

# DIAGSIGN

A POWERFUL TOOL FOR  
DETECTION, CLASSIFICATION AND PROGNOSTIC

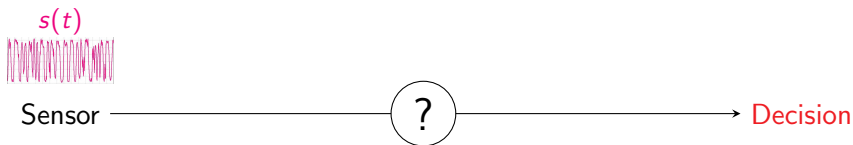


Link*Si*um  
technology transfer & startup building  
Grenoble Alpes

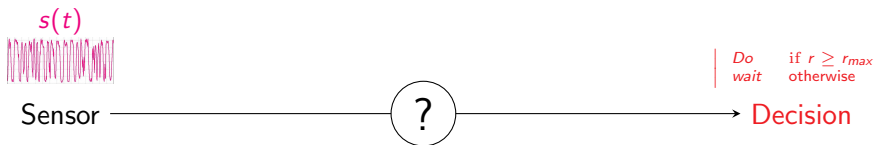
## OUTLINE

- ▶ DiagSign
- ▶ Examples
- ▶ Partners
- ▶ Next

## WHAT IS DIAGSIGN?



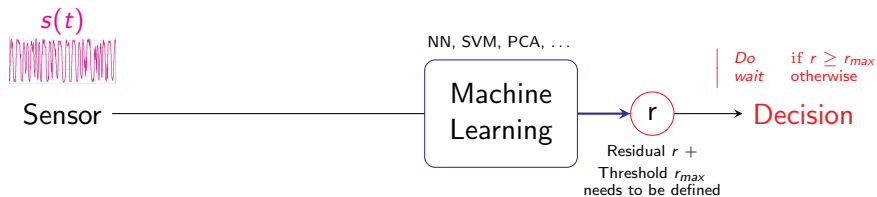
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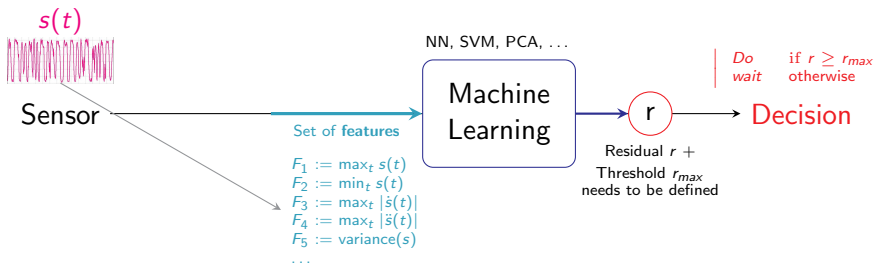
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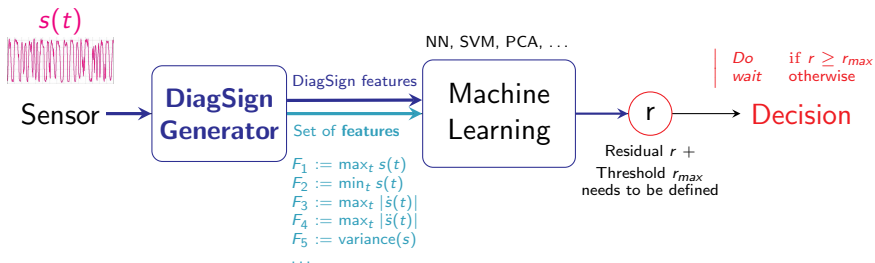
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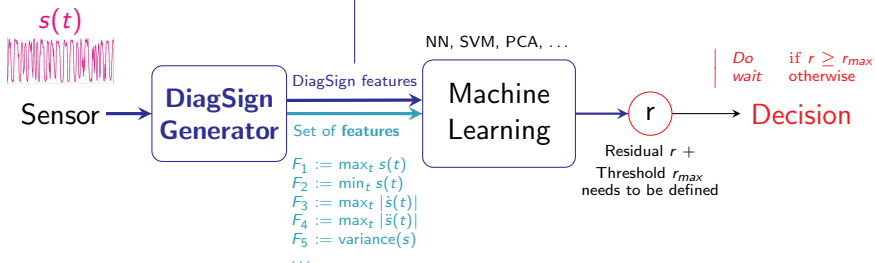
## WHAT IS DIAGSIGN?



