# HL Mando

November 13–14, 2024 | Online

## An AI-Powered Predictive Maintenance Platform for Testing Autonomous Vehicle Components

*Seongil, Lee    HL Mando*
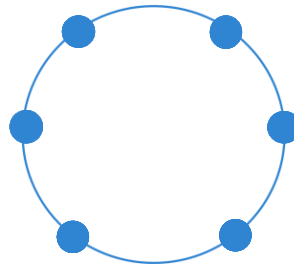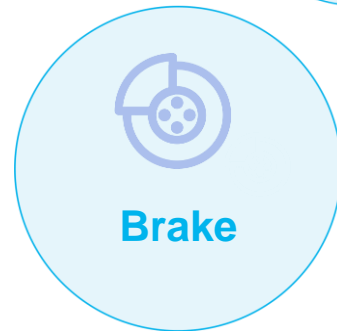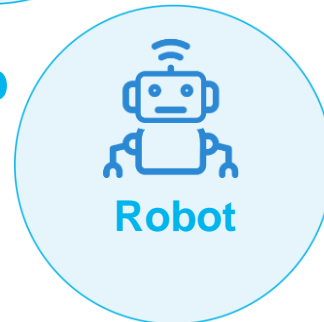
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# HL Mando in a glimpse

**Automotive Chassis Parts**

**ADAS, Lidar, Radar etc.**

**HL Klemove**

**Mobility Solution Tech. Group**

**SW Campus**



Steering

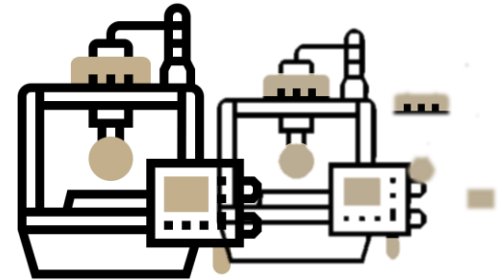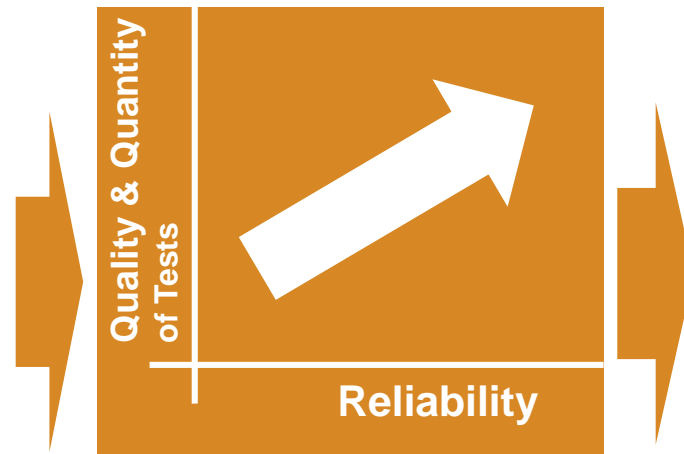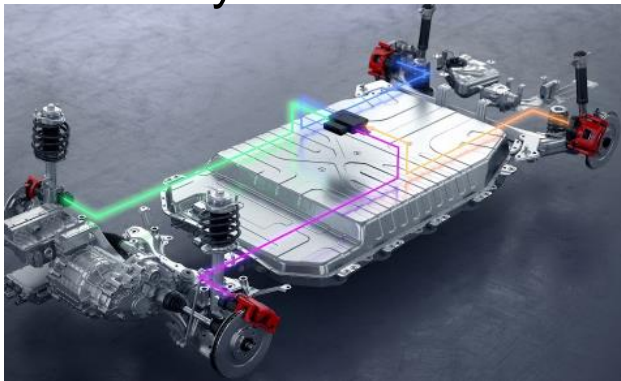Suspension

Brake

Autonomous Driving

Robot

Software

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# New products like X-by-wire requires high performance and efficient test environment

Steer by wire

Brake by wire



Quality & Quantity of Tests

Reliability

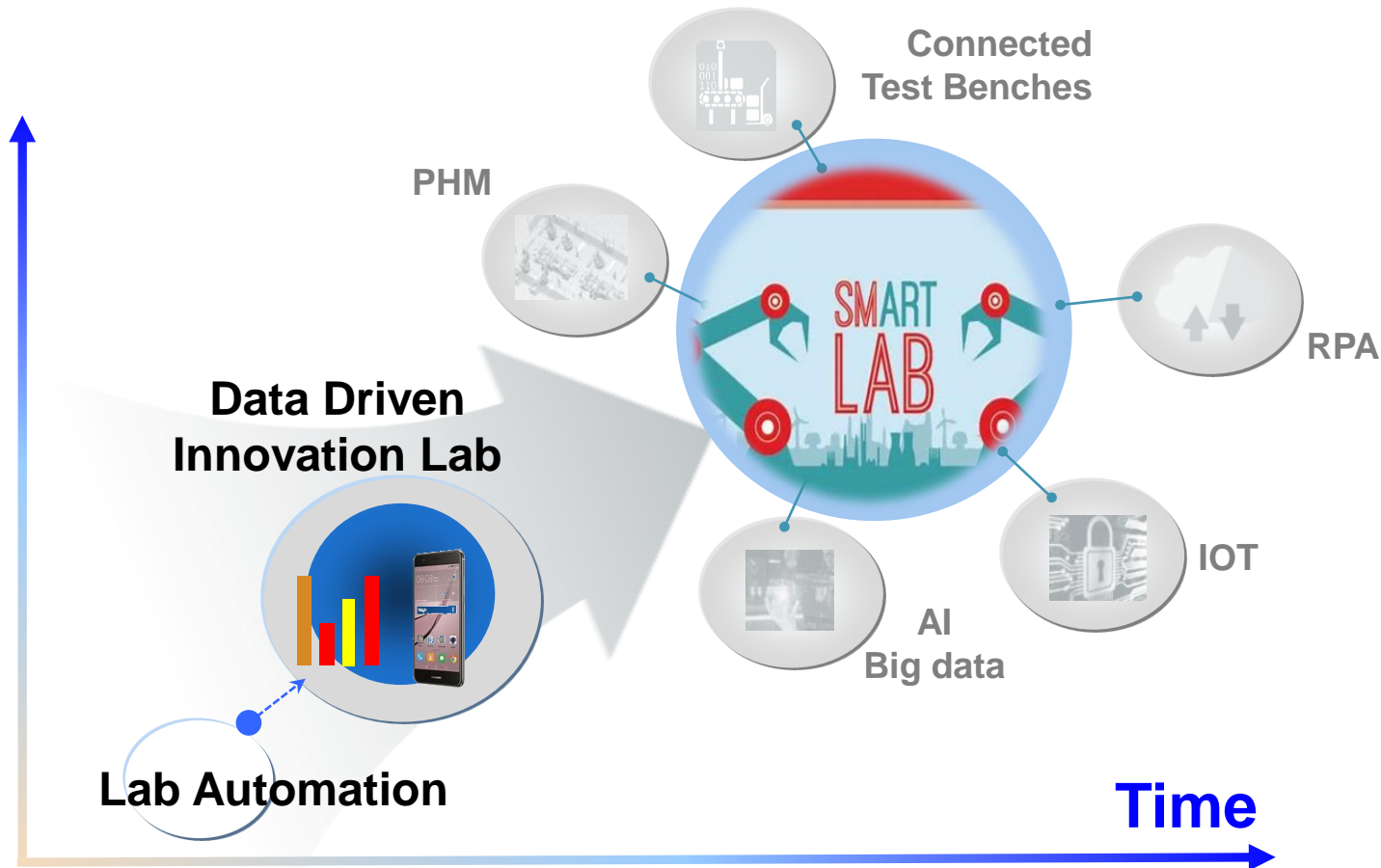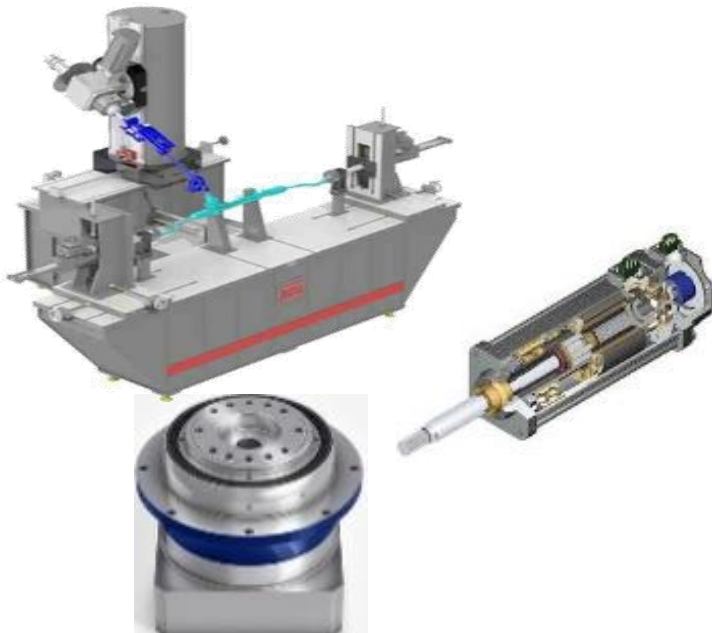MATLAB EXPO
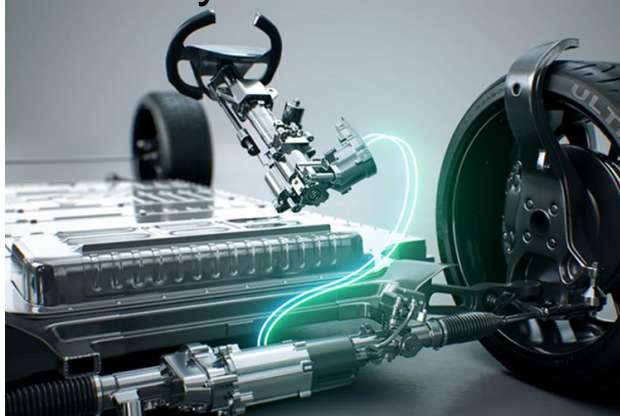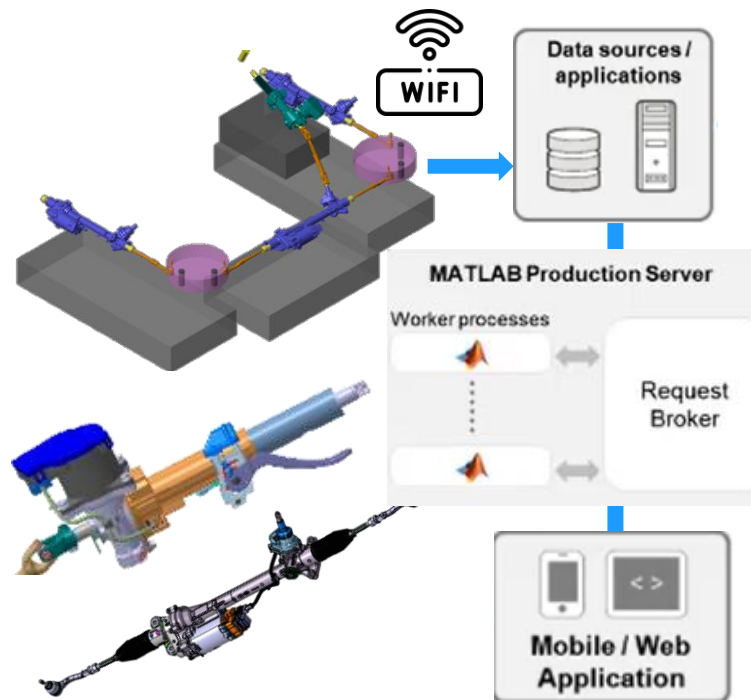
# Smart Lab for Digital Transformation in HL Mando



