Sensors Converge

Intelligent sensing: past, present, and future

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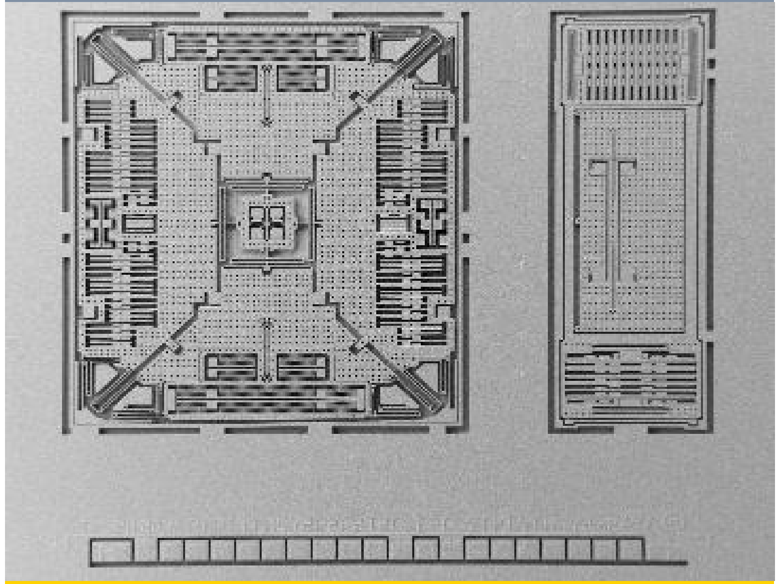
#SensorsConverge

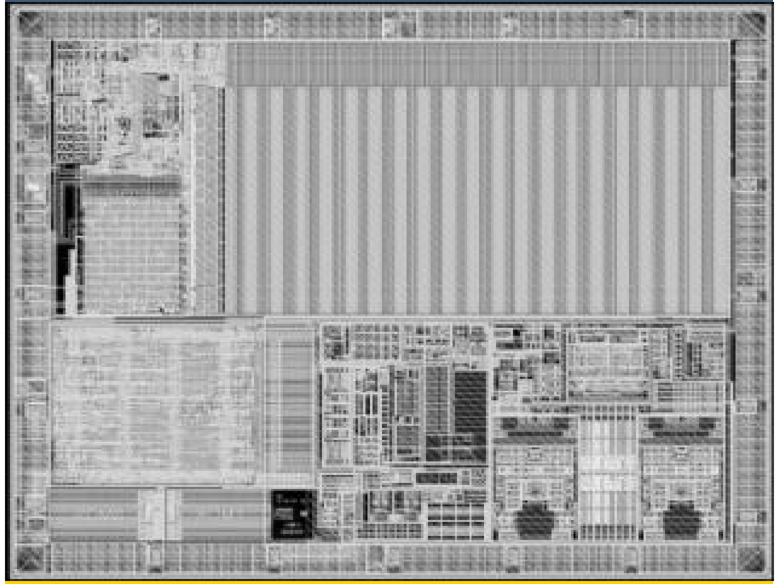
MEMS sensors' three key elements

Transducer



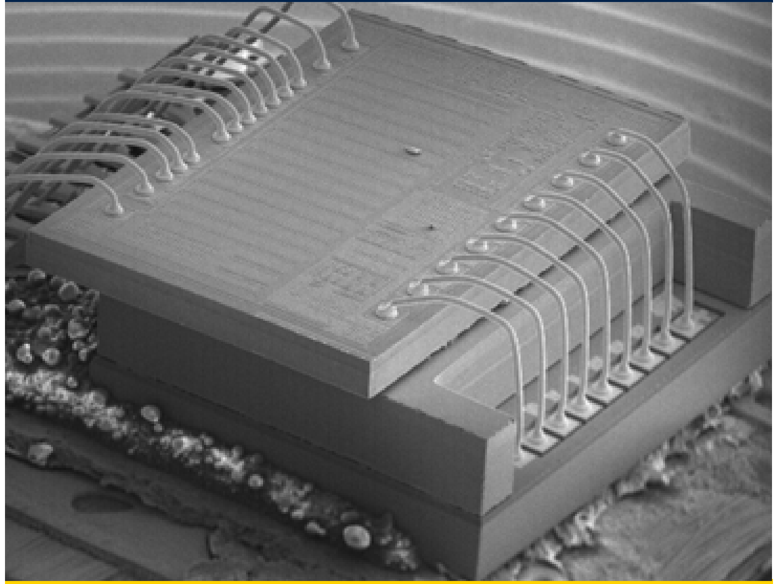
Micron-sized **transducer** realized through a specific process called Micro-Machining