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## DiagSign features are:

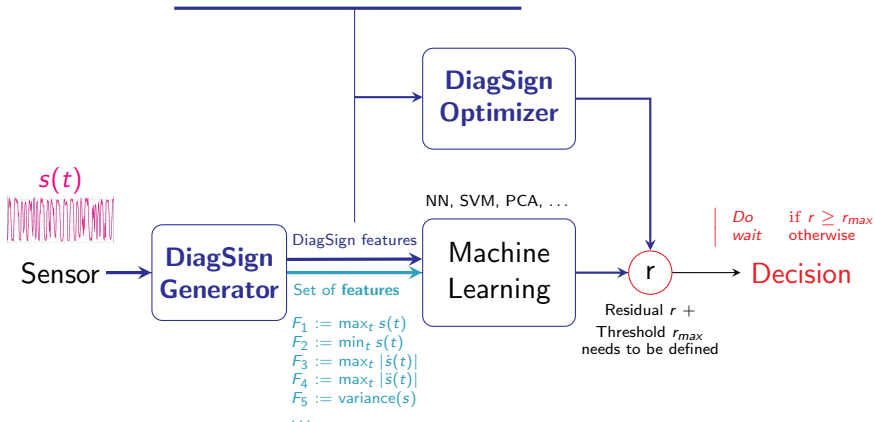
Infinitely rich  
 Highly discriminant  
 Easy to compute  
 Automatically generated  
 Proved to often outperform standard features



## WHAT IS DIAGSIGN?

## DiagSign features are:

Infinitely rich  
 Highly discriminant  
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## ESTIMATING REMAINING USEFUL LIFE (RUL) OF POWER CONTACTORS



**Product** Power contactor  
**Problem** Estimate the RUL  
**Sensor** Discharge current  
**Source** Schneider Electric Industrie

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Click on the link below to see a video showing a snapshot of the shut down current after an increasing number of cycles.

▶ see video

## ESTIMATING REMAINING USEFUL LIFE (RUL) OF POWER CONTACTORS



**Product** Power contactor  
**Problem** Estimate the RUL  
**Sensor** Discharge current  
**Source** Schneider Electric Industrie

### QUESTION:

Is there any property of this signal that increases monotonically with the contactor state-of-health?

Click on the link below to see a video showing a snapshot of the shut down current after an increasing number of cycles.

▶ see video



## ESTIMATING REMAINING USEFUL LIFE (RUL) OF POWER CONTACTORS

1. Generate  $n_F$  **DiagSign** features:

$$F_i( \text{Discharge current vs. Time} ) \quad i = 1, \dots, n_F$$


## ESTIMATING REMAINING USEFUL LIFE (RUL) OF POWER CONTACTORS

1. Generate  $n_F$  **DiagSign** features:

$$F_i( \text{  ) \quad i = 1, \dots, n_F$$

2. Compute during the first  $N_\ell$  cycles:

$$F_i^{max} = \max_{1 \leq n \leq N_\ell} F_i(s_n)$$

$$F_i^{min} = \min_{1 \leq n \leq N_\ell} F_i(s_n)$$

## ESTIMATING REMAINING USEFUL LIFE (RUL) OF POWER CONTACTORS

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3. Define the candidate residuals by:

$$r_i := \Psi \left( \frac{F_i - F_i^{min}}{F_i^{max} - F_i^{min}} \right) \quad i = 1, \dots, n_F$$

## ESTIMATING REMAINING USEFUL LIFE (RUL) OF POWER CONTACTORS

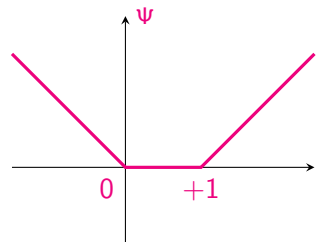
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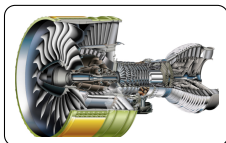
# ESTIMATING REMAINING USEFUL LIFE (RUL) OF POWER CONTACTORS

## Results

Click on the link below to see the application of the above methodology to design several aging indicators solving the above problem thanks to the powerful property generation feature of DiagSign.