Smart Lab comprises

1. Connected test benches

2. IOT based monitoring system

3. AI powered big data training and predictive analysis

# Concept of connected test benches



| Conventional test benches | New test benches |
|---|---|

Advantages of new test benches

1. Cost reduction by using in-house actuators
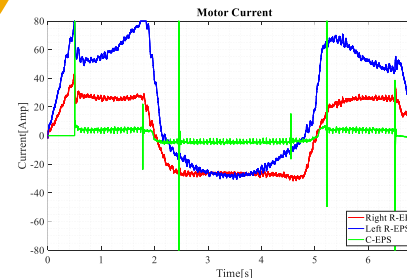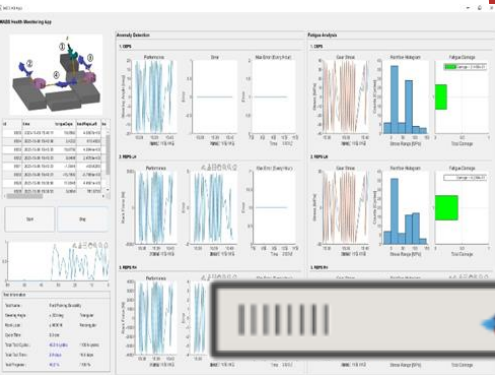
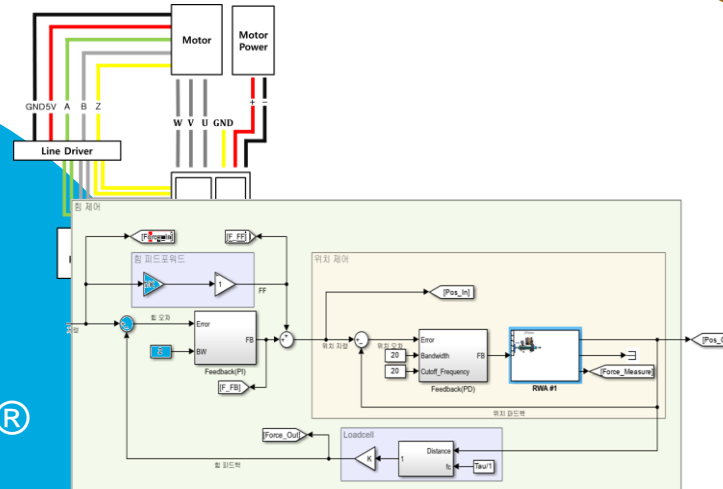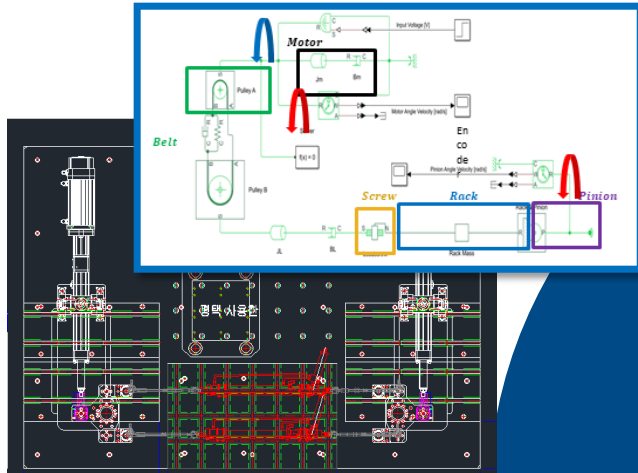2. Maintenance platform

