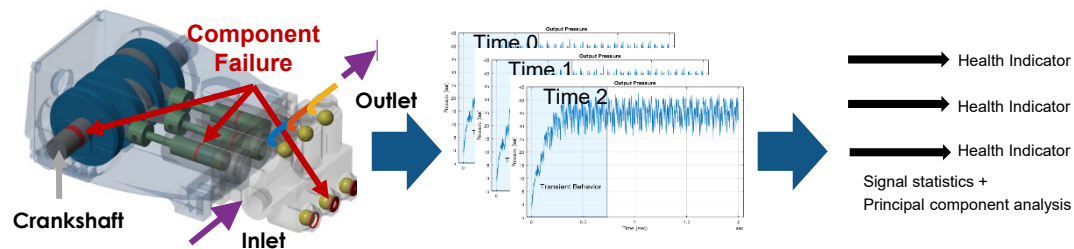


Simulink和MATLAB支持多种仿真机制：连续、离散、状态机、异步事件、物理、数据驱动

# 建模仿真与AI的融合

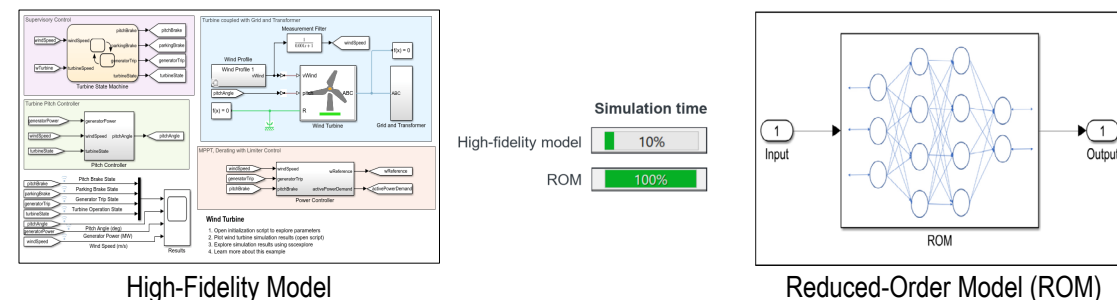
## Data synthesis for AI training

- Predictive maintenance



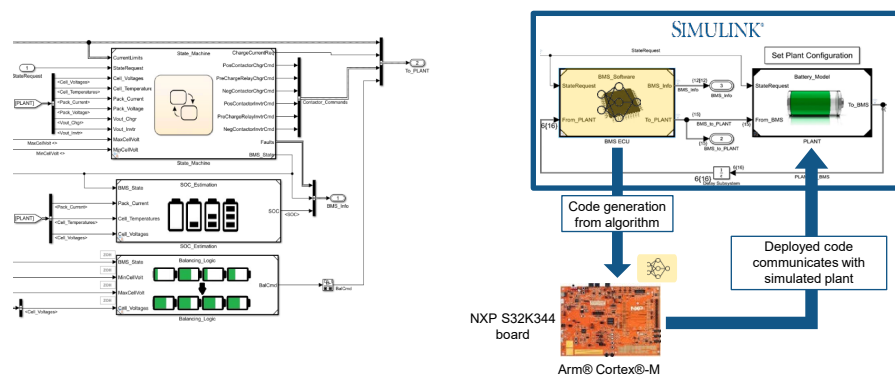
## AI for component modeling

- Reduced-order models (ROM)