▶ see video

## ESTIMATING REMAINING USEFUL LIFE (RUL) OF TURBOFANS



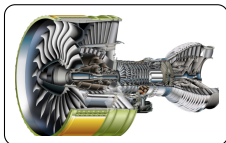
**Product** Turbofan

**Problem** Estimate the RUL

**Sensor** 24-dimensional measurement vector

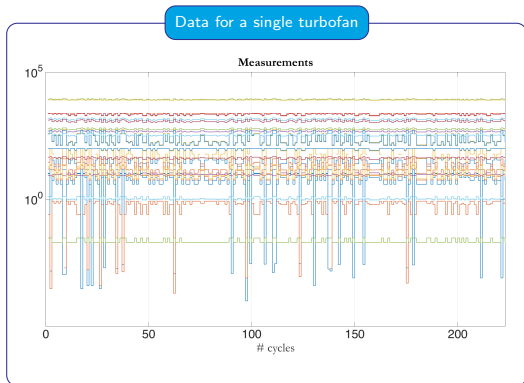
**Source** NASA center of PHM (Dataset 8)

## ESTIMATING REMAINING USEFUL LIFE (RUL) OF TURBOFANS

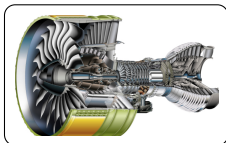


**Product** Turbofan  
**Problem** Estimate the RUL  
**Sensor** 24-dimensional measurement vector  
**Source** NASA center of PHM (Dataset 8)

Such 24-sensor data is given for 218 different turbofans are given until end-of-life.

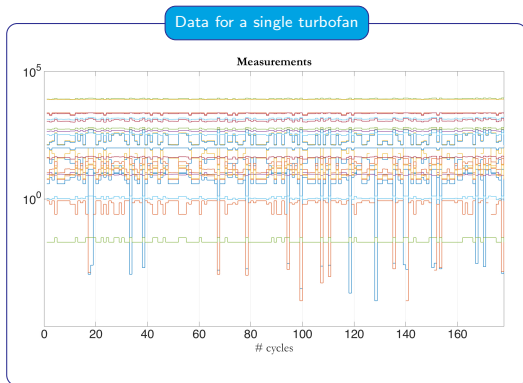


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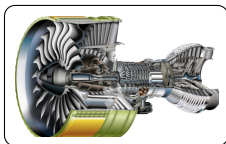


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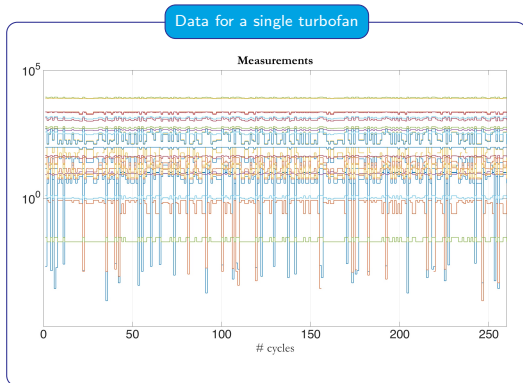


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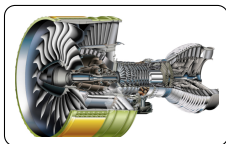


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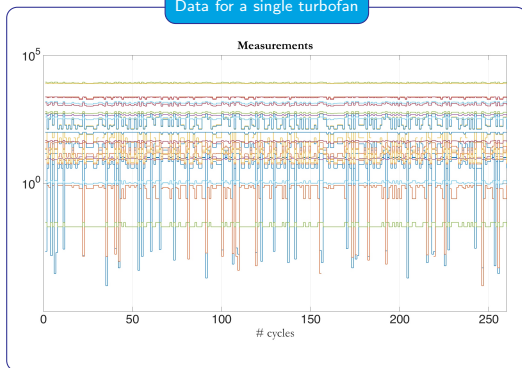
**Product** Turbofan  
**Problem** Estimate the RUL  
**Sensor** 24-dimensional measurement vector  
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Such 24-sensor data is given for 218 different turbofans are given until end-of-life.

QUESTION:

Is there any property of these signals that increases monotonically with the turbofan state-of-health?