3. High performances
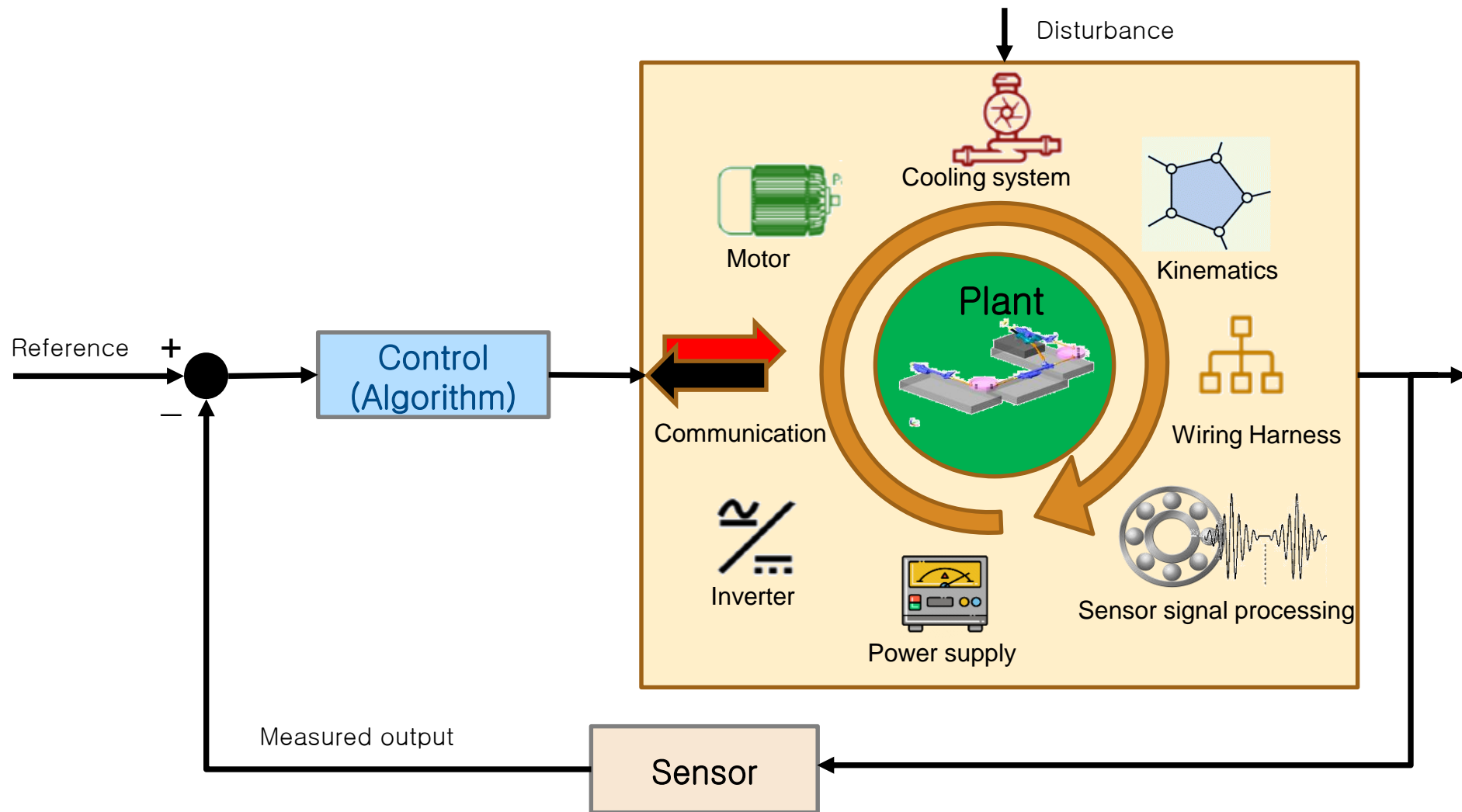
# Building SmartLAB with model based design



Design by Simscape®

Control by Simulink®

Maintenance by MPS®

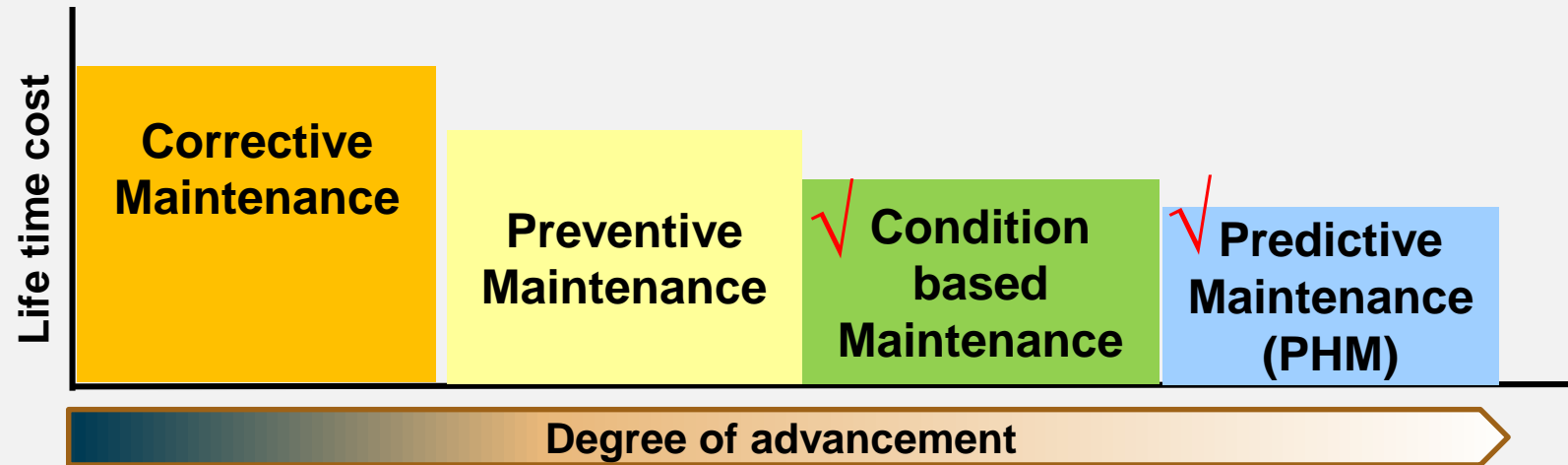Test by Speedgoat®

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# Patented new control algorithms for high performances of test rigs

# Comparison of strategies for new test bench maintenance

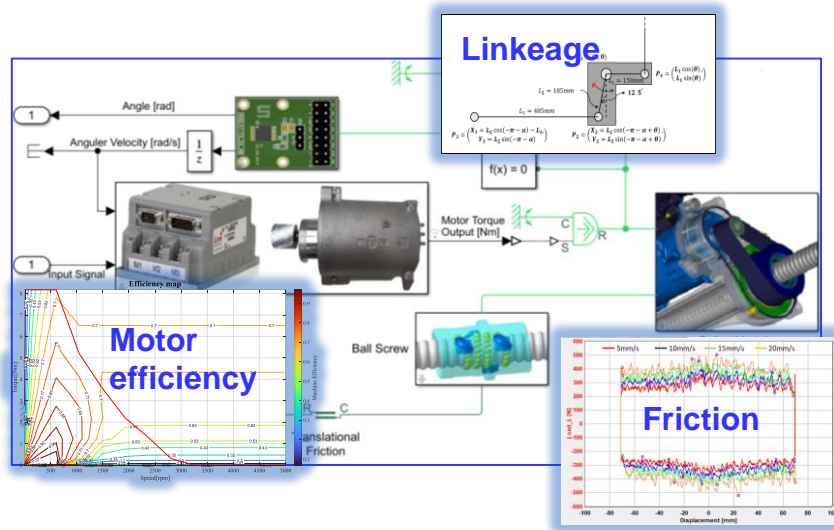☑ **Condition Based Maintenance(CBM) , Predictive Maintenance(PHM)**
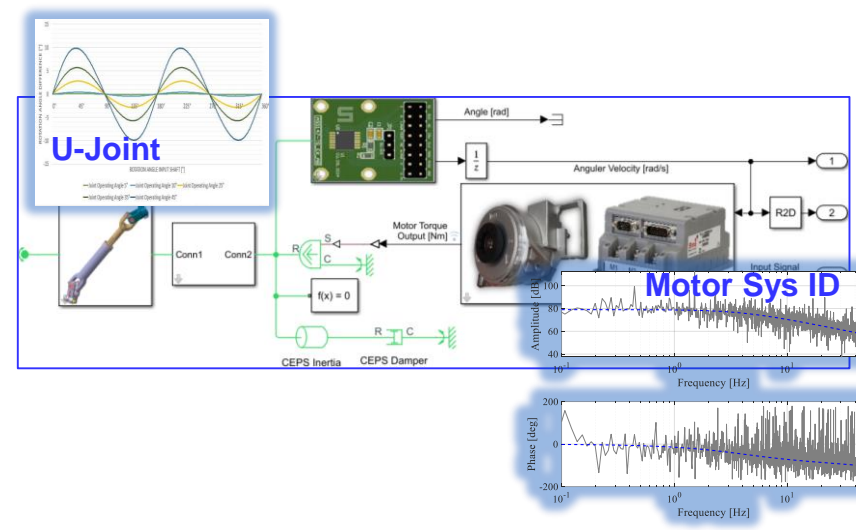