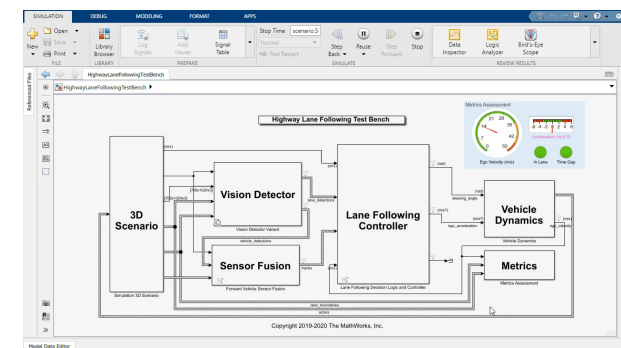
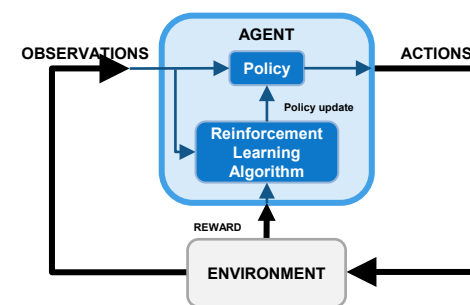
## AI for algorithm development

- Virtual sensor modeling
- Sensor fusion
- Object detection

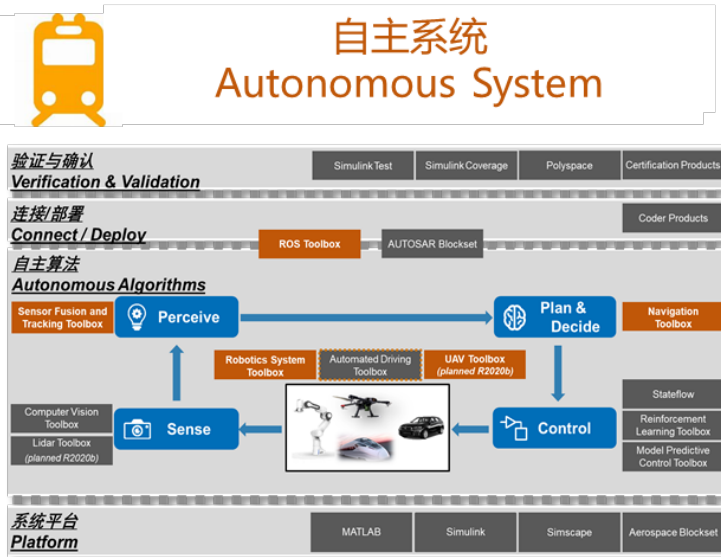
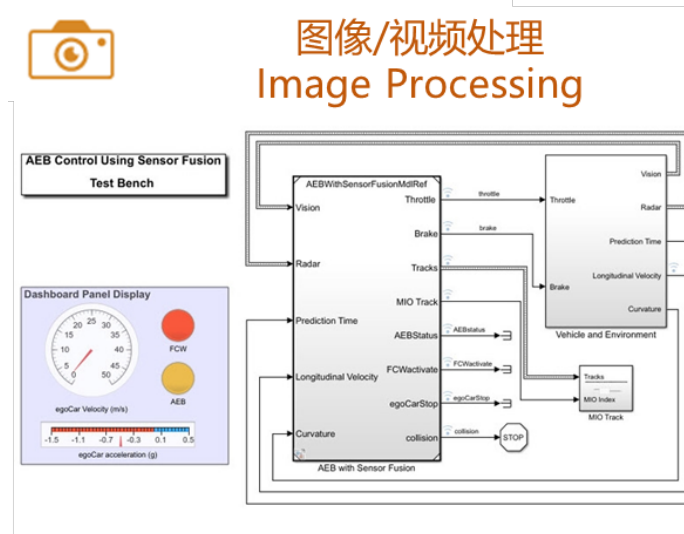
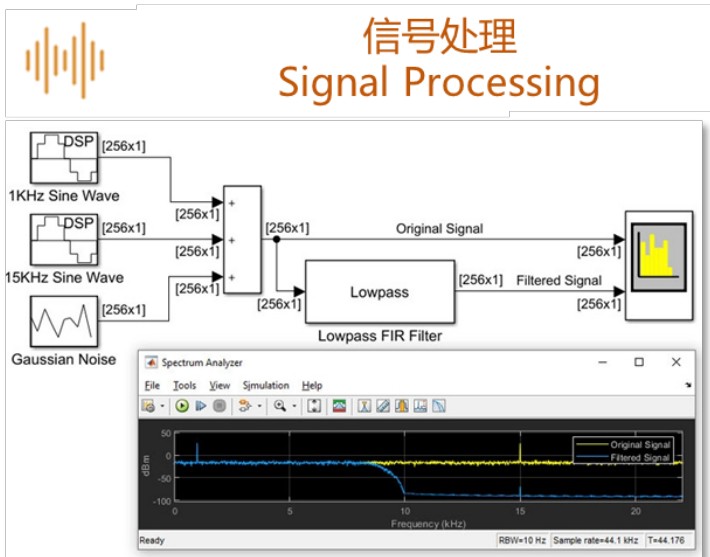