ASIC



A dedicated **ASIC** with embedded smart functionalities

Package



Dedicated **package** and **calibration** features

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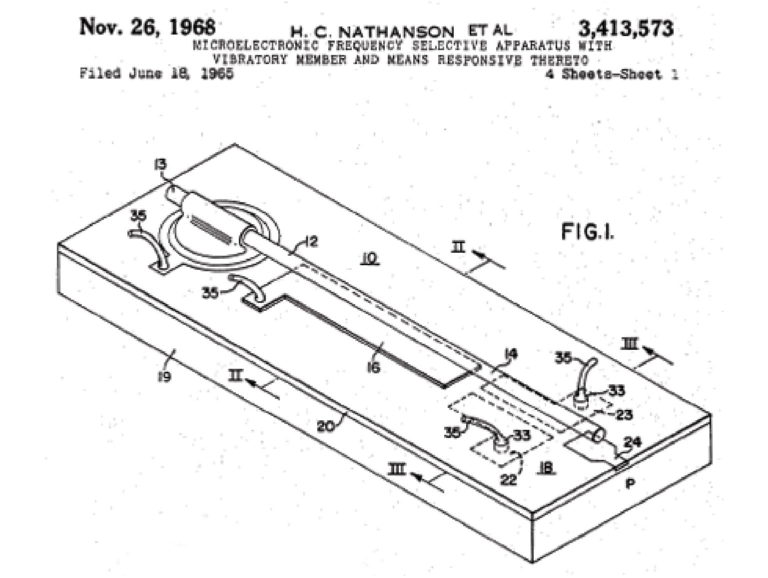
Sensors: past



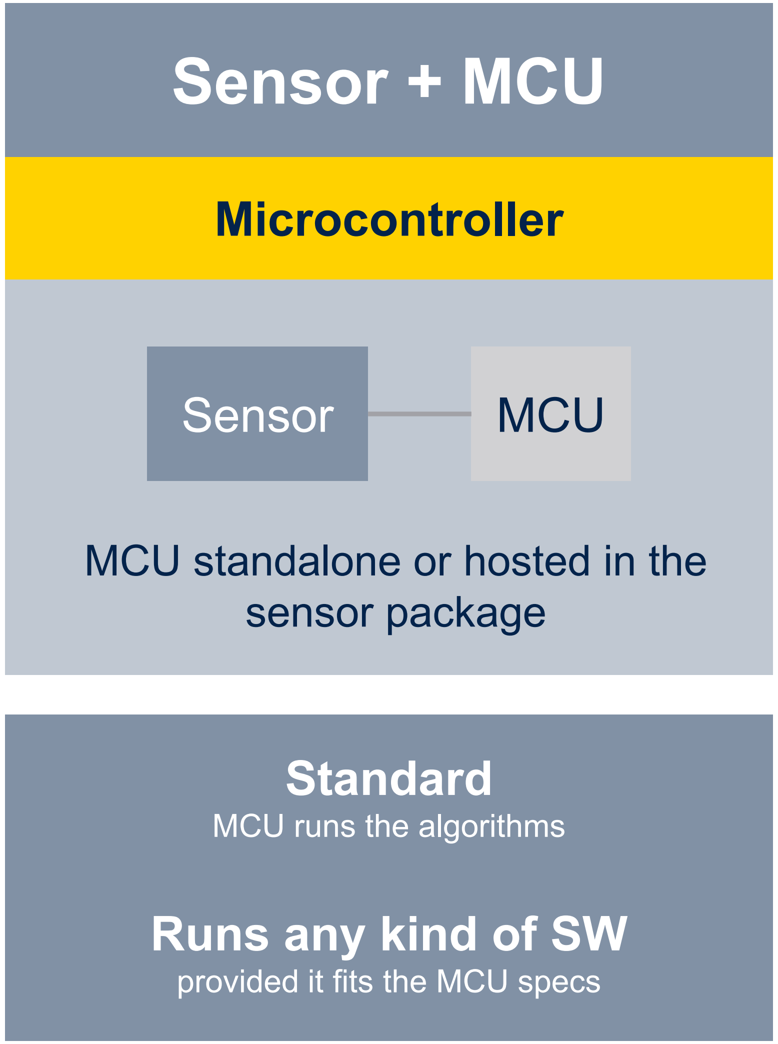
Early 1960s: Invention of MEMS: Resonant Gate Transistor used as frequency filter for ICs.