☑ **Global R&D web-based smart maintenance platform**
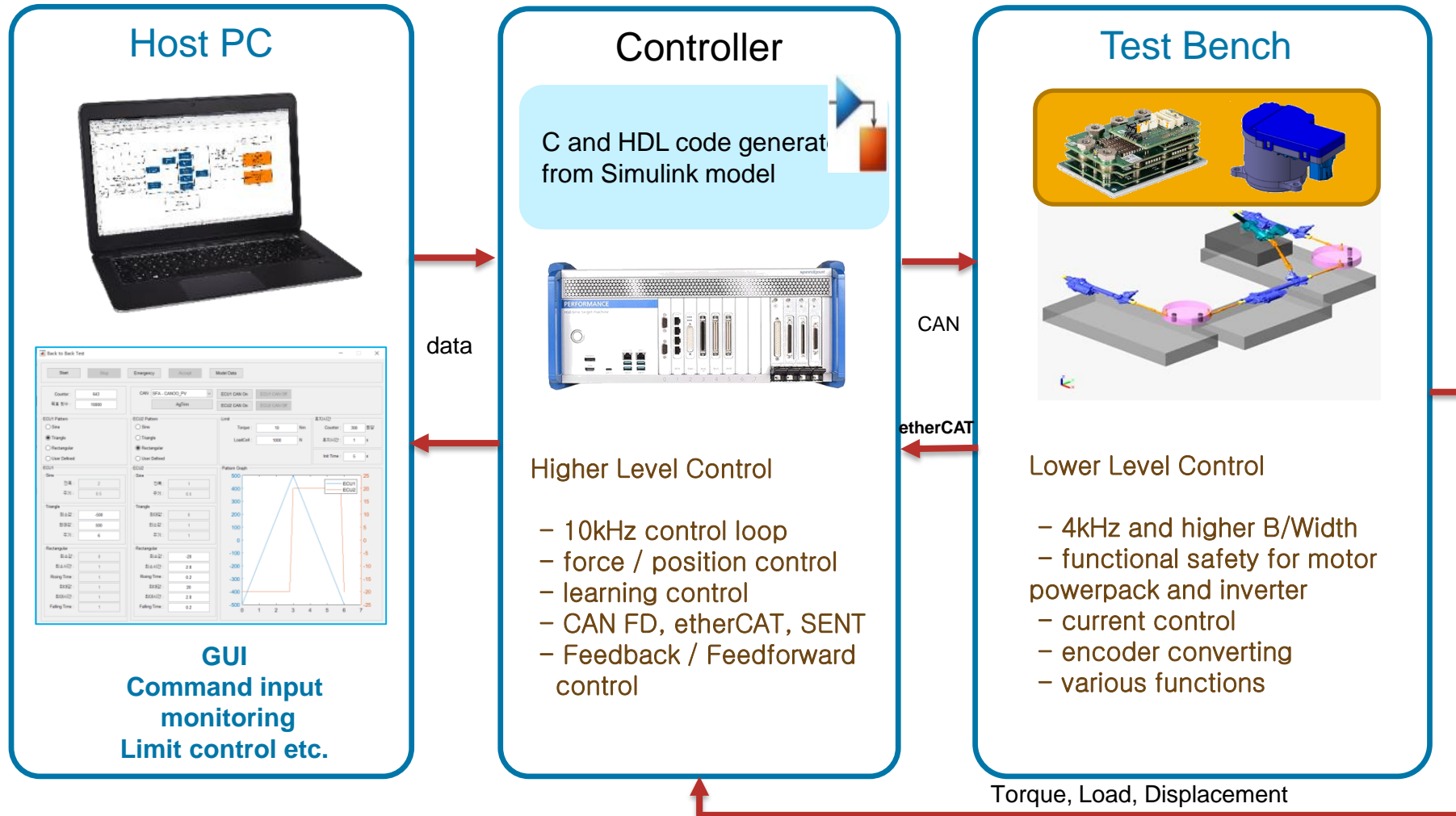
# Bench design using digial twin – physical modeling



< Linear actuator modeling>

< Rotary actuator modeling>

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# Control architecture



**Host PC**

GUI
Command input
monitoring
Limit control etc.

data

**Controller**

C and HDL code generate
from Simulink model

Higher Level Control

- 10kHz control loop
- force / position control
- learning control
- CAN FD, etherCAT, SENT
- Feedback / Feedforward
  control

CAN

etherCAT

**Test Bench**

Lower Level Control

- 4kHz and higher B/Width
- functional safety for motor
  powerpack and inverter
- current control
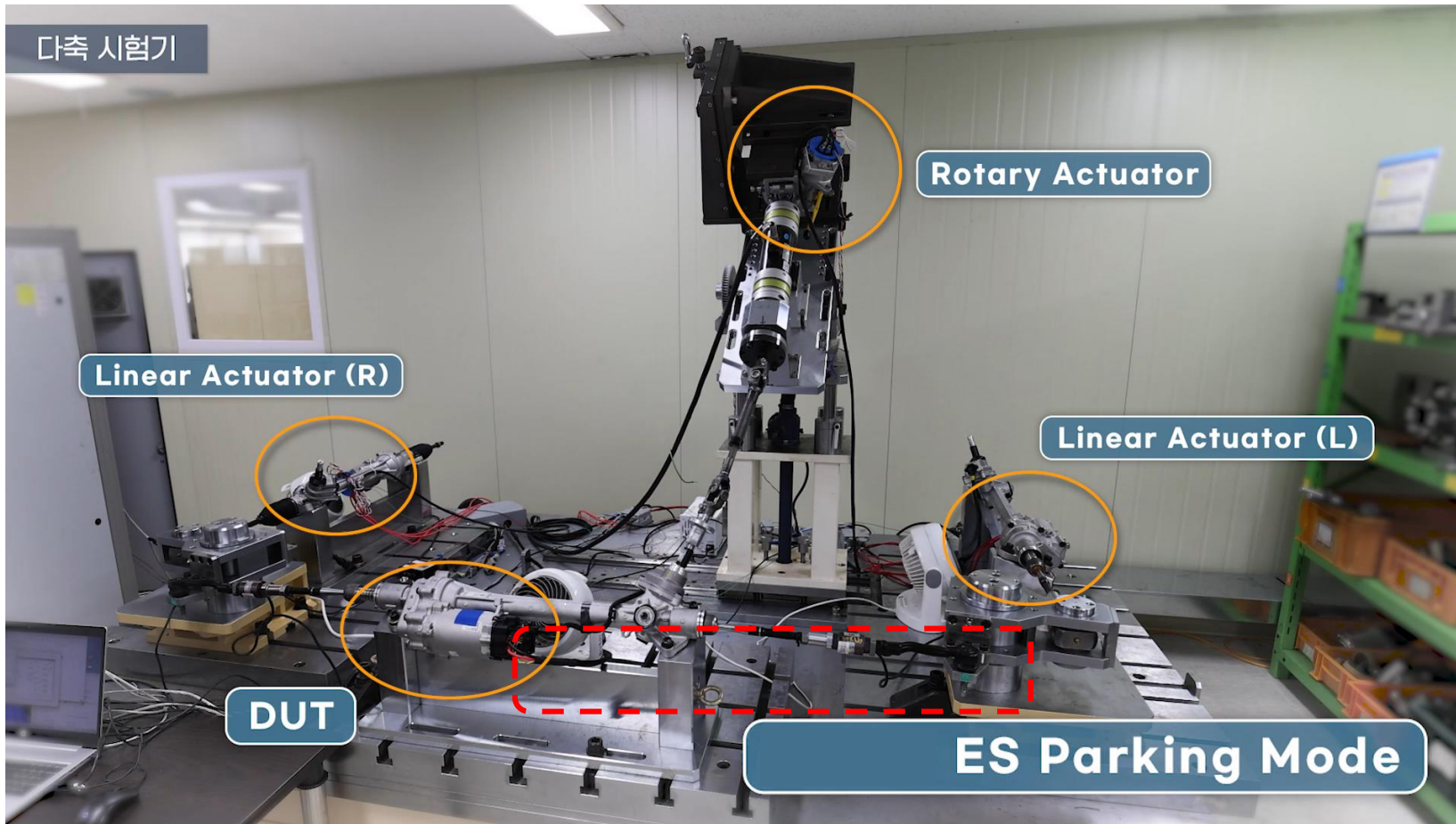- encoder converting
- various functions