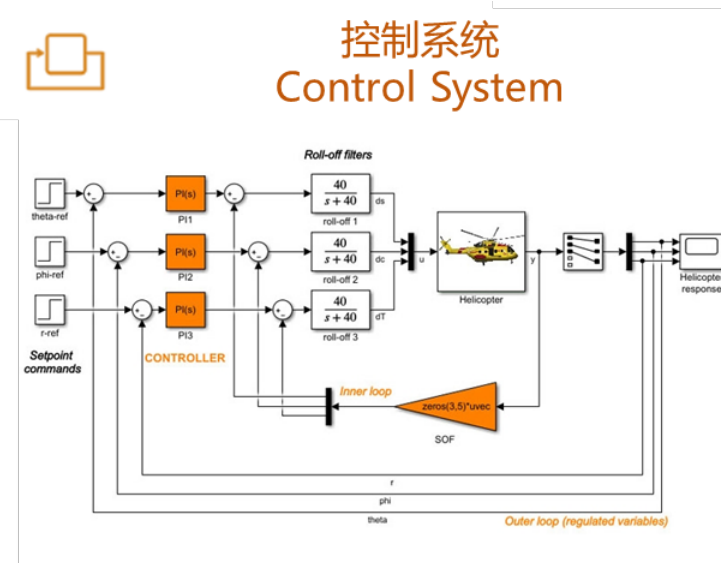
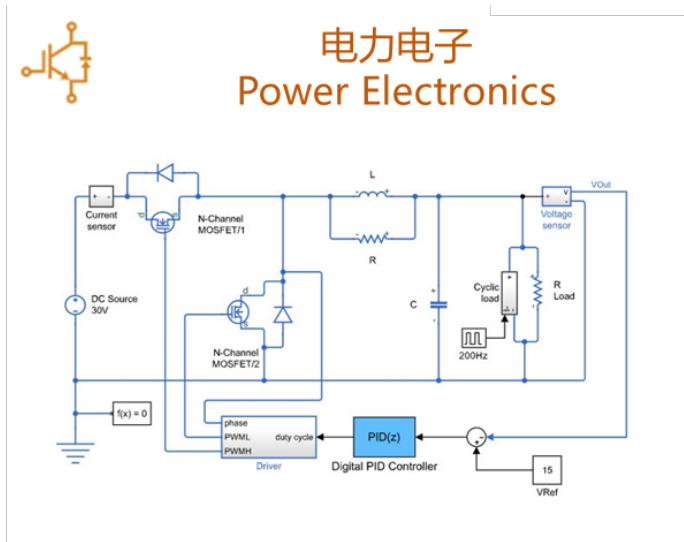


## AI for system development

- Reinforcement learning
- AI-driven systems



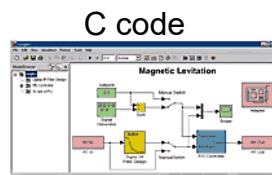
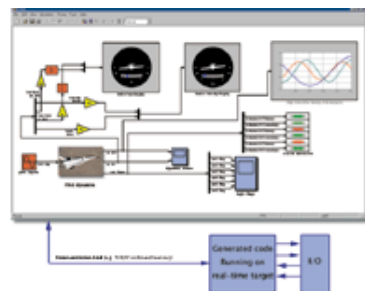
# 支持多种类型系统的建模与仿真