2006: game controllers using accelerometers for swinging, shaking, tilting. **2008** generation introduced the use of gyro-scopes for complex movements

2007: first full touchscreen smartphone with an accelerometer to adjust portrait / landscape mode

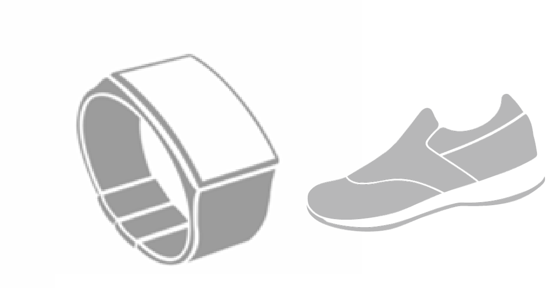
Sensors: past

- Early sensors: MEMS sensing element + ASIC for signal conditioning and data acquisition
- Most intelligence resided on uControllers or application processors
- There was gradual addition of intelligence in sensors through embedded features on sensor ASIC



Accelerometers use cases

Asset tracking
Shock/Wake-up

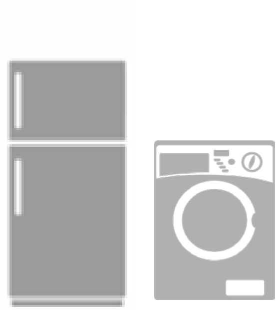


IoT / Wearables
Activity tracking / Pedometer

People monitoring
Freefall / Man-down / Activity

Predictive maintenance & Monitoring
Vibration / Tilt

Alarms
Tilt / Wake-up



White Goods
Vibration / Tilt

Industrial
Positioning / Tilt

Car crash / Car alarms
Tilt / Movement

Pressure sensors use cases

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6-axis IMUs use cases

IMU = Inertial Measurement Unit

IoT / Wearables
Movement tracking
and Shock detection

High-precision sports tracker
Activity monitoring

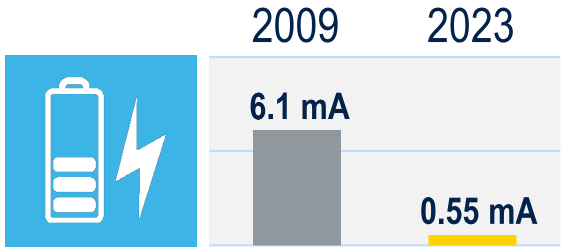
Robots / Drones
Position tracking / Stabilization