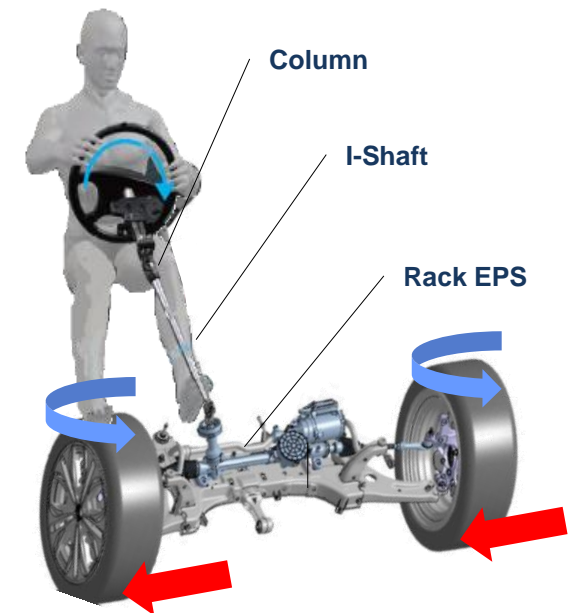Torque, Load, Displacement

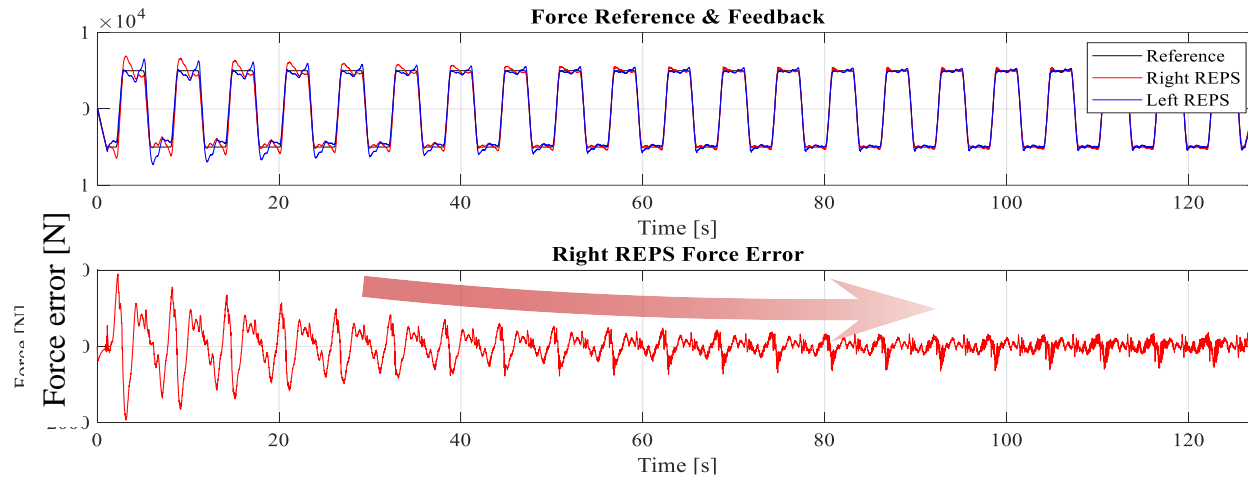MATLAB **EXPO**

# 3 Axes steering durability test stand

Target test stand – 3 axes steering durability test rig



Newly developed
steering test stand
simulate real vehicle

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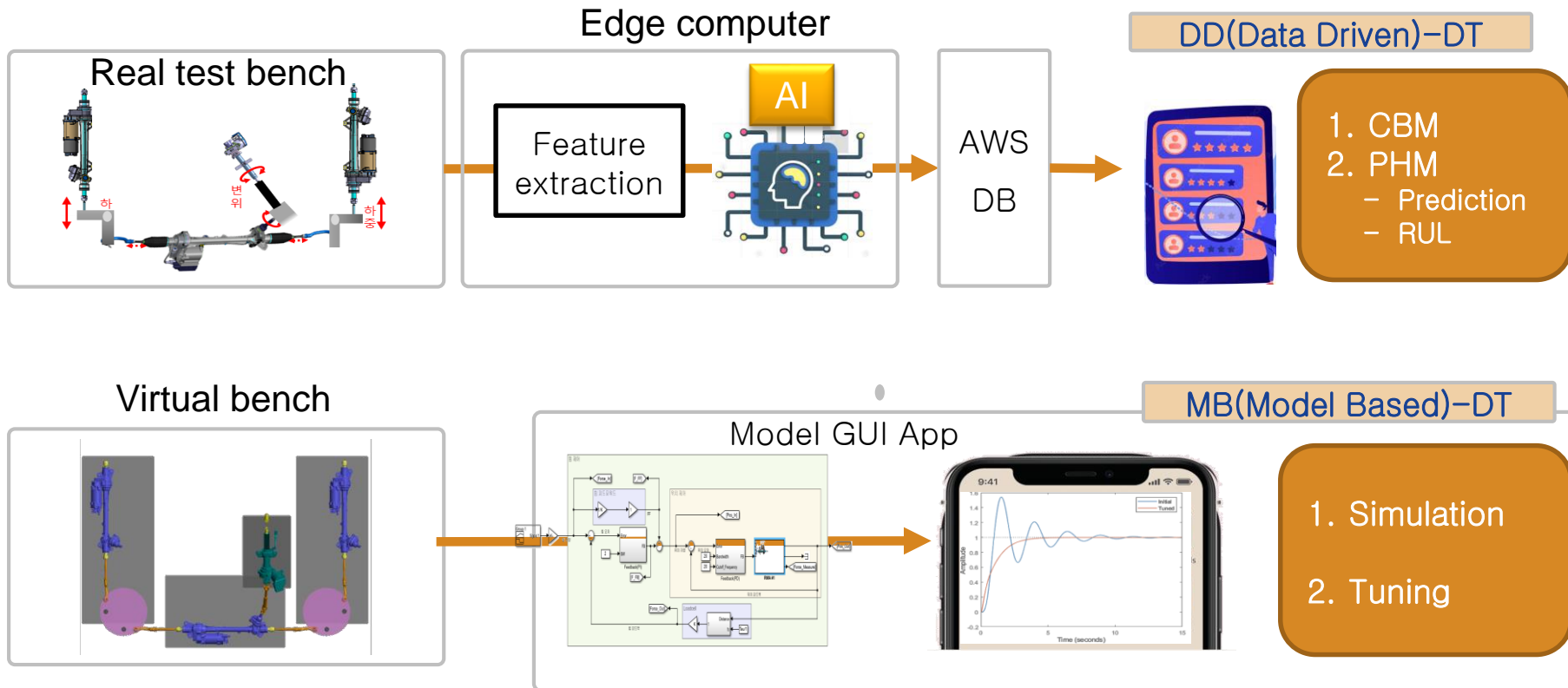# New benches with ILC(Iterative Learning Control) shows better performances



Force Reference & Feedback

Right REPS Force Error

- Response per command error reduced by 33% ( target $Error_{RMS} < 10\%$ )

| | Existing bench | New bench with ILC control | |
|---|---|---|---|
| RMS error (%) |  |  |  |

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# PHM basic architecture
- Data driven and model based digital twin

