

Predictive Maintenance: Use of Advanced Sensors in Smart Industry Applications

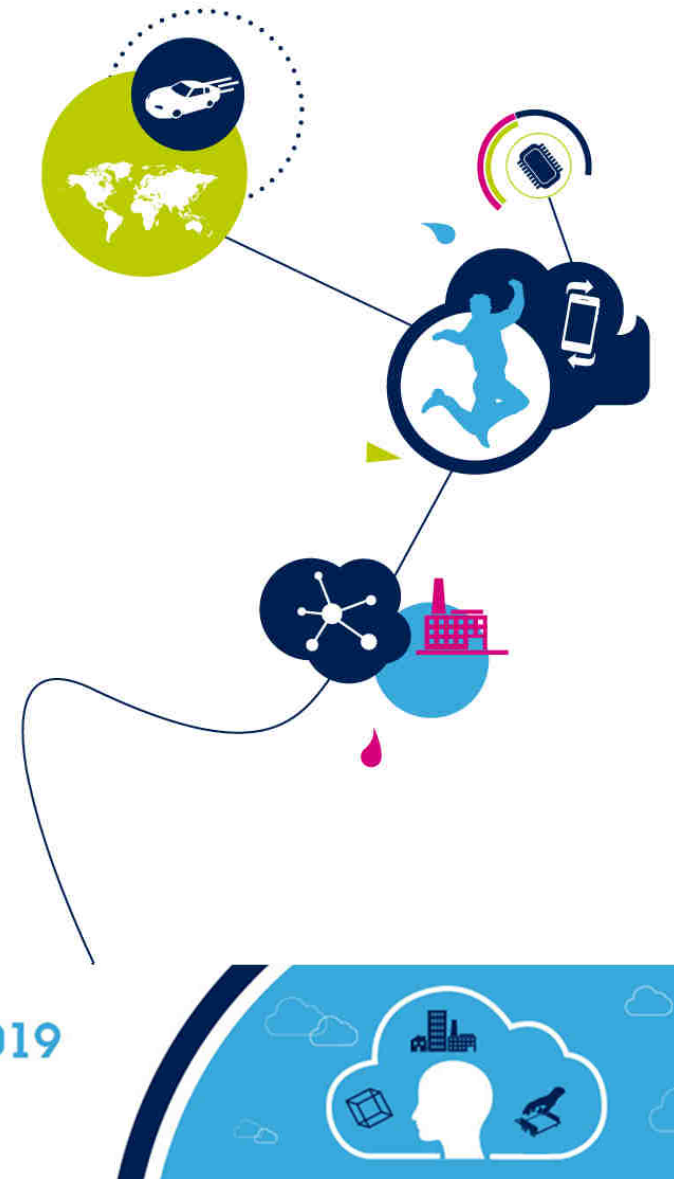
Ernesto Manuel CANTONE

AME IoT Marketing



Technology Tour 2019

Vancouver, BC | September 24



What is “Smart Industry”?

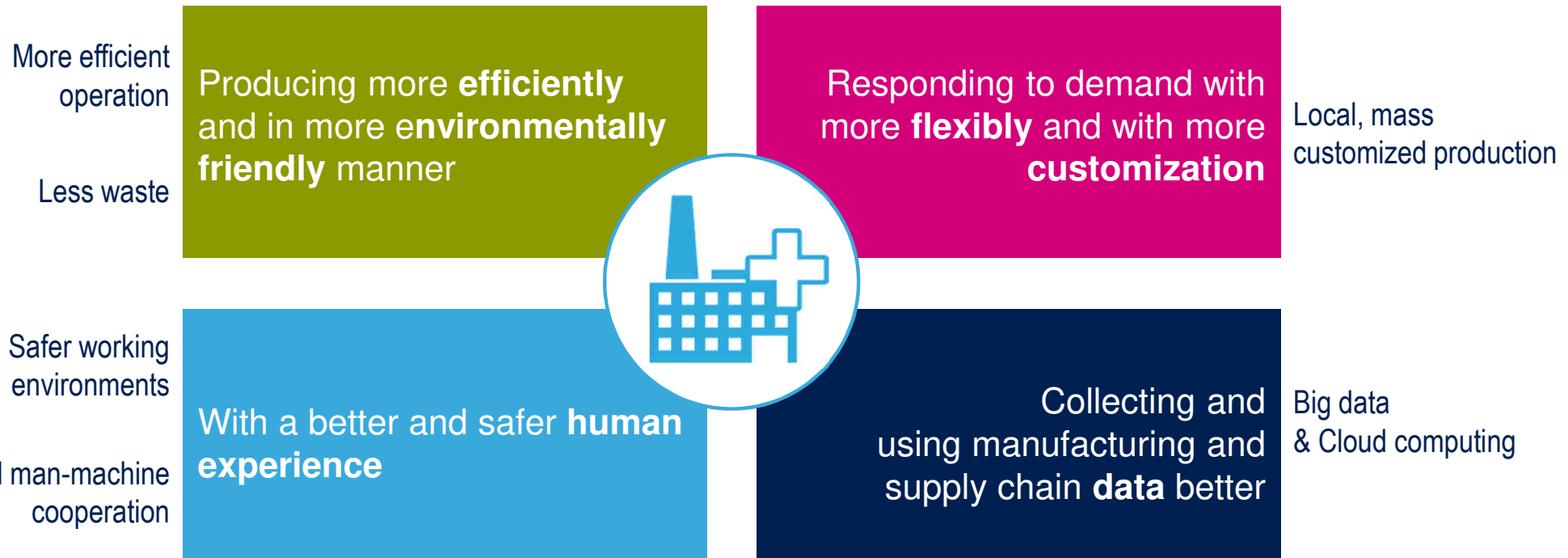
- Industry 1.0: Mechanization, Steam Power
- Industry 2.0: Mass Production, Assembly Line, Electrical Energy
- Industry 3.0: Automation, Computers and Electronics
- Industry 4.0: Cyber Physical Systems, IoT, Networks



Smart Industry

Scope and Goals

3



Predictive Maintenance

A Smart Industry hot topic

4

Maintenance is a set of actions to keep a machine working properly

Preventive Maintenance



Scheduled maintenance tasks based on a time schedule – don't care of the actual status of the equipment

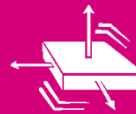
Advantages

- Simple to plan

Drawbacks

- Maintenance may happen too late (or too early)
- Maintenance may not be necessary

Condition Based Maintenance



Maintenance is based on the estimated conditions of the machine, typically monitored through inspection or sensors

Advantages

- Maintenance only takes place when necessary

Drawbacks

- Maintenance only after machine begins to show signs of failure

Predictive Maintenance



Maintenance actions predicted in advance based on monitoring combined with a dynamic predictive model for failure analysis

Advantages

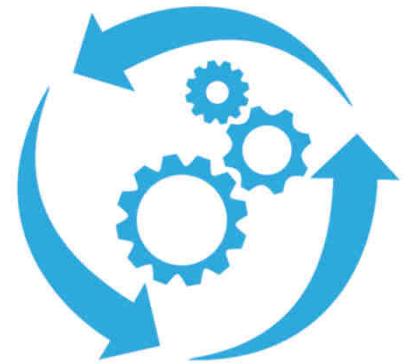
- Maintenance optimized for machine life and production efficiency