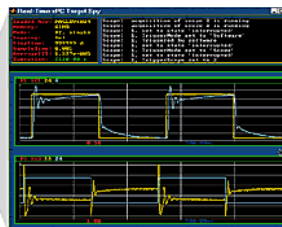
# 将基于模型的设计应用于工业控制系统的开发

Hardware-in-the-loop

对象模型



Simulink Real Time & Target Computer



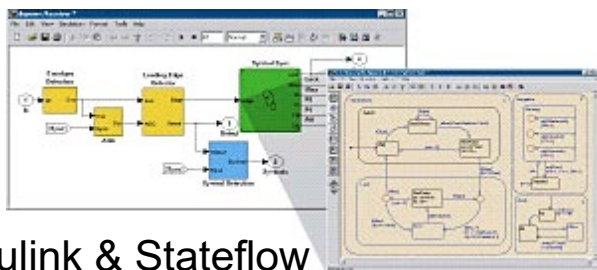
Ethernet Connectivity



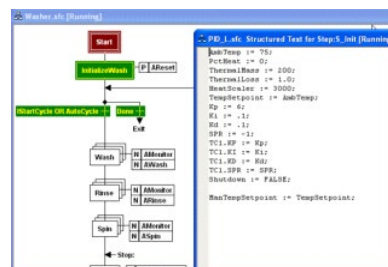
PLC Hardware

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