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# PHM platform architecture for administering multiple test stands at various sites
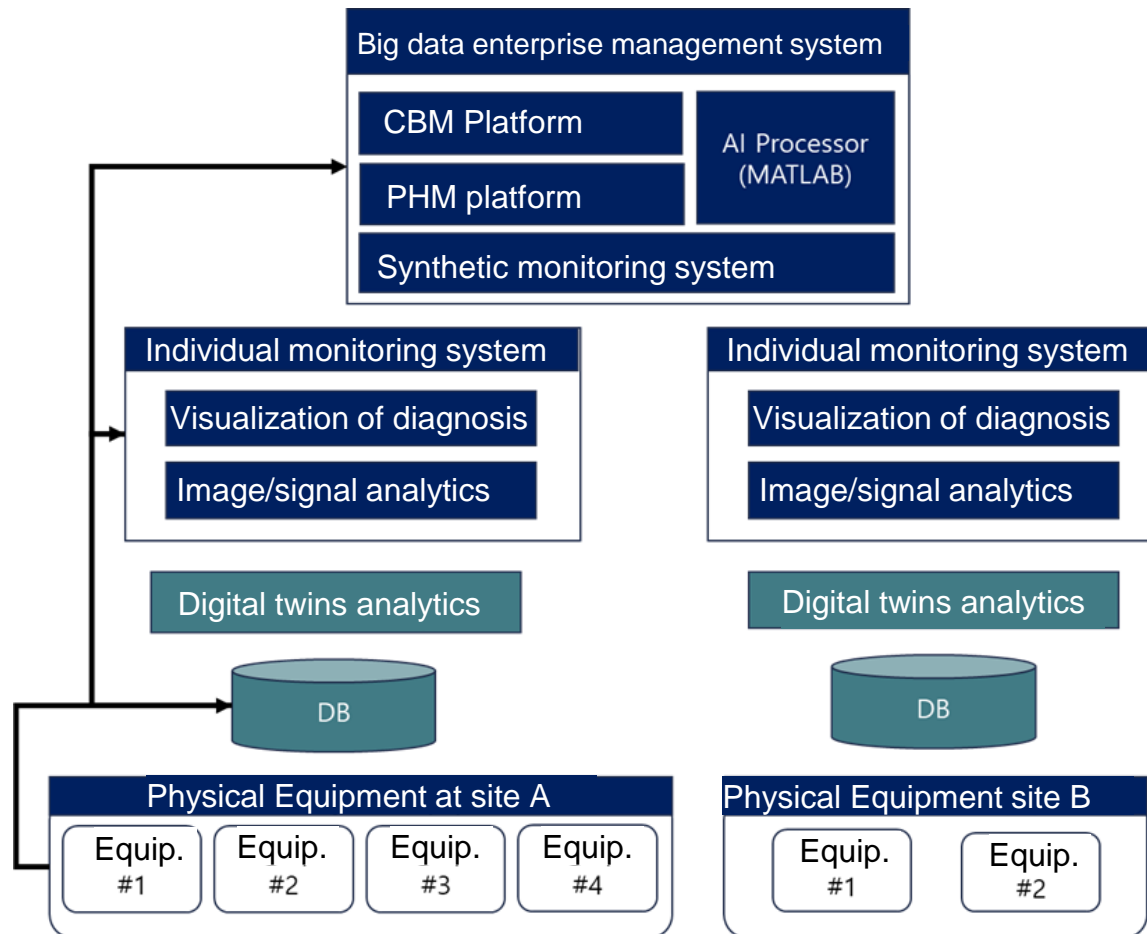


**Data and information flow**

**EMS (enterprise management system)** : data integration to main server and analyse the machine status based on CBM and PHM
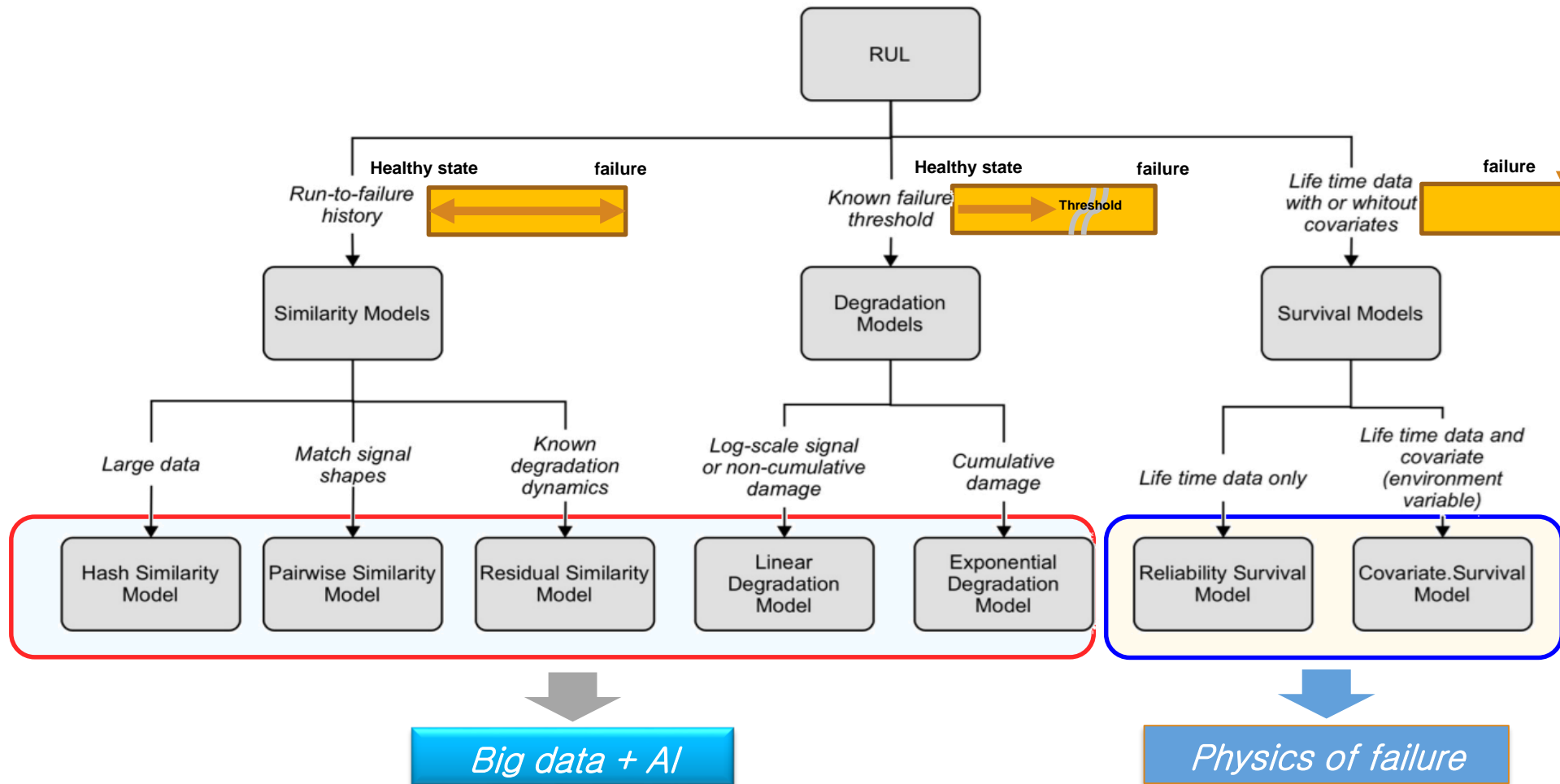
**Real time monitoring**

**Prediction based on physics and machine learning**

**Quality control and diagnosis**

Detection of failure and diagnose its cause

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# RUL(Remaining Useful Life) estimation requires models with right big data

# Collecting life data by implementing accelerated life test or accelerated degradation test

What is Accelerated Life testing?