Drawbacks

- Requires complex overall system



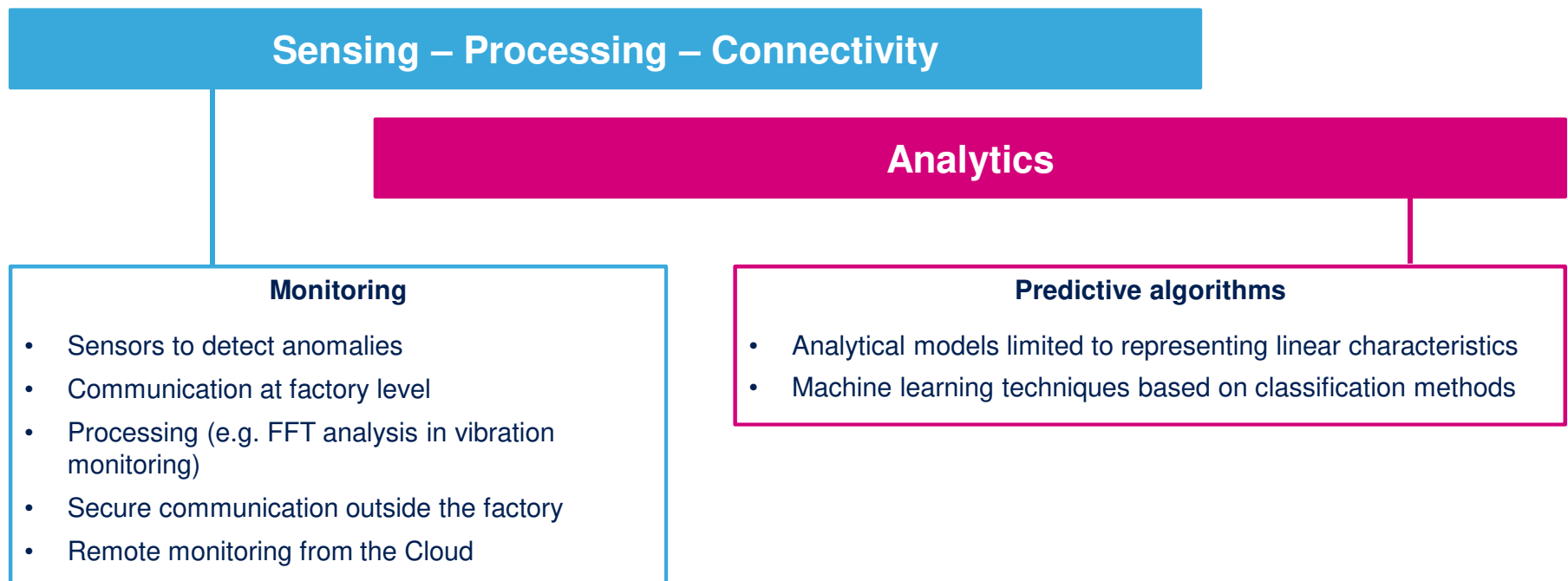
Predictive Maintenance Architecture



Architecture for Predictive Maintenance

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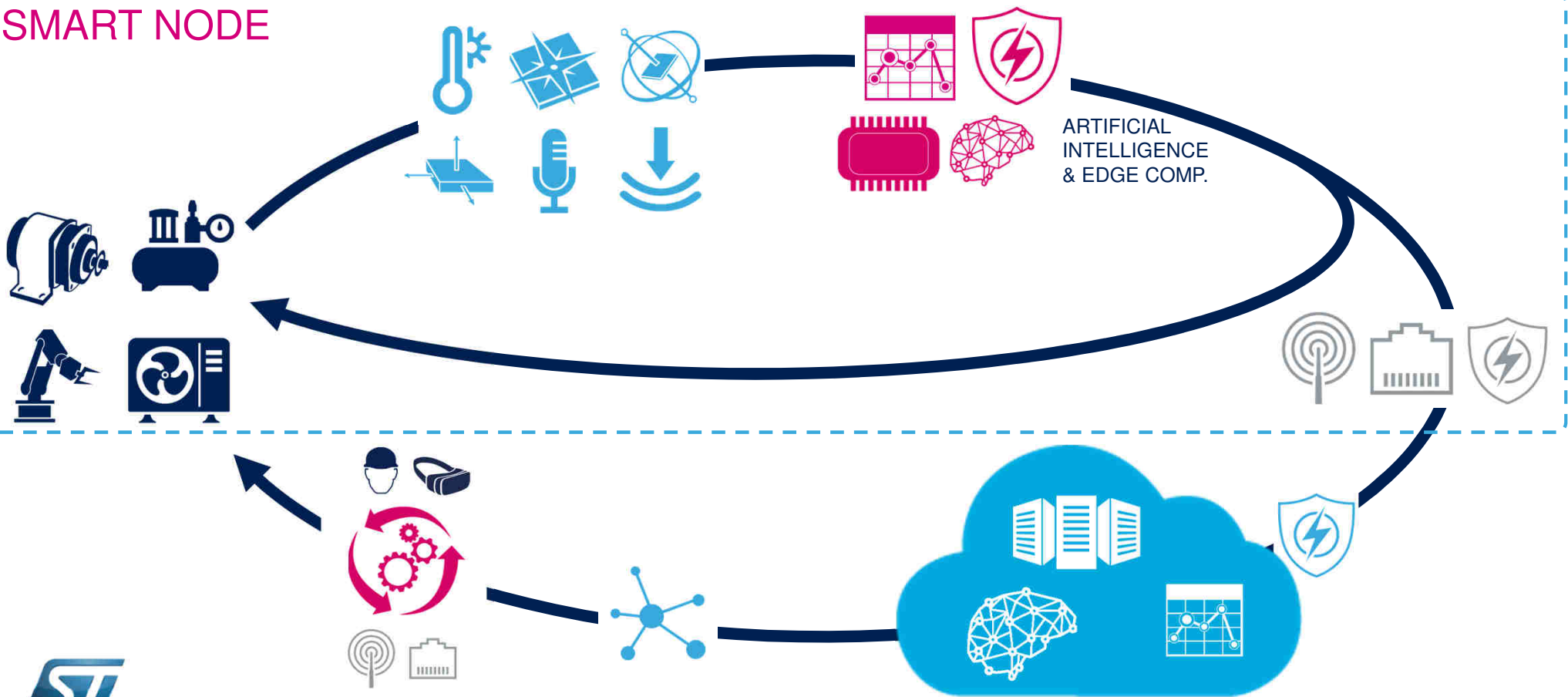
Low power / Scalable / Secure / Real-time



Smart Industry: Trends and Enablers

7

SMART NODE



Smart Industry: Trends and Enablers

8

SMART NODE





Sensors Technologies and Predictive Maintenance

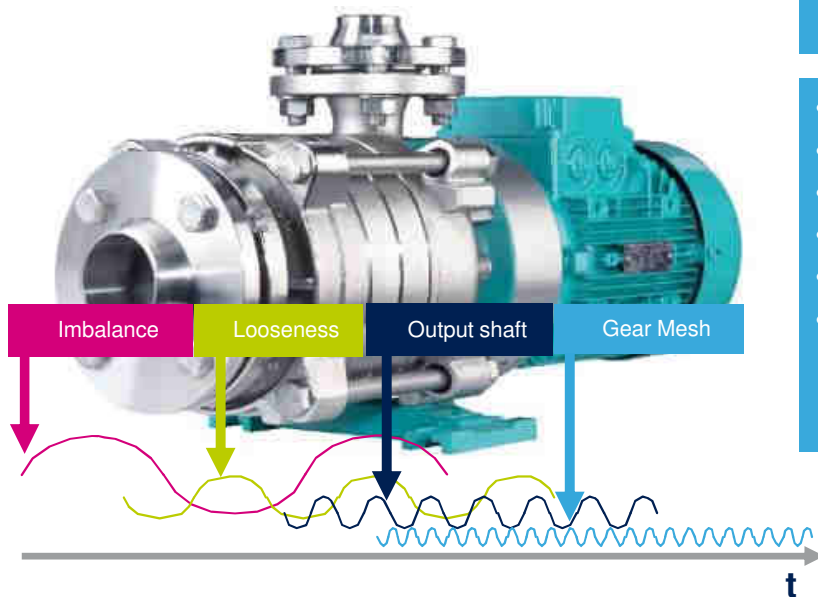


Monitoring of an Industrial Motor

Typical Use Case

10

Any parameters deviation is an indicator of potential failure



Mechanical vibration

- Displacement
- Speed
- Acceleration
- Acoustic noise
- Angular speed
- Torque

Thermal

- Winding temperature
- Bearing temperature

Electromagnetic

- Current
- Voltage
- Electrostatic discharge
- Magnetic flux – internal
- Magnetic flux – external

Monitoring and Predictive Maintenance

Use of Environmental Sensors

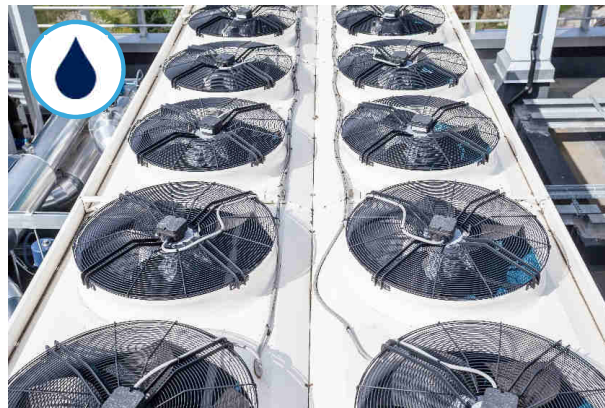
11

Key components for process and quality control in industrial applications

Pressure measurements for **"air management" systems**, which monitor the performance indicators and the different stages of the air compressors connected to the compressed-air supply grid



Humidity sensors are adopted in **HVAC systems** to control water vapor level or to help in regulating parameters such as air temperature and blowing speed