Simulink & Stateflow

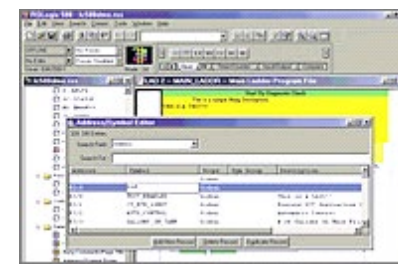


控制算法



IEC 61131-3  
代码生成

IEC 61131-3  
compliant  
language



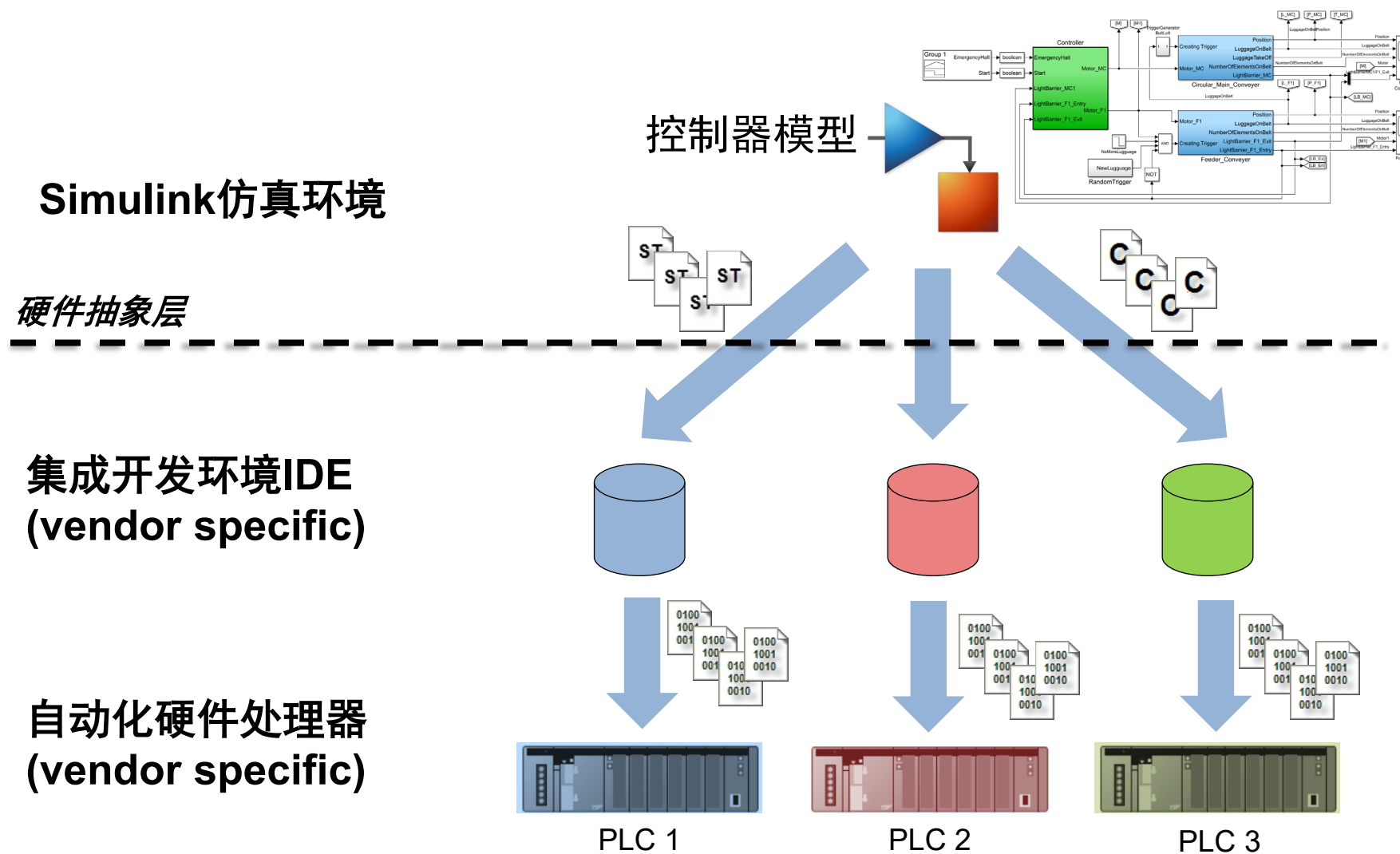
Vendor specific PLC IDE

## 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	✓	