Obtaining life or degradation data is difficult because of long life times of products

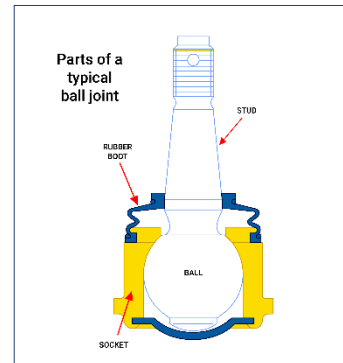So life in devised condition could be used to quickly fail the product.

$$Acceleration\ Factor = \frac{Life\ in\ normal\ condition}{Life\ in\ accelerated\ condition}$$

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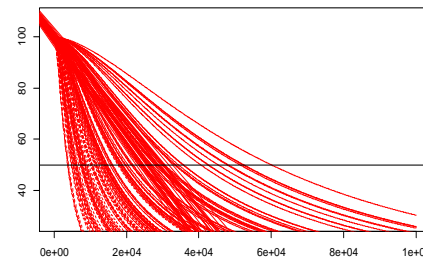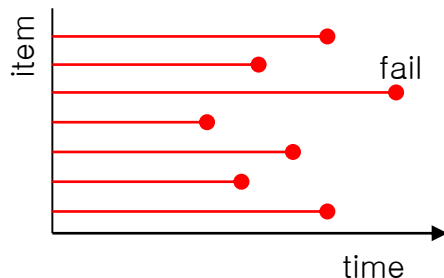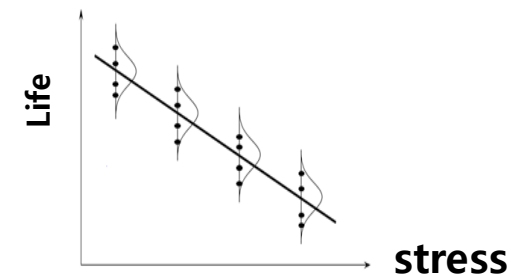
# Physics of failure like fatigue can estimate the life of product
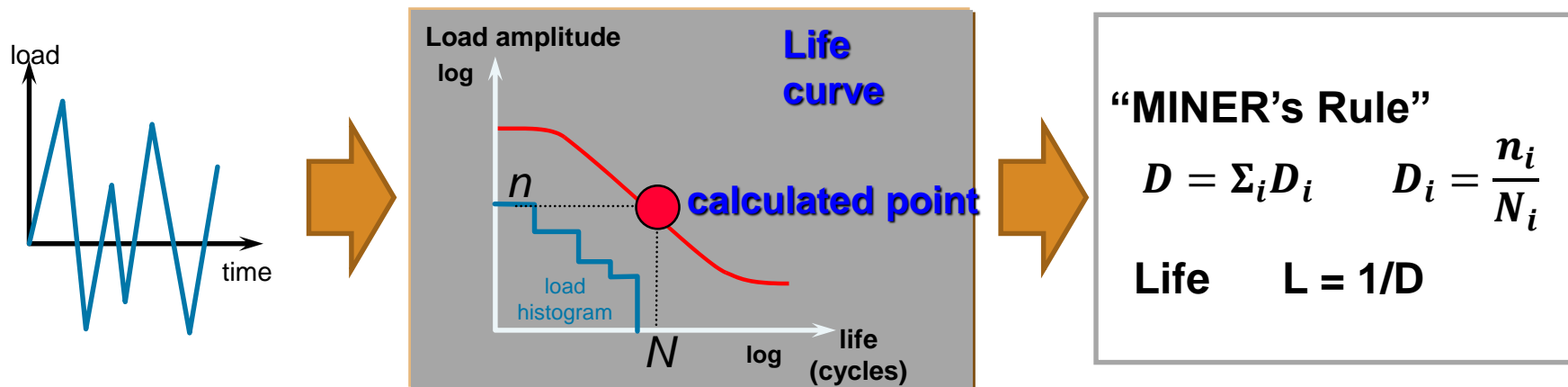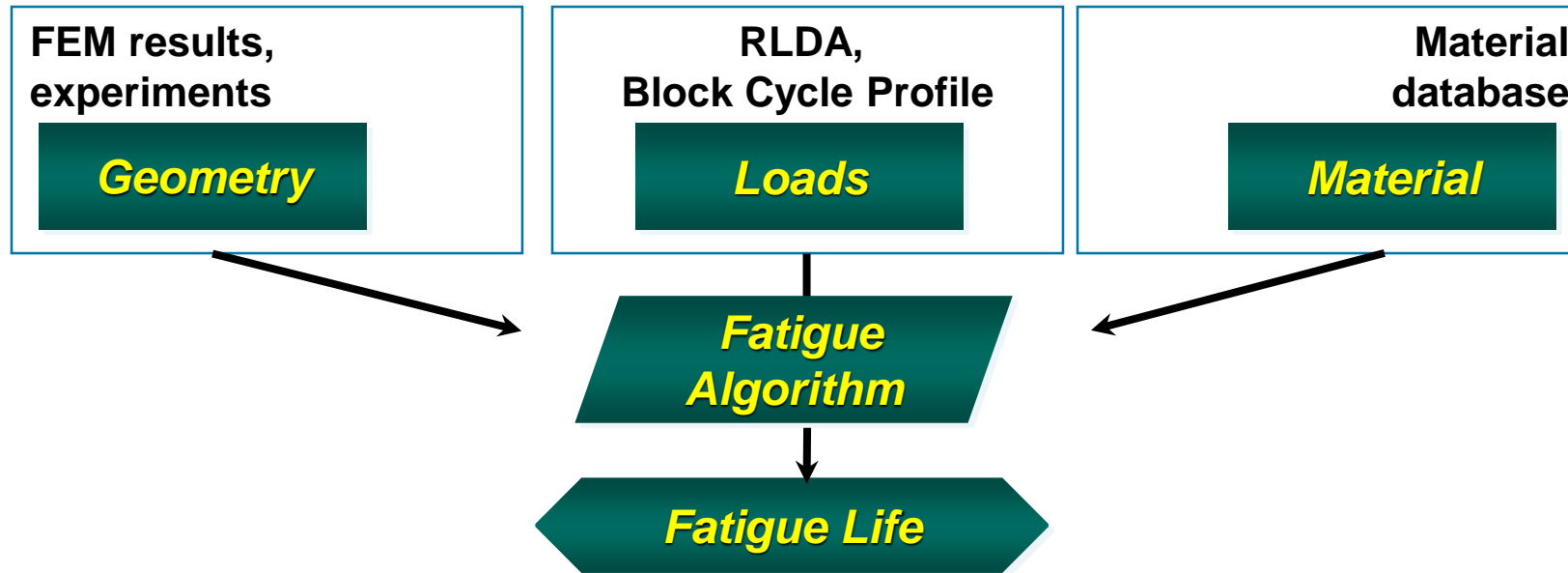
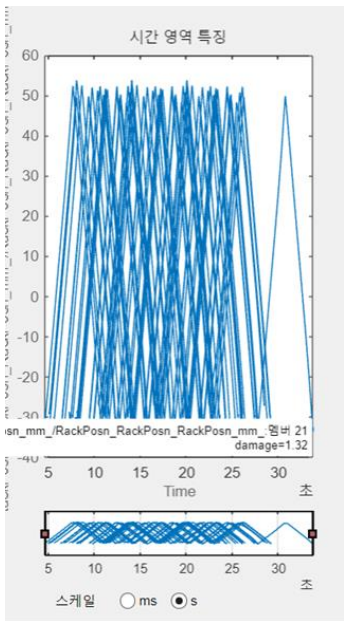# Example.  plastic bearing