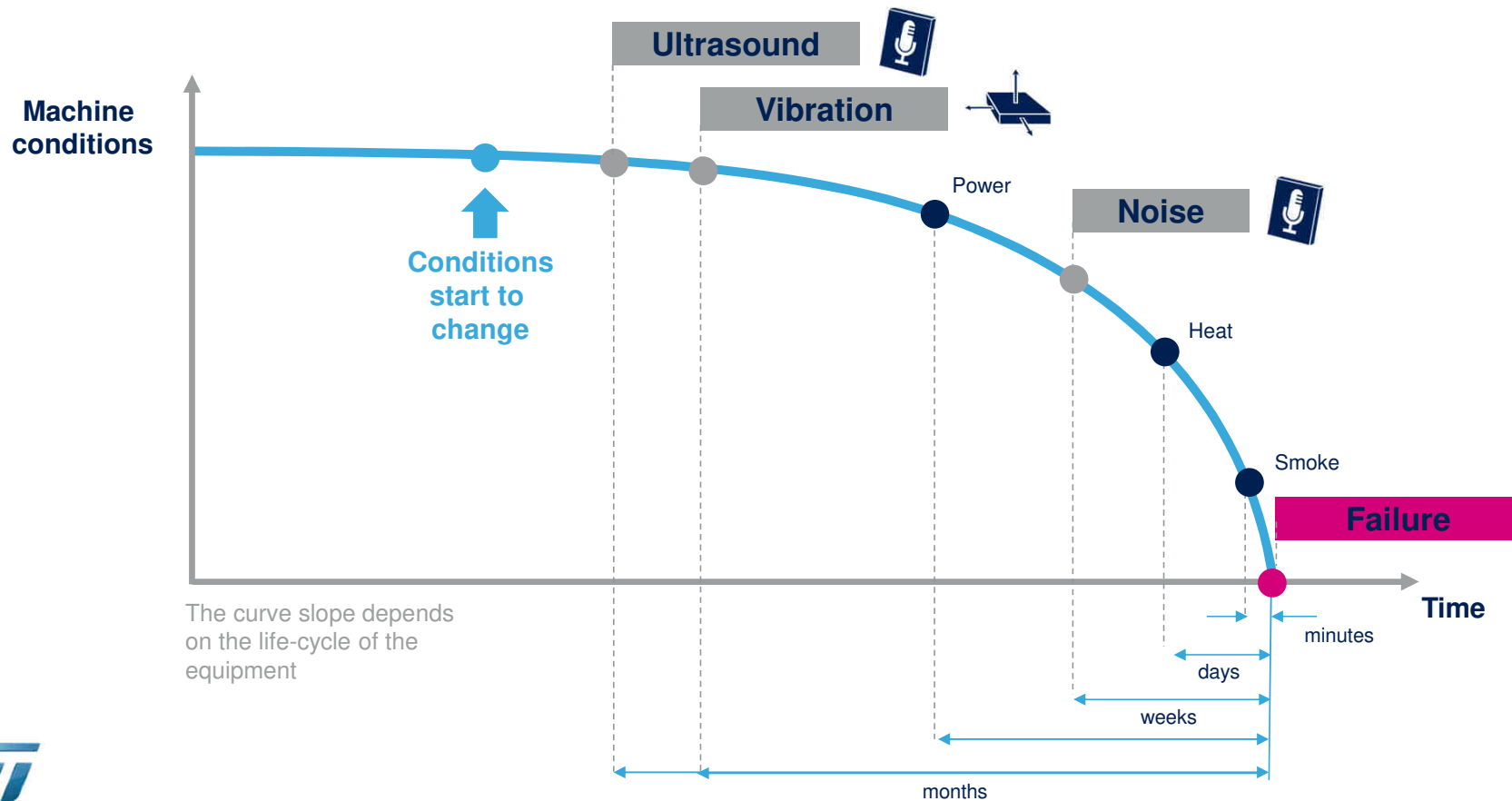
Measuring **operating temperatures** is crucial for detecting losses or improperly terminated electrical connections, overloading, defective contacts, phase imbalances and other electrical issues



Accelerometer and Microphone

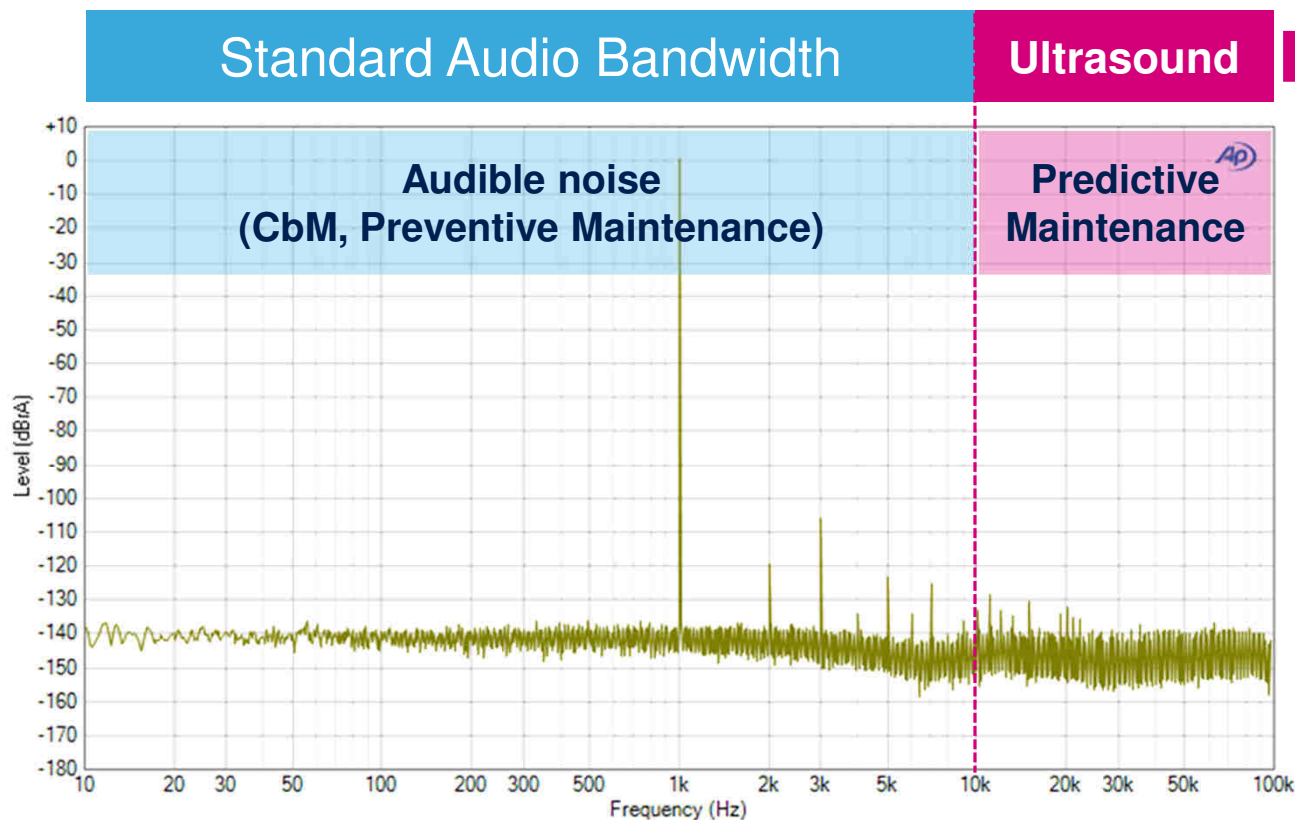
Distinctive sensors for Predictive Maintenance

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Standard Audio vs Ultrasound

13



Post processing analysis
Ultrasound frequencies
to **detect** and **classify** leaks

Most common maintenance applications

- Air Leak Detection of compressed air equipment
- Vibration monitor
- Compressor Valve Inspections
- Acoustic Lubrication
- Heat Exchanger and Condenser Leaks
- Hydraulic Systems
- Pump Cavitation

Embedded Analytics

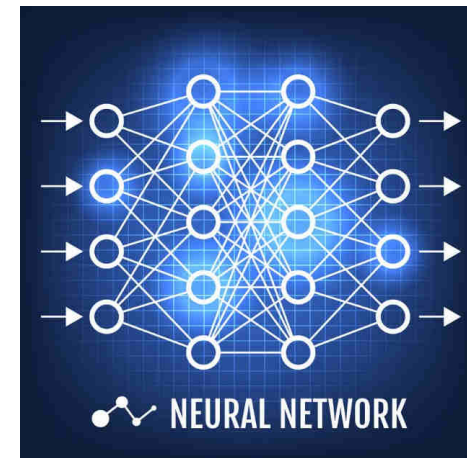
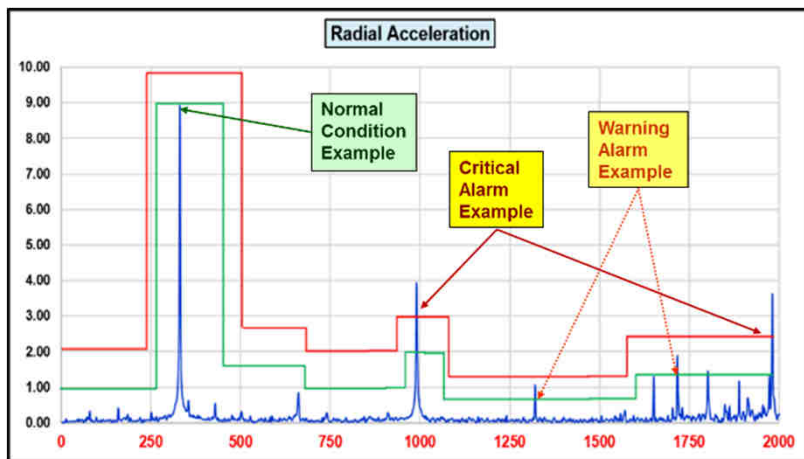
From FFT to AI

14

While FFT are widely used, Deep Learning and AI can enable new scenarios

- **Embedded FFT** analysis on the sensor can **isolate vibration**
- **Alarm** can be set according to specific threshold to detect potential defects