Predictive maintenance
and Condition monitoring
Vibration / Tilt

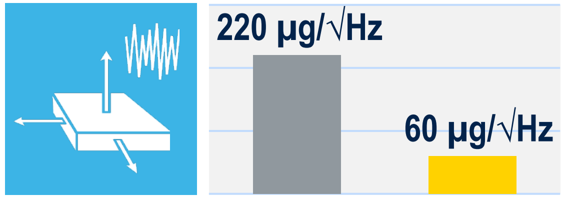
Industrial Robots
Vibration / Tilt / Stabilization

Global Navigation Satellite System (GNSS) /
Telematics / Rotation / Movement

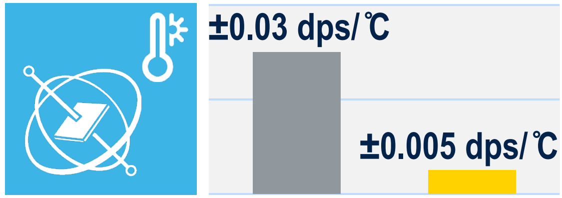
Sensors improvements made over a 14-year period



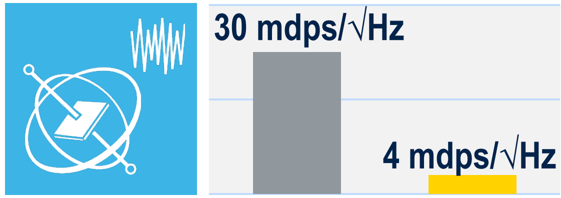
91%
Power Reduction



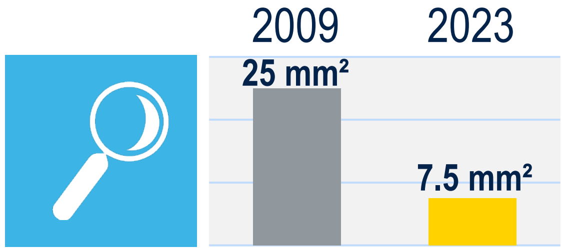
73%
Accelerometer noise reduction



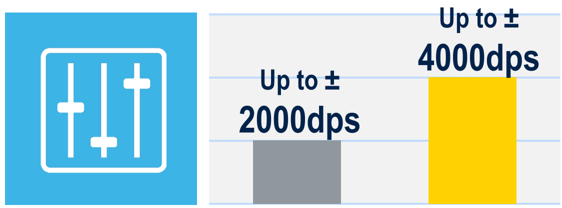
83%
Temperature stability Improvement for gyroscope



90%
Gyroscope noise reduction

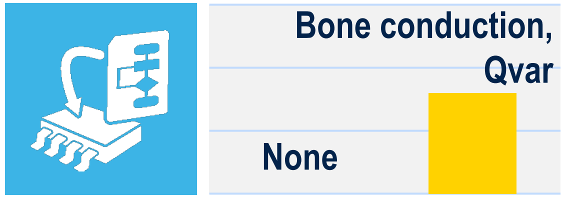


70%
Size Reduction



100%
Increase in Full-scale Range

Embedded Finite State Machine and Machine Learning core
SFLP (Sensor Fusion Low Power)
ISPU (Intelligent Sensor Processing Unit)



Bone conduction (audio accel.)
Qvar (electrostatic sensor)

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Intelligent sensor: present

Intelligent sensors offer a variety of embedded features	Sensors with embedded sensor fusion to generate orientation	Intelligent sensors have Finite State Machine (FSM)	Intelligent sensors have Machine Learning Core (MLC)
Pedometer Significant motion detect, Wake-up, Free fall detection, 6D orientation, ..	They compute the orientation of device in 3D space outputting Euler Angles or Quaternion	They use a computational model represented by the FSM, a set of predefined states and transition rules	They offer a unique combination of high-quality measurements and capabilities to process data using ML algorithms on the sensor