Data for a single turbofan



# ESTIMATING REMAINING USEFUL LIFE (RUL) OF TURBOFANS



## ESTIMATING REMAINING USEFUL LIFE (RUL) OF TURBOFANS

Equipment independent common coefficients

 $i$ -th DiagSign featureMeasurement until instant  $t$ 

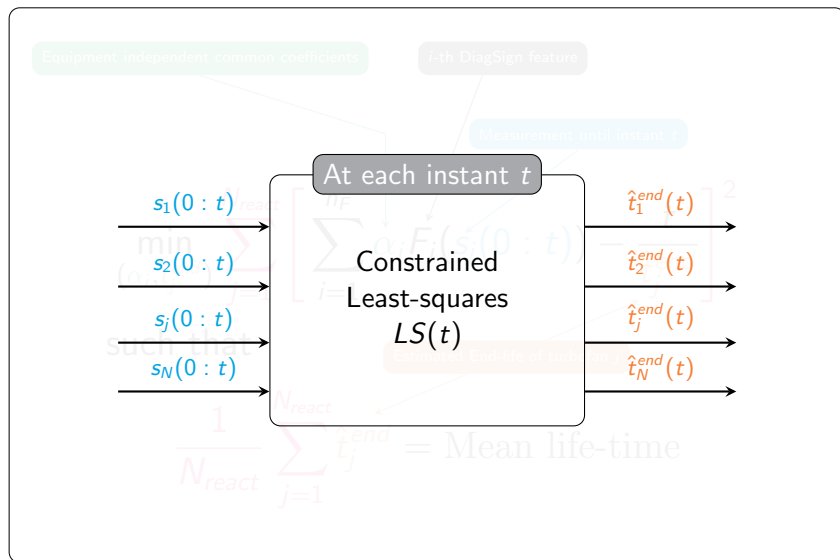
$$\min_{(\alpha_i, \hat{t}_j^{end})} \sum_{j=1}^{N_{react}} \left[ \sum_{i=1}^{n_F} \alpha_i F_i(s_j(0:t)) - \frac{t}{\hat{t}_j^{end}} \right]^2$$

such that

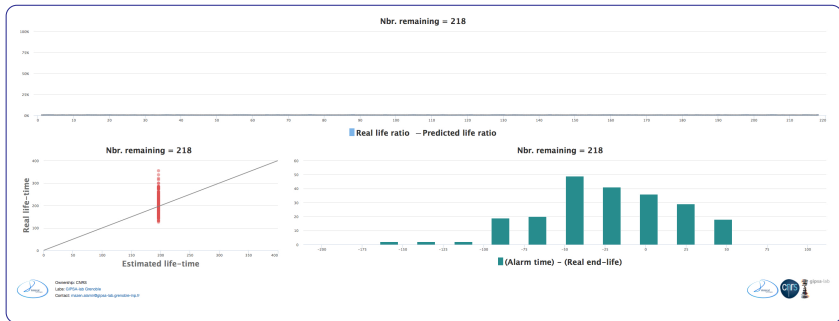
Estimated End-life of turbofan  $j$ 

$$\frac{1}{N_{react}} \sum_{j=1}^{N_{react}} \hat{t}_j^{end} = \text{Mean life-time}$$

## ESTIMATING REMAINING USEFUL LIFE (RUL) OF TURBOFANS



# ESTIMATING REMAINING USEFUL LIFE (RUL) OF TURBOFANS

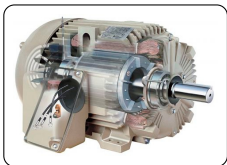


## ESTIMATING REMAINING USEFUL LIFE (RUL) OF TURBOFANS

Click on the link below to see the application of the above methodology the NASA 218 Turbofan database. This is an example of prognostic approach without a priori given learning data.