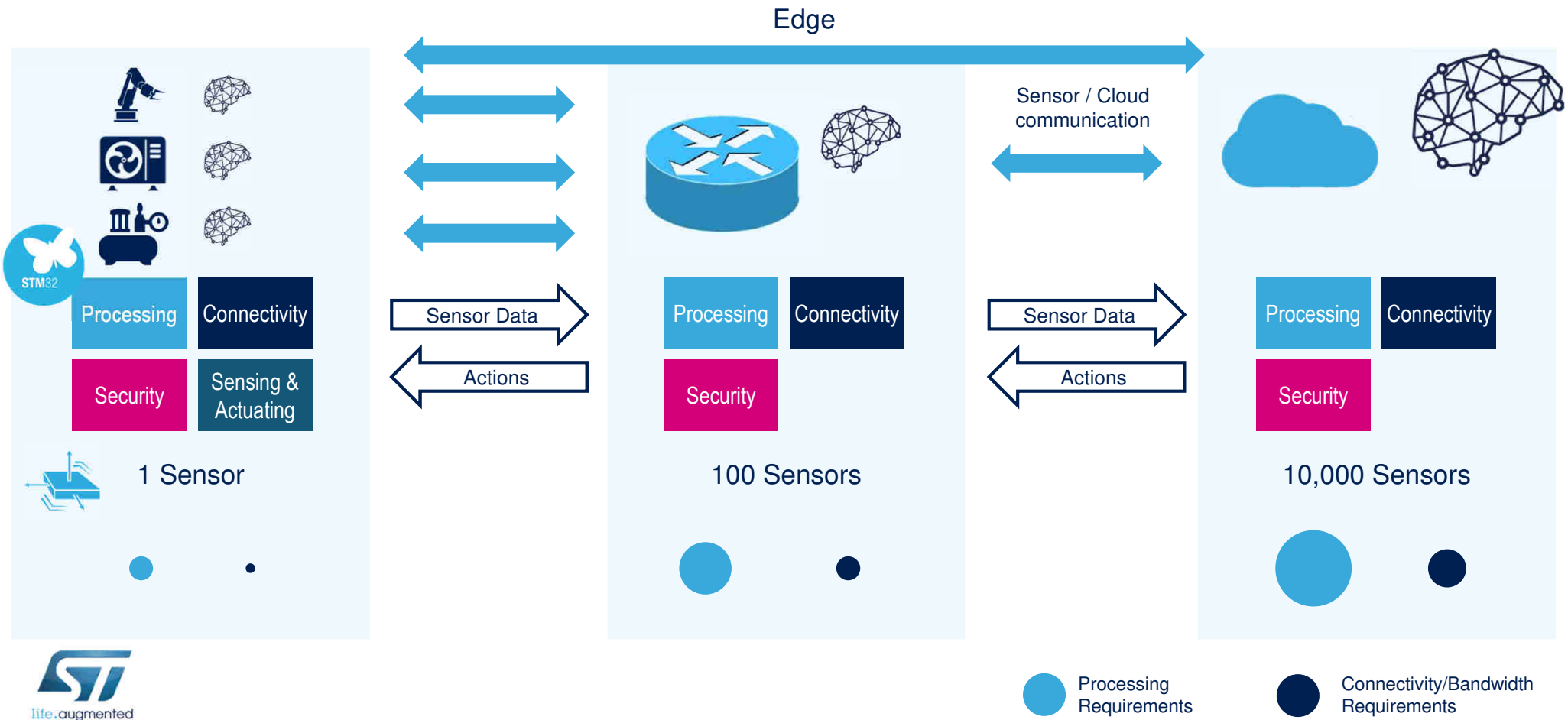
- **AI** improves the data analysis (vs FFT) hence the capabilities of failure prediction
- AI models, resulting of a “learning process” can be distilled down into a **Neural Network hosted into MCUs** or even down to new generation of smart sensors.



Predictive Maintenance

ST enables new approaches with a distributed architecture

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ST Enablers: Products and Solutions

Complete Ecosystem Offering by ST

17

All building blocks
for IoT devices

Microcontrollers



Secure solutions



Sensors & actuators



Connectivity solutions



Power management



Motor control



Analog components



Lower barriers for
developers getting started

Stackable boards
& modular SW



STM32 Nucleo Development
& Expansion boards

Form-factor boards



Discovery Kit IoT
Node



SensorTile.box



NFC Dynamic Tag
Sensor Node



BlueTile



SensorTile

Lower barriers from
prototyping to first product

Pre-integrated software
for vertical applications



Smart Things



Smart Home
& City



Smart Industry

Development ecosystem



Code generators



Prototyping
software



Development
environments



Artificial
Intelligence
toolbox



Debug
solutions



Simulation
and analysis tools



On-line
design tools

Enable product & service
commercialization

Integration of Cloud Provider SDKs



Microsoft Azure



Google Cloud



Partner Program and ST community



Partner
Program





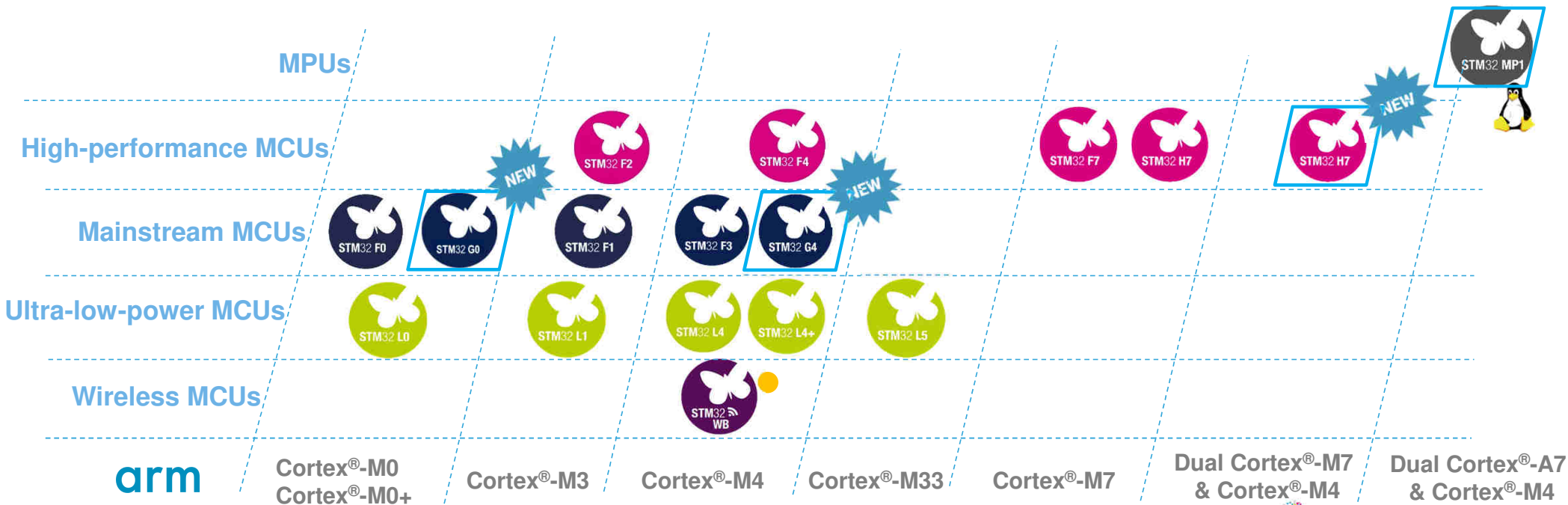
Microcontrollers and Microprocessors



Today - STM32 portfolio positioning

19

15 product series / More than 50 product lines



arm

Cortex®-M0
Cortex®-M0+

Cortex®-M3

Cortex®-M4

Cortex®-M33

Cortex®-M7

Dual Cortex®-M7
& Cortex®-M4

Dual Cortex®-A7
& Cortex®-M4



Note ● : Cortex-M0+ Radio Co-processor

More than
40,000 customers



STM32 Rolling Longevity Commitment

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Longevity commitment is renewed every year



starting January
1st 2019
→ Until 2029

• STM32F1	(launched in 2007)	22 years of commitment
• STM32L1	(launched in 2009)	20 years of commitment
• STM32F2	(launched in 2010)	19 years of commitment
• STM32F4	(launched in 2011)	18 years of commitment
• STM32F0	(launched in 2012)	17 years of commitment
• STM32F3	(launched in 2012)	17 years of commitment
• STM32L0	(launched in 2013)	16 years of commitment
• STM32F7	(launched in 2014)	15 years of commitment
• STM32L4	(launched in 2015)	14 years of commitment
• STM32L4+	(launched in 2016)	13 years of commitment
• STM32H7	(launched in 2016)	13 years of commitment
• STM32WB	(launched in 2018)	11 years of commitment
• STM32G0	(launched in 2018)	11 years of commitment

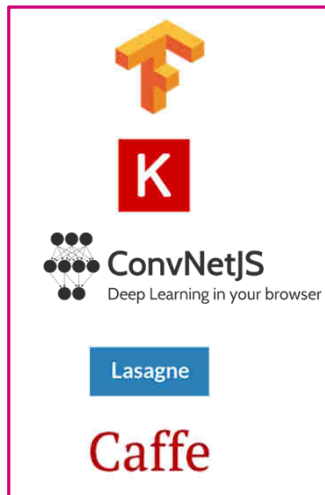
STM32 Artificial Intelligence

Neural Networks for STM32

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STM32Cube.AI SW tool allows our customers to innovate...