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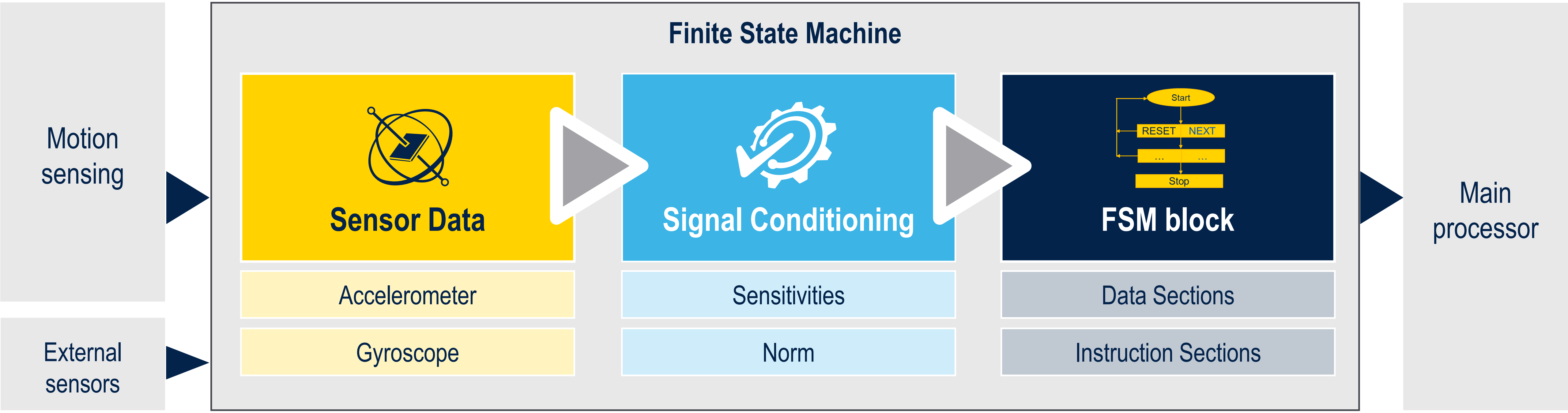
Sensors with Finite State Machine

FSM is an in-sensor behavioral model composed of a finite number of states and transitions between states



FSM is able to generate interrupt signals activated by user-defined motion patterns

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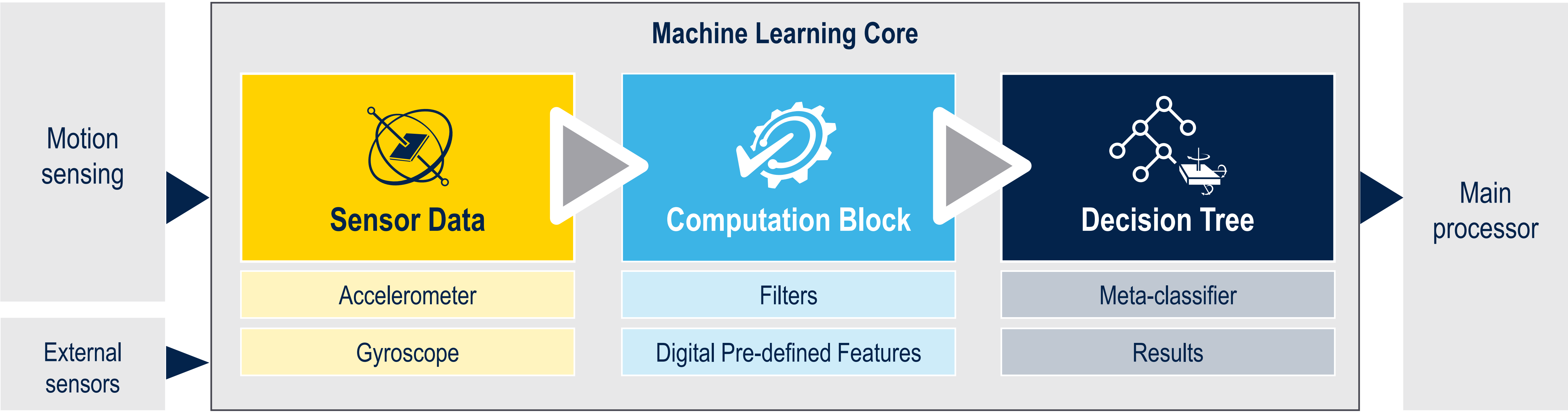
Sensors with Machine Learning Core