Plastic Bearing

- **Degradation data**

# RUL estimation process

```
Acquire      →    Preprocess    →    Condition     →    Train      →    Deploy
Data              Data               Indicators         Model           - RUL
```
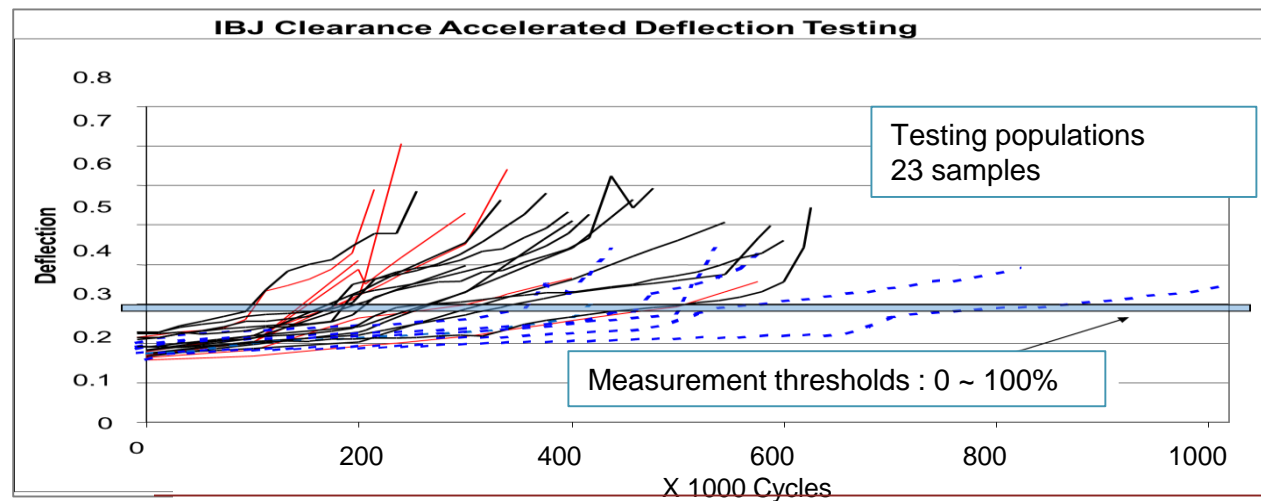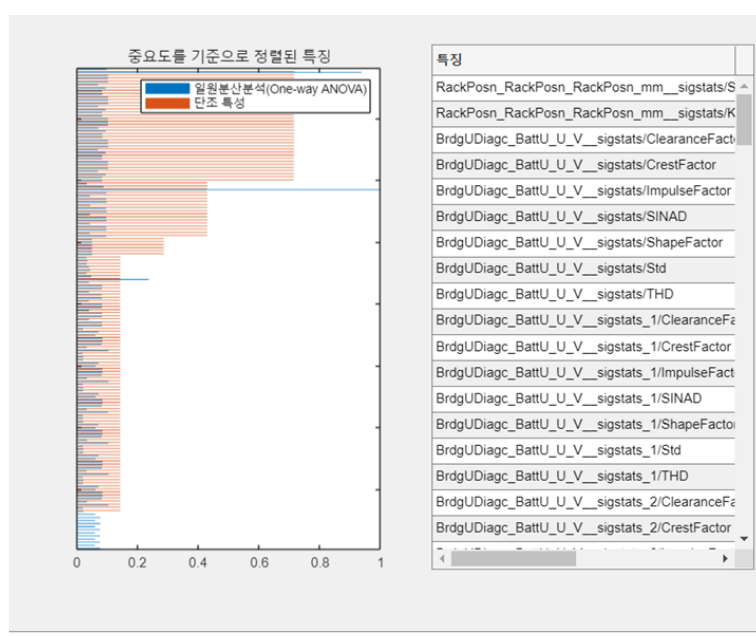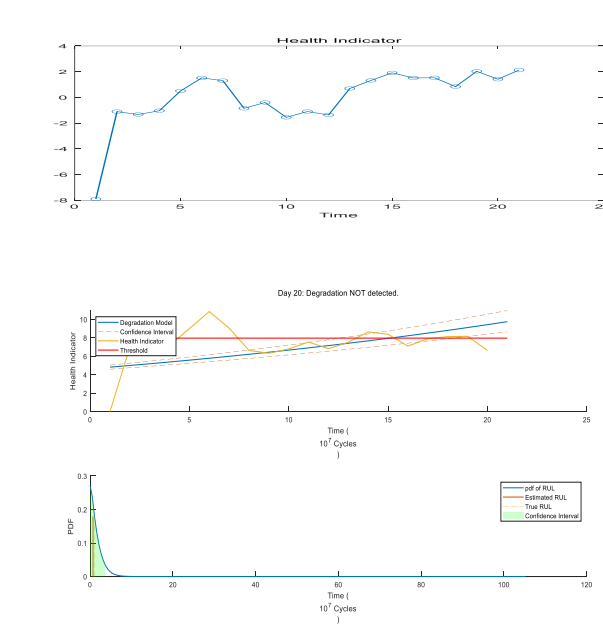
Tie Rod data collection
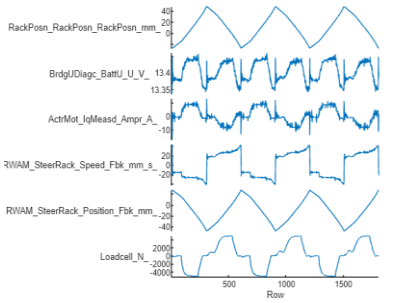
Time features
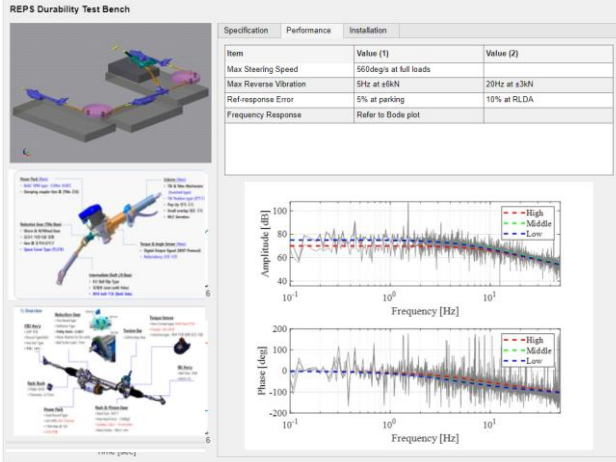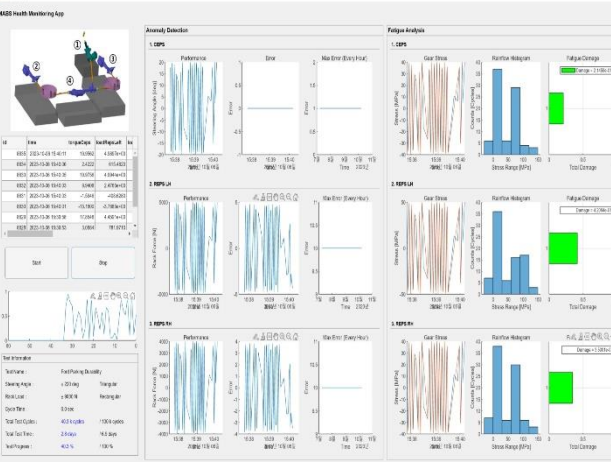
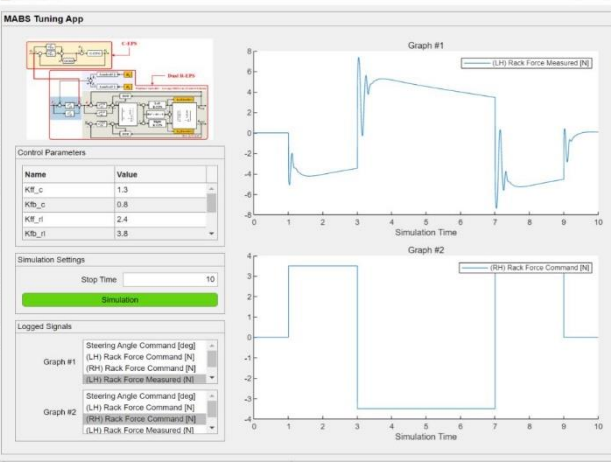Feature extraction (70ea)

RUL estimation

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# PHM platform consists of three basic functions

| Information App | Monitoring App (DD-DT) | Tuning App (MB-DT) |
|---|---|---|
|  |  |  |
| **Basic information**<br>① **Specification**<br>② **Performances**<br>③ **Install and repair history** | **Realtime Monitoring**<br>① **Warning and alarm**<br>② **RUL estimation** | **Parameter tuning**<br>**Simulation** |

# Key takeaways

1. A Whole process for the big data processing is accomplished
   by making connected test benches and real time PHM platform

2. Newly developed equipment and platform helped to accelerate
   the maturity of our product - autonomous components like X-by-wire
   system

3. Further plan
   - Wider application to other area : robots and medical environment

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