Off-the-shelf tools



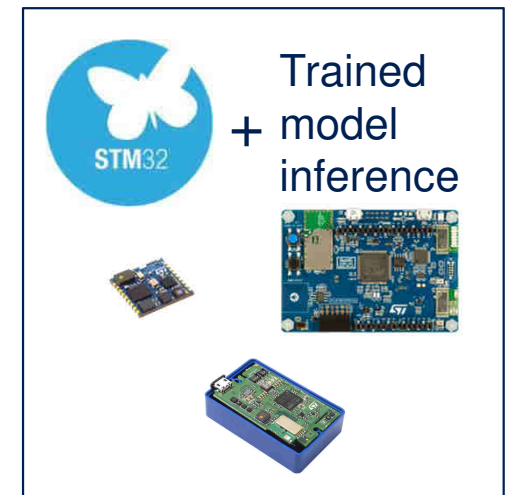
Pre-trained
Neural Network
Model from
major framework

ST SW tools



Optimized
Neural Network
code
automatically
generated for
STM32

ST AI solution



... bringing AI into the STM32 Portfolio



Sensors



A Broad Sensor Portfolio

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Market leading
#1 in the
Consumer
MEMS segment

 Motion sensors
40% share (#1)

 Pressure sensors
31% share (#2)



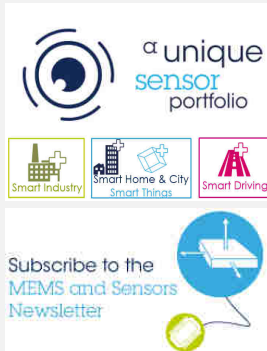
IHS Motion Sensors Market
Share Report 2017



New sensors
portfolio for
**Industrial
applications**



Broadest sensors
portfolio
addressing
Personal
Electronics,
Industrial &
Automotive



High stability
IMU for
Always ON
applications,
finite state
machine, w/
I3C Interface



MIPI I3C -- High
Performance
Interface &
Scalable solution

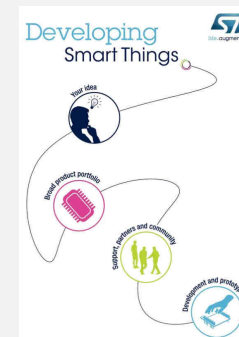


IMU = Inertial
Measurement Unit

Unique Pressure
Sensors portfolio:
Dust and **Water**
resistant
packages



Complete
system
solutions
and official
Partners for
**fast go-to-
market**



life.augmented



ST Industrial Sensors

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10-Year Product Longevity

Benefits

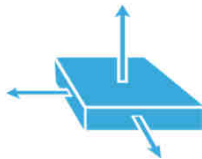
10-YEAR
LONGEVITY FROM
PRODUCT
INTRODUCTION
DATE

DESIGN AND
MANUFACTURING
FOR HIGHER
ROBUSTNESS &
PERFORMANCES

CALIBRATION &
TESTING FOR
HIGHER
ACCURACY &
QUALITY

EXTENDED
TEMPERATURE
RANGE AND
ENDURANCE TO
SHOCK AND
VIBRATION

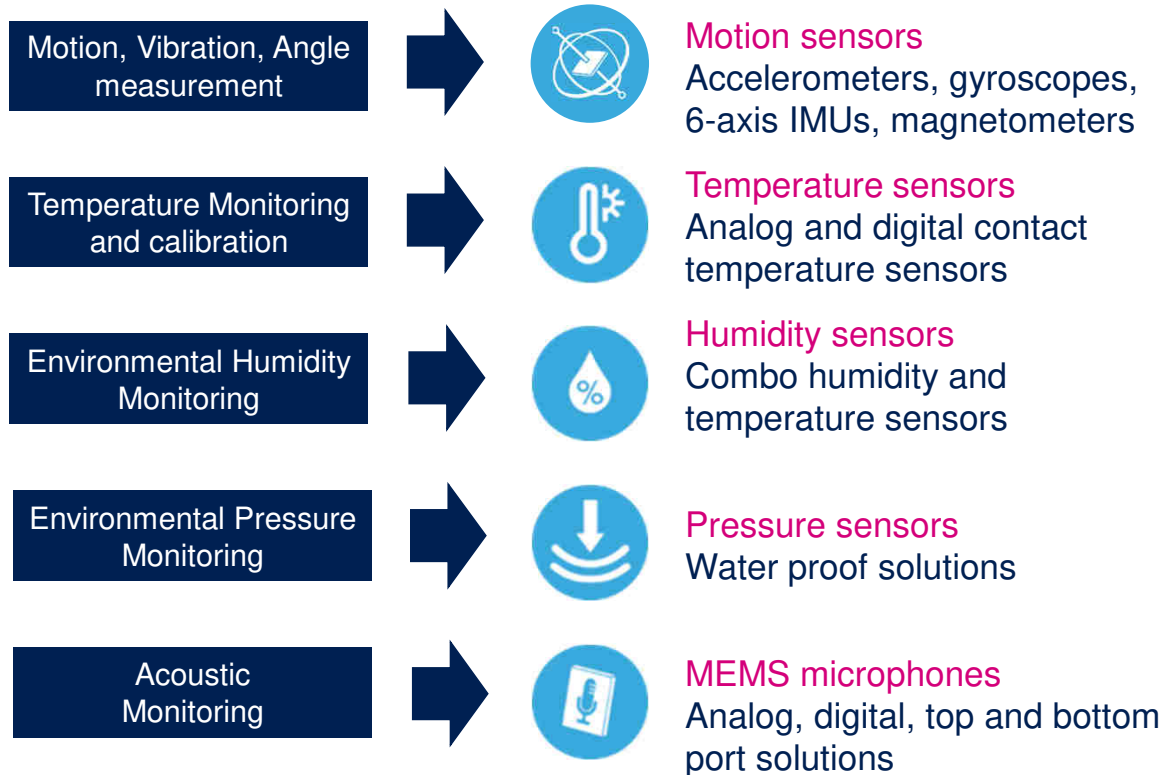
Growing Product Family



Motion Sensors and more

25

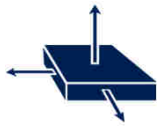
Humidity and temperature sensors as enablers for in-situ calibration





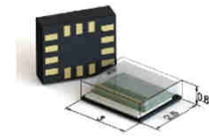
Motion MEMS Sensors for Smart Industry

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IIS3DWB*

Vibration Sensor - Ultra Wide Bandwidth



LGA-14 2.5x3 mm

COMING
SOON!

ES NOW

3D Vibration Sensor – 16g Full Scale
Digital Output
Ultra Wide Bandwidth (to 5 kHz)
Ultra Low Noise
Up to 105°C Operating Temp



IIS3DHHC/IIS2ICLH*

Inclinometer

High Resolution, Ultra Low Power



LGA-16 5x5 mm

Inclinometer – Digital Output
High Accuracy (<0.5° over Temp. and Time)
Ultra Low Current consumption: 400 uA



IIS2DH/IIS2DLPC

Accelerometer - Wide Bandwidth, Ultra-low-power



LGA-12 2x2 mm

3D Accelerometer – Digital Output
Wide Bandwidth (up to 2.3 kHz)
Ultra Low Power – Ultra Compact



IIS2MDC

Magnetometer Low-Noise, Low Power



LGA-12 2x2 mm

3D Magnetometer – Digital Output
AMR Technology - up to 50 Gauss Full Scale
Ultra Low Noise, Low Power



(*)Contact Sales
for availability



Motion MEMS Sensors for Smart Industry

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ISM330DLC

Combo accelerometer & Gyroscope
Wide Bandwidth



LGA-14 2.5x3 mm

3D accelerometer with full scale up to $\pm 16g$
3D gyroscope with full scale up to ± 2000 dps
Accelerometer with Wide Bandwidth (up to 3 kHz)
Ultra Low Power and Smart Features



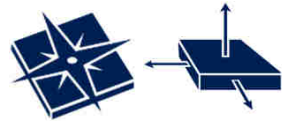
ISM330DHCX

Combo accelerometer & Gyroscope
Wide Bandwidth



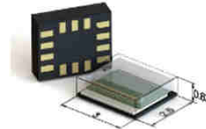
LGA-14 2.5x3 mm

3D accelerometer with full scale up to $\pm 16g$
3D gyroscope with full scale up to ± 4000 dps
Accelerometer with Wide Bandwidth (up to 3 kHz)
Ultra Low Power and Machine Learning Core



ISM303DAC

E-Compass
Combo Accelerometer and Magnetometer



LGA-12 2x2 mm

3D Accelerometer – Digital Output
3D Magnetometer – Digital Output
 $\pm 2/\pm 4/\pm 8/\pm 16$ g selectable acceleration full scales
Up to ± 50 gauss magnetic dynamic range

Environmental Sensors for Smart Industry

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LPS22HH

Pressure Sensor – High Accuracy – Compact Size



HLGA-10L 2x2x0.76 mm

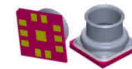
Absolute Pressure Sensor
260 to 1260 hPa Range - Digital Output
High Accuracy (± 0.75 hPa)
Low noise (0.75 Pa RMS)
Ultra Compact full molded package