✓	✓

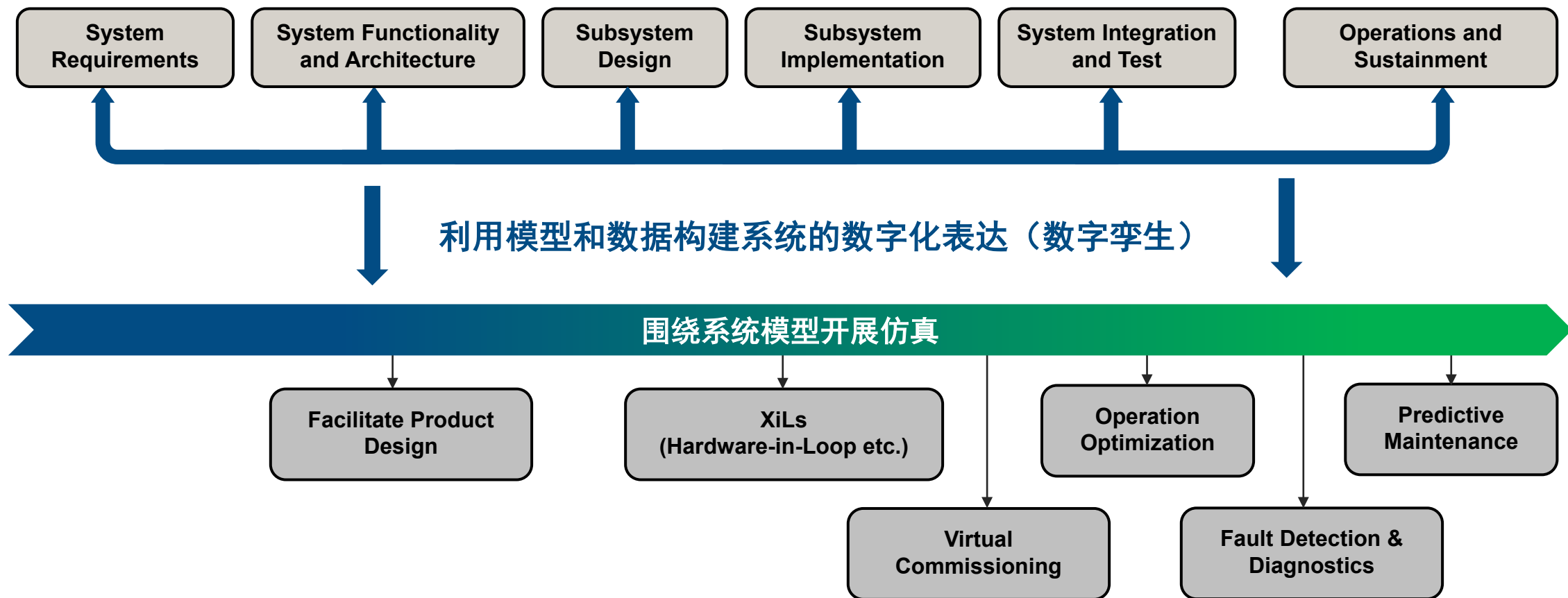
# 与PLC硬件平台的“解耦”

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

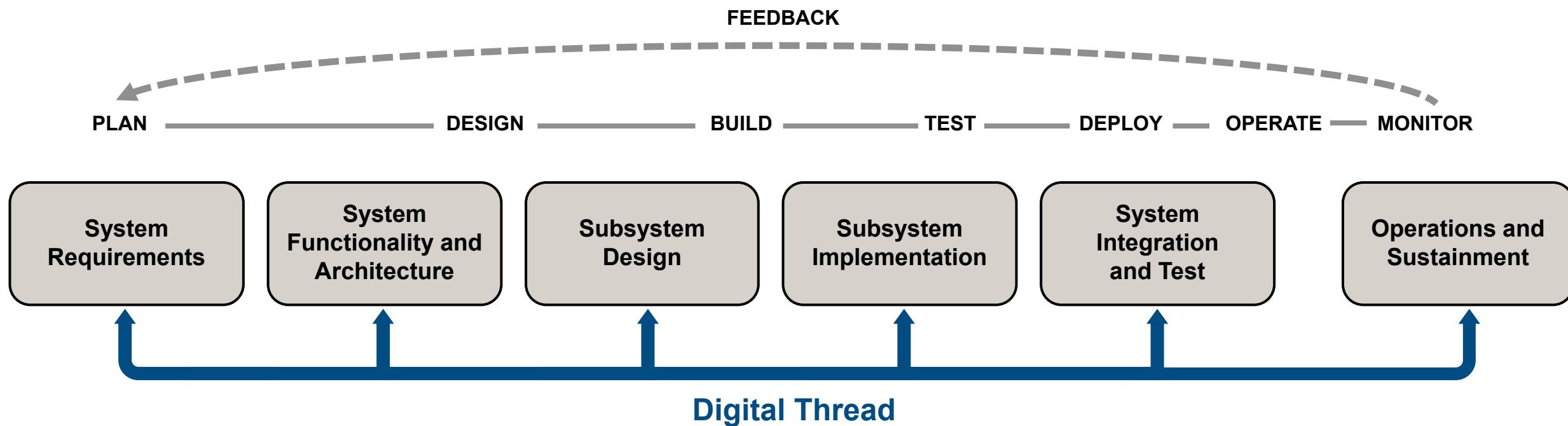
## ■ 总结





## 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



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