▶ see video

## STATE OF HEALTH ESTIMATION OF INDUCTION MOTORS



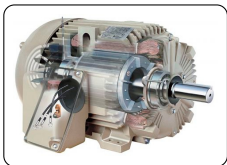
**Product** Induction Motor

**Problem** Estimate State of health

**Sensor** 10-dimensional measurement vector

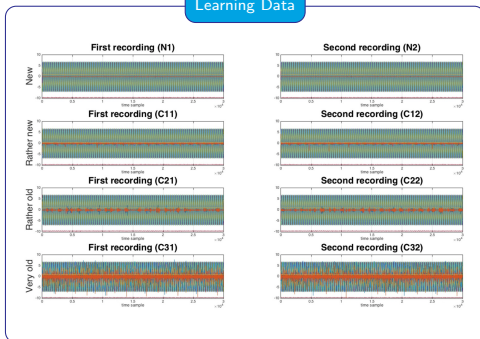
**Source** SCHNEIDER ELECTRIC INDUSTRIE

## STATE OF HEALTH ESTIMATION OF INDUCTION MOTORS

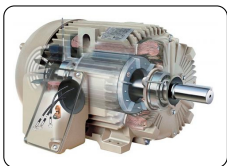


**Product** Induction Motor  
**Problem** Estimate State of health  
**Sensor** 10-dimensional measurement vector  
**Source** SCHNEIDER ELECTRIC INDUSTRIE

## Learning Data



## STATE OF HEALTH ESTIMATION OF INDUCTION MOTORS

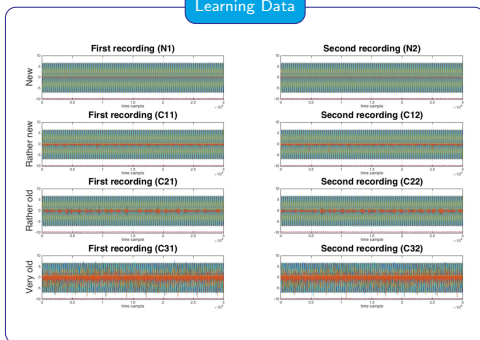


**Product** Induction Motor  
**Problem** Estimate State of health  
**Sensor** 10-dimensional measurement vector  
**Source** SCHNEIDER ELECTRIC INDUSTRIE

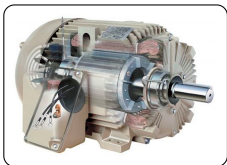
QUESTION:

How to use these measurement to define **discriminant residuals** that are tightly linked to the state-of-health?

## Learning Data



## STATE OF HEALTH ESTIMATION OF INDUCTION MOTORS



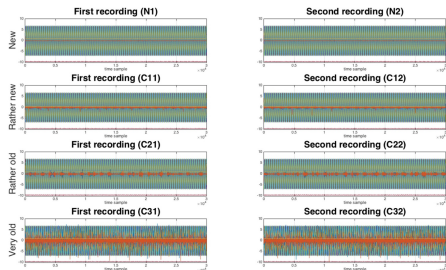
**Product** Induction Motor  
**Problem** Estimate State of health  
**Sensor** 10-dimensional measurement vector  
**Source** SCHNEIDER ELECTRIC INDUSTRIE

Example to show the easiness of use and the **high speed** prototyping capability of DIAGSIGN