LPS33W/LPS27HHW

Pressure Sensor – Water Resistant



3.3x3.3x2.9 mm



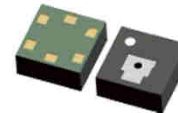
2.7 x 2.7 x 1.7 mm

Absolute Pressure Sensor
260 to 1260 hPa Range - Digital Output
High Accuracy (± 2.5 hPa / ± 0.5 hPa)
Low noise (0.8 Pa / 0.7 Pa)
Water resistant up to 10 ATM



HTS221

Humidity and Temp Sensor – High Accuracy



HLGA-6 2x2x0.9 mm

Humidity and Temperature Sensor
Digital Output
High Accuracy:
• Humidity: ± 3.5 %RH
• Temperature: ± 0.5 deg
Low Power



STTS751

Digital Temperature Sensor

UDFN-6L or SOT23-6L

Accuracy ± 1.0 °C ; Programmable resolution

LM235 – STLM20

Analog Temperature Sensor

TO92/SO8

Accuracy ± 1.0 °C ; Op. Temp up to 150 °C

STTS22H*

Digital Temperature Sensor – High Accuracy



UDFN-6L 2.0 x 2.0 x 0.5mm

High Accuracy:
• Temperature: ± 0.2 deg
Low Power

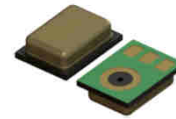


MEMS Microphones for Smart Industry

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MP23ABS1
Analog Differential Microphone

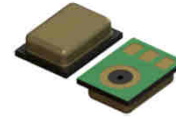


3.35x2.5x0.98 mm

Bottom Port Microphone
Analog Differential Output
Wide Acoustic Bandwidth (up to 80 kHz)
Wide Dynamic Range (AOP up to 135 dBSPL)



MP23DB01HP*
Digital Bottom Port Microphone



3.35x2.5x0.98 mm

Bottom Port Microphone
Multi mode PDM Output
Wide Dynamic Range (AOP up to 137 dBSPL)
Hi SNR 65.5dB



IMP34DT05
Digital Top Port Microphone



3x4x1 mm

Top Port Microphone
Digital Output
Wide dynamic range (AOP up to 122 dBSPL)
-26dBFS $\pm$ 3 dB sensitivity

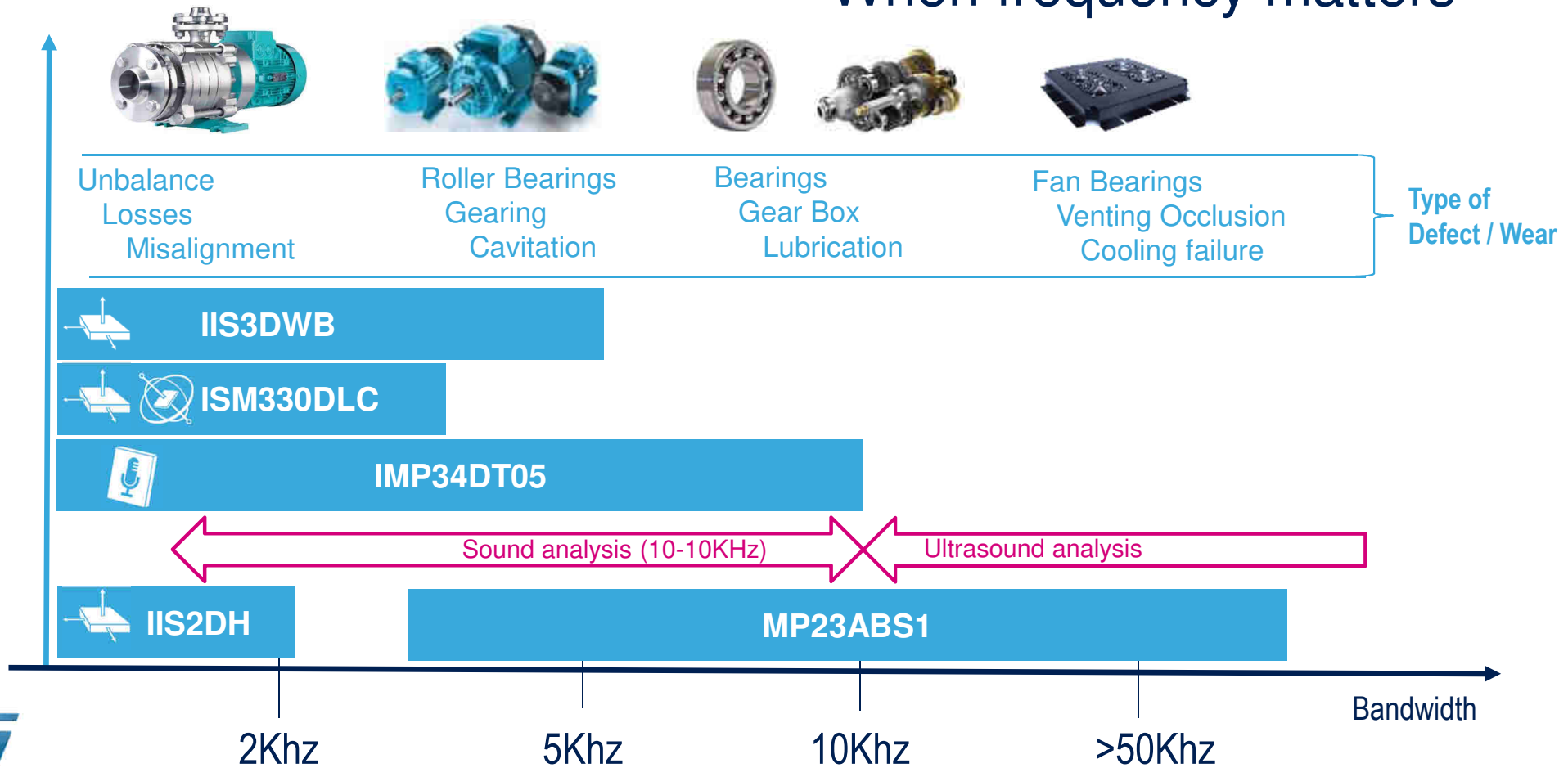


(*)Contact Sales
for availability

Accelerometer and Microphone

When frequency matters

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Connectivity

Connectivity Options

Match the needs of Industrial Environments



Wired Connectivity

P2p, Industrial Fieldbus, Industrial Ethernet



And more ..

Any Industrial protocol for any STM32



Wireless Connectivity

Retrofit, flexibility of technologies and protocols, interoperability with Ethernet and Cloud





Development Kits

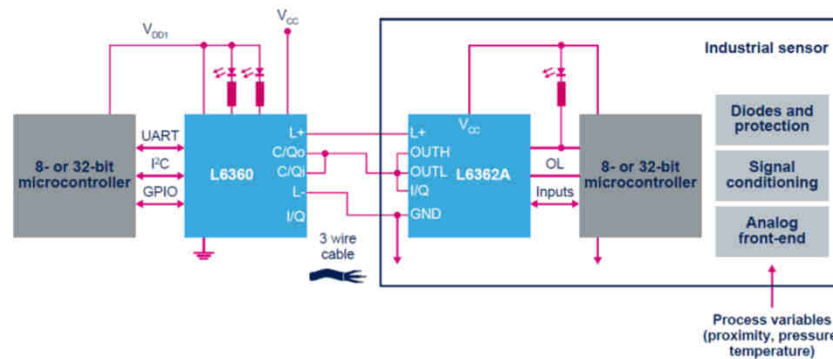
IO-Link: from ICs to a wide offering of solutions

L6360

Single port Master PHY for IO-Link and SIO mode



- Supply voltage up to 32.5 V
- Up to 200 mW max. power dissipation
- Over-voltage (>36 V) and over-temperature protection
- ESD protection according IEC 61000-4-2
- Conform to IEC 61000-4-4, IEC 61000-4-5



L6362A

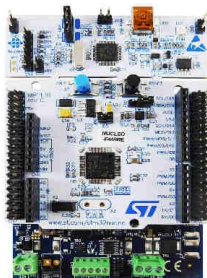
Transceiver Device for IO-Link and SIO mode



- Configurable Output stage: High Side, Low Side, Push-Pull
- Reverse Polarity and Surge protections
- Up to 400 mA output Current with Overload and Cut-OFF protections
- 5 V or 3.3 V / 8 mA selectable linear regulator

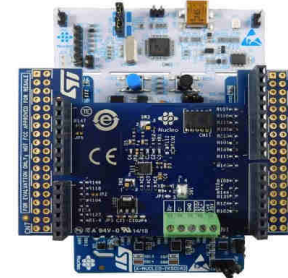
Visit st.com for the full list of IO-Link solutions

Based on **Master** L6360



The **P-NUCLEO-IOM01M1** is a STM32 Nucleo pack for IO-Link Master with IO-Link v1.1 PHY and stack

Based on **Device** L6362A



The **P-NUCLEO-IOD01A1** is a STM32 Nucleo pack for IO-Link Device fully compatible with IO-Link v1.1 PHY and stack