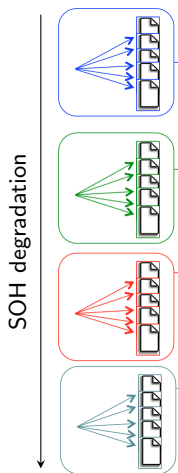
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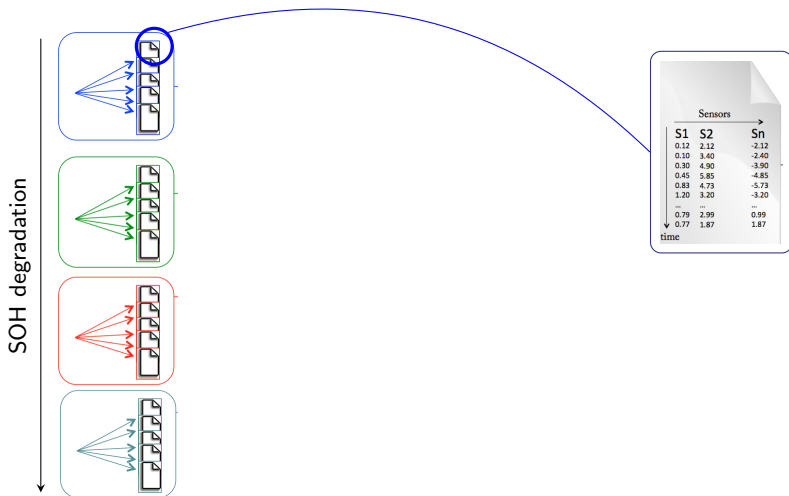
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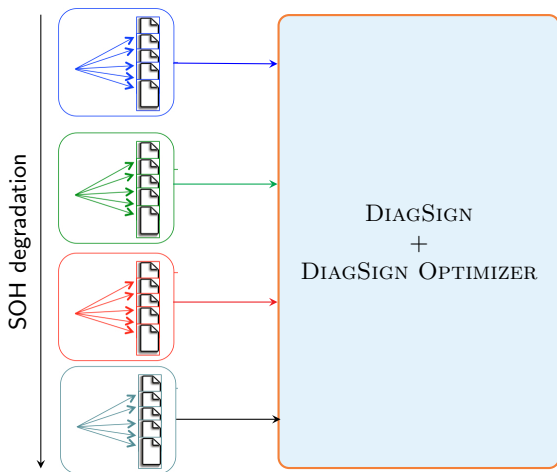
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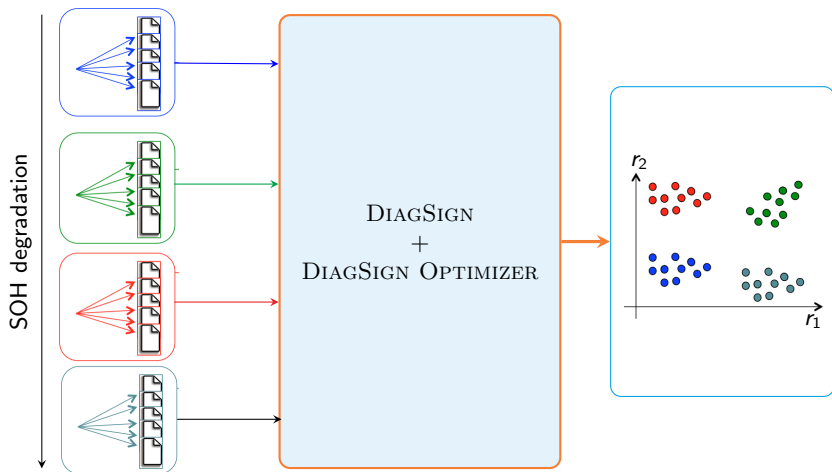
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## STATE OF HEALTH ESTIMATION OF INDUCTION MOTORS

The following video shows:

1. A general presentation of DiagSign [▶ see video](#)
2. How to prepare the data [▶ see video](#)
3. How to design a solution [▶ see video](#)

## DETECTION OF DOMESTIC EQUIPMENTS



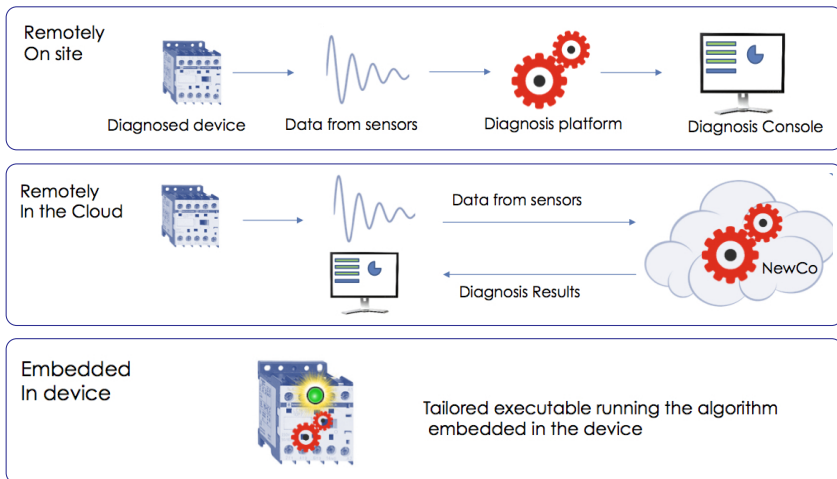
**Product** Domestic Equipment  
**Problem** Detection  
**Sensor** Switch-on Current Signal  
**Source** SCHNEIDER ELECTRIC







## DIAGSIGN POSSIBLE USE



## NEXT STEPS

1. Apps for open platforms (Blue-e, Predix, Schneider, ...)
2. Autonomous DiagSign-Based Web-server
3. Definition of product packaging:
  - 3.1 Versions per (Market/Product)
  - 3.2 Input/Output, protocol, ...
  - 3.3 Industrialization, commercial launch.