From Sensor to Fieldbus

Predictive maintenance kit with sensors and IO-Link capability

Use cases



Motors



Equipment



Environment



AI ready

Sensing



Vibration and Environmental

- **ISM330DLC** 6-Axis digital MEMS axel + gyro (*)
- **MP34DT05-A** Microphone
- **LPS22HB** MEMS Pressure sensor
- **HTS221** Humidity & Temperature Sensors

Connectivity



Wired

- **L6362A** IO-Link communication transceiver device IC

Processing



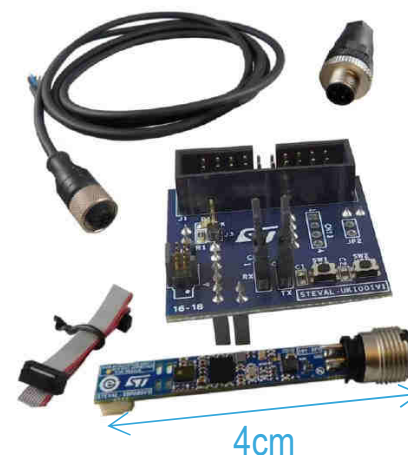
Local Processing

- **STM32F469AI** 32-bit ARM Cortex-M4 microcontroller



**ISM330DLC bandwidth is 3 kHz, coming soon replacement with IIS3DWB (5 kHz)*

STEVAL-BFA001V1B



Main Features

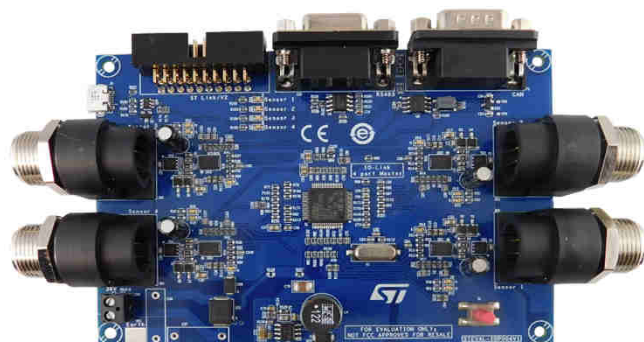
- Optimized form factor for industrial M12 connector
- Embedded algorithm for sensors data analysis, detecting anomalies like unbalance, misalignment, or bad equipment condition
- Logging of worst working condition events

STEVAL-IDP004V1

Applications with 2+ nodes to be monitored

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Adapter RS485 / USB
Optional USB



STEVAL-IDP004V1

Also available the firmware package [STSW-IO-LINK](#)



Axel spectrum



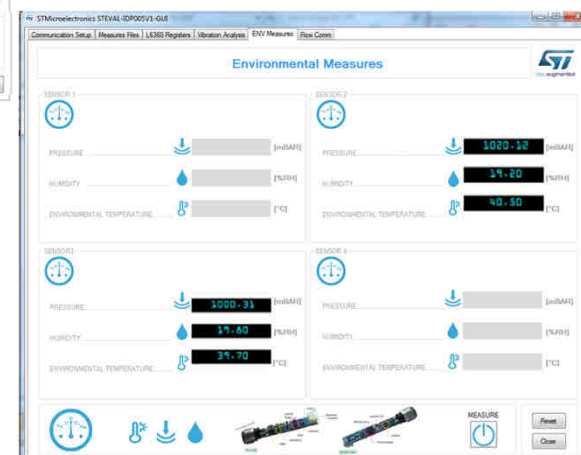
STEVAL-BFA001V1B

Download the *condition monitoring_iol* fw from the STSW-BFA001V1 Demonstration folder

Axel Peak

Speed RMS

P, T, H parameters



STM32 Cloud Connected IoT Nodes

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• X-CUBE-AWS

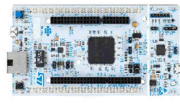
- Cloud Connector: libraries and application examples

• FP-CLD-AWS1

- Companion AWS-based web dashboard

• Amazon FreeRTOS

- STM32's port of the Amazon operating system for microcontrollers that makes small, low-power edge devices easy to program, deploy, secure, connect, and manage.



NUCLEO-H743ZI



B-L475E-IOT01A



32F413HDiscovery



32F769IDiscovery



• X-CUBE-AZURE

- Cloud Connector: set of libraries and application examples

• FP-CLD-AZURE1

- Companion Dashboard with full support for Azure device management primitives and sample implementation for firmware update over the air (FOTA).



NUCLEO-F429ZI



SensorTile.box



B-L475E-IOT01A



32F413HDiscovery



32F769IDiscovery

• X-CUBE-WATSON

- Cloud Connector: libraries and application examples
- IBM Quickstart and Registered Mode support.

• FP-CLD-WATSON1

- Includes pre-integrated FFT algorithms for the processing of accelerometer



NUCLEO-F429ZI



B-L475E-IOT01A



32F413HDiscovery



32F769IDiscovery



• X-CUBE-GCP

- Cloud Connector: set of libraries and application examples, MCU acting as end devices.



B-L475E-IOT01A



32F413HDiscovery



32F769IDiscovery

• X-CUBE-CLD-GEN

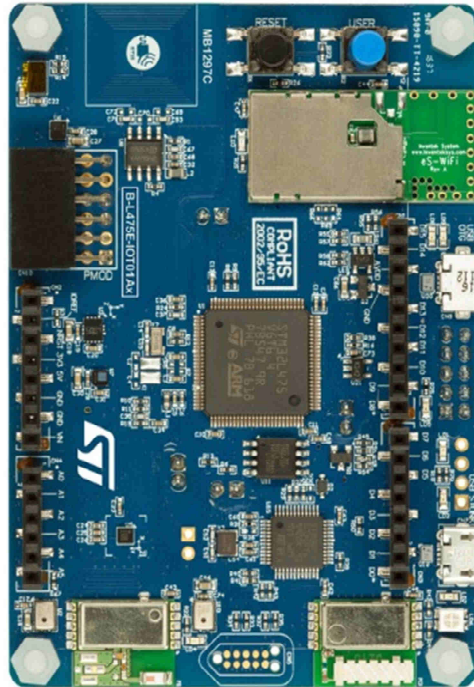
- Cloud Connector: libraries and application examples

STM32L475 Discovery Kit IoT Node

B-L475E-IOT01A

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Cloud Connectivity Out-of-the-Box



- Ultra-low-power STM32L475 Arm® Cortex®-M4, 1 Mbyte Flash memory, 128 Kbytes of SRAM
- Firmware example for IoT end node connected with Wi-Fi®
 - 802.11 b/g/n compliant Wi-Fi® module
- Low Power Communications
 - Bluetooth 4.1, Sub-GHz, Dynamic NFC Tag
- Multiway Sensing
 - 3D Accelerometer, 3D Gyroscope, 3D Magnetometer, Temperature/Humidity, Pressure, Time of Flight, Microphones

Alpha engagements

STWIN SensorTile Wireless Industrial Node

STEVAL-STWINKT1

Use cases



Motors



Equipment



Environment



Sensing

Industrial grade sensors for

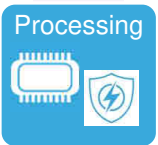
- Vibration analysis
- Sound Emission up to 80 kHz
- Environmental



Connectivity

Embedded Wireless and Extension

- BLE, WiFi (Inventek)
- Modular expansion: LTE, LoRa, Industrial Ethernet



Processing

Local Processing & Security

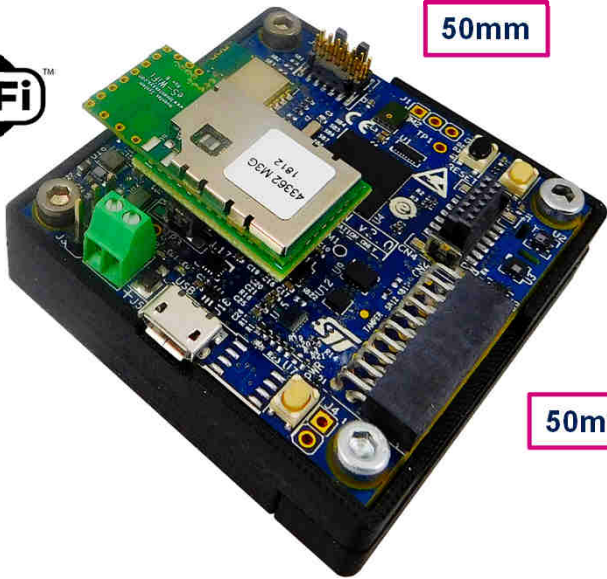
- ARM® Cortex®-M4 STM32L4R9
- Secure Element STSAFE on request



Power

Power Management

- Li-Ion linear battery charger with load switches
- Miniaturized synchronous step down converter with high efficiency conversion



AI ready

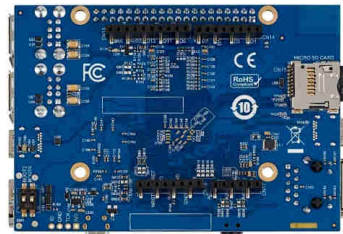
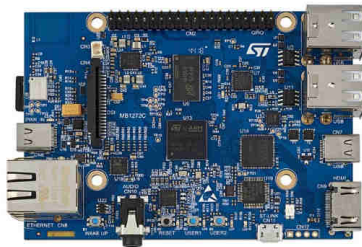


STM32MP157C MPU Discovery Kit

STM32MP157C-DK2

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AWS IoT Greengrass v1.8.0 Certified



- STM32MP157 Arm®-based dual Cortex®-A7 32 bits + Cortex®-M4 32 bits MPU in TFBGA361 package
 - ST PMIC STPMIC1
 - 4-Gbit DDR3L, 16 bits, 533 MHz
 - 1-Gbps Ethernet (RGMII) compliant with IEEE-802.3ab
 - USB OTG HS
 - Audio codec
 - 4 user LEDs
- Ethernet RJ454, USB Type-A, USB Type-C™, DRPMIPI DSISM, HDMI®, headset jack including analog microphone input, micro SD™ card
- GPIO expansion connector
 - Raspberry Pi® shields capability
 - ARDUINO® Uno V3 expansion connectors



Sensor to Cloud

From Dev Kits to End to End solution

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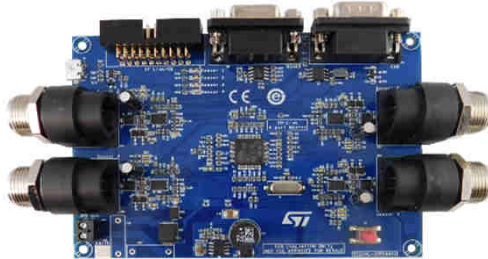
STEVAL-BFA001V1B

Stand Alone Sensor Node



STEVAL-IDP004V1

Expand your capabilities up to 4 Nodes



STM32MP157C-DK2

Discovery Kit



B-L475E-IOT01A

Discovery Kit IoT Node

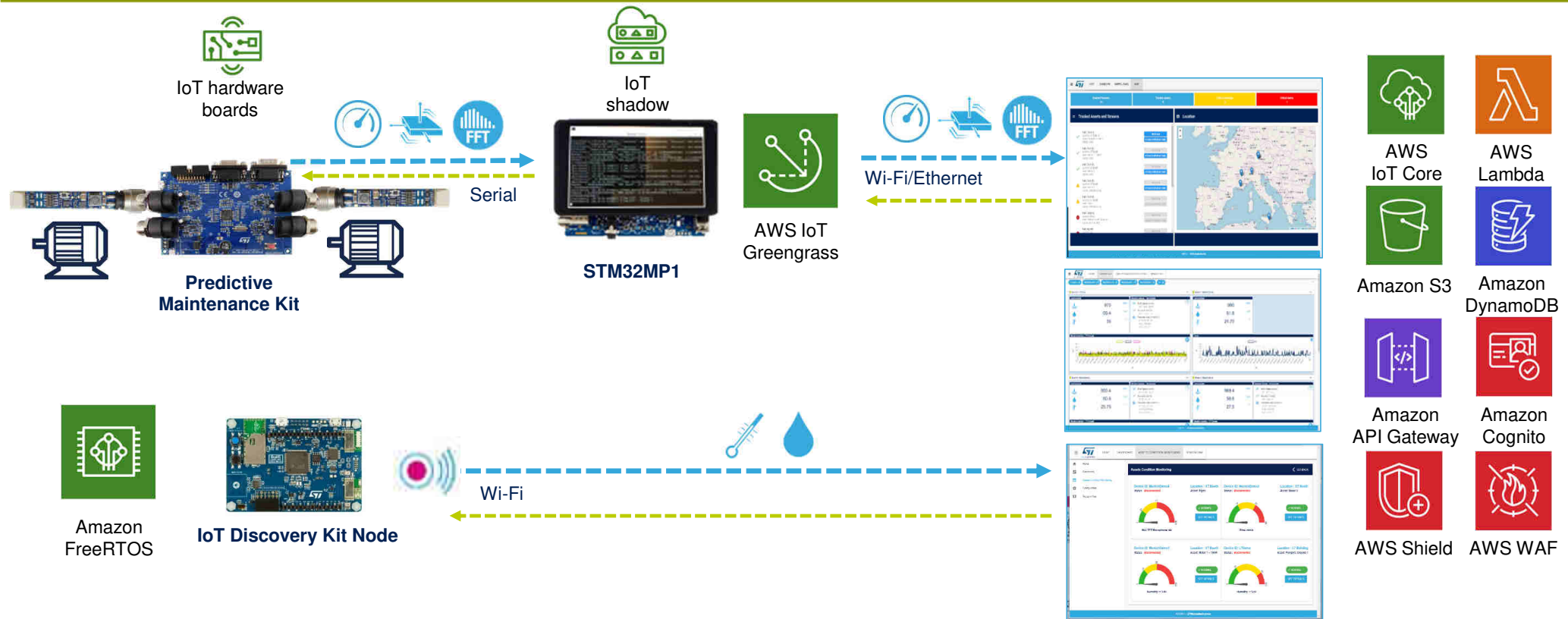


STEVAL-STWINKT1

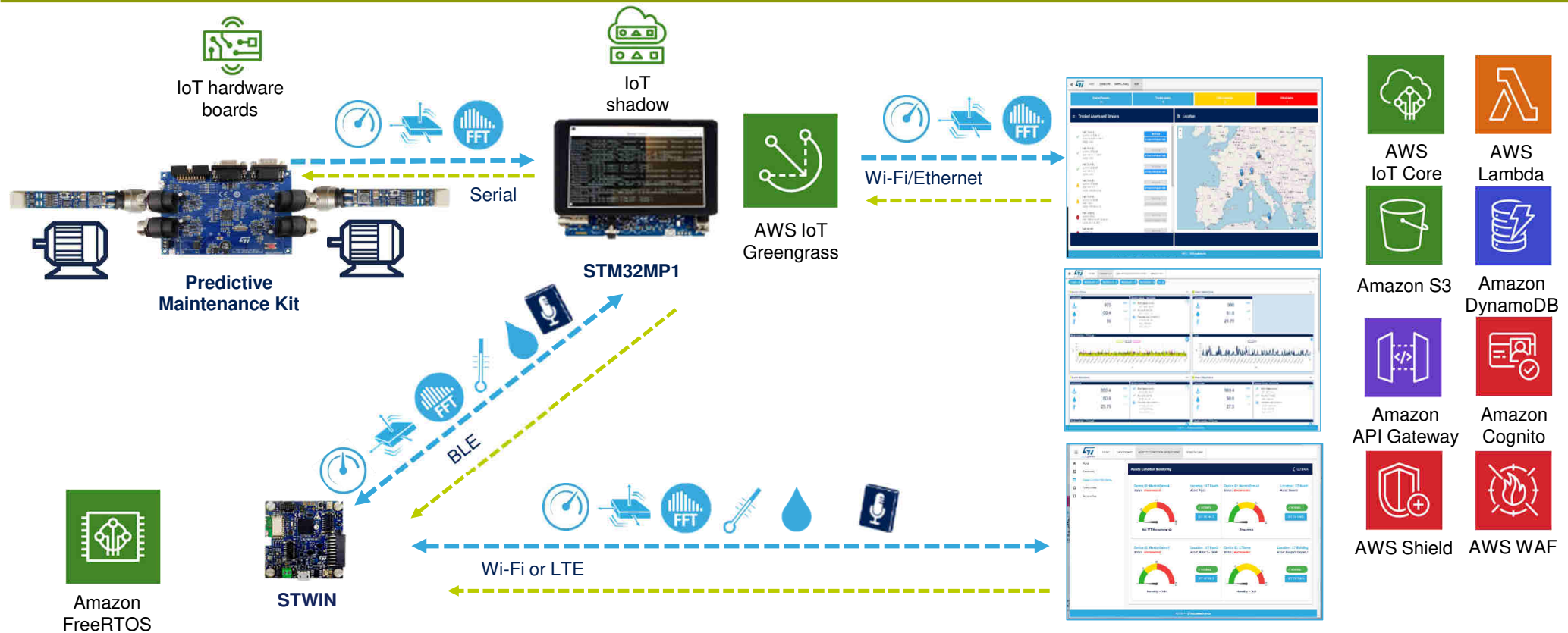
SensorTile Wireless Industrial Node



Ultrasound, Vibration, Environmental sensing



Ultrasound, Vibration, Environmental sensing



Predictive Maintenance Solutions

45

Value Proposition

Smart Sensor Nodes: different connectivity and UI to evaluate specific products

Edge and Cloud: e2e

Evaluation
FP-IND-PREDMNT1

PoC
STEVAL-BFA001V1B

Field Test: Predictive
Maintenance Platform



Understanding Needs

Full feature evaluation: Equipment/Asset Retrofitting

Framework to ingest sensors
data in the cloud and work on
insight (analysis or ML)

Same SW Library shared with same features: Vibration and Sound Analysis

- HW Available
- SW available
- BLE Data log with APP

- STEVAL-BFA001V1B and STEVAL-IDP004 available
- STWIN available end of July 2019 (Alpha Engagements)
- PC Data log, GUI and DLL for Matlab
- BLE Data log with APP

- Gateway SDK available on GitHub
- Dashboard on st.com available end of September 2019
- Cloud dashboard Data Log



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