MLC is an in-sensor classification engine based on a decision tree logic



MLC is able to **increase accuracy** with a **better context detectability**, **offloading the main processor** while the built-in sensors identify motion data

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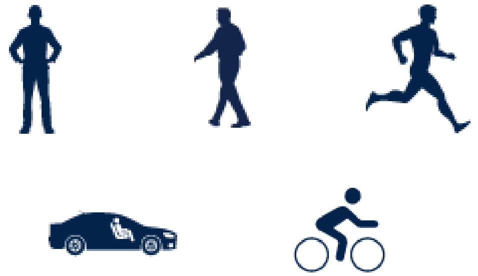
Machine Learning Core efficiency

10x less current consumption for activity recognition on MLC than on GP MCU

	General Purpose MCU*	MLC
Activity recognition for wrist-worn device	**51 µA** @ 32 MHz + Sensor** 7 µA	**5 µA** + Sensor** 7 µA



~10x improvement

* Ref STM32L4
**Accelerometer low-power mode @ ODR 26 Hz

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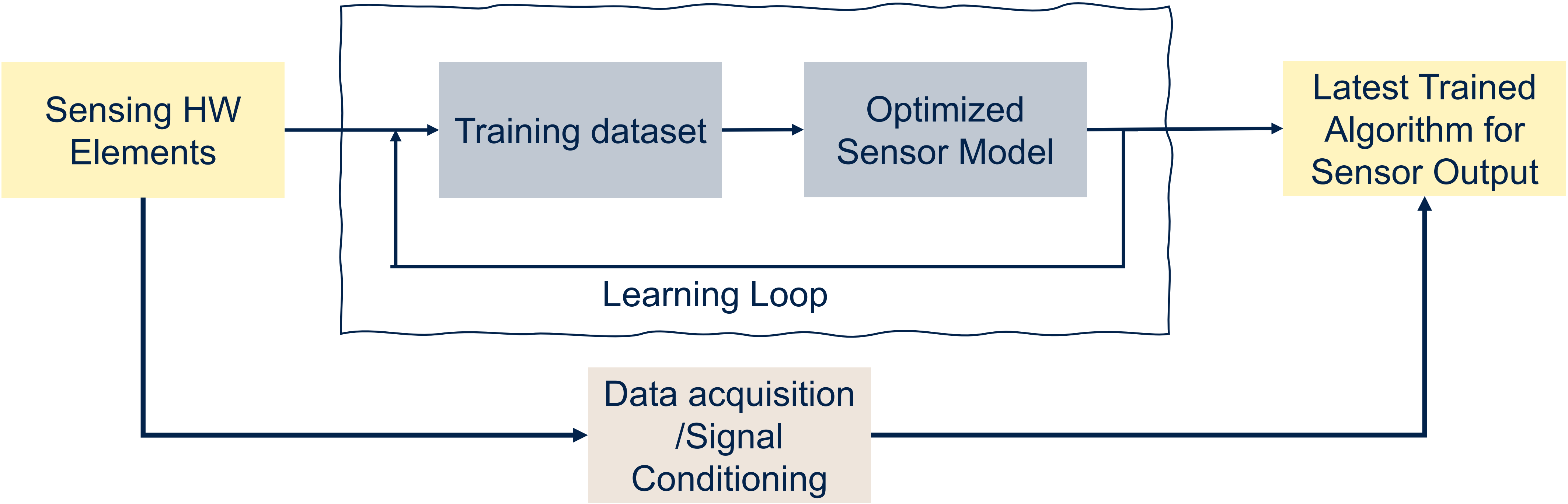
Future intelligent sensors

Future Intelligent Sensors: More adaptable and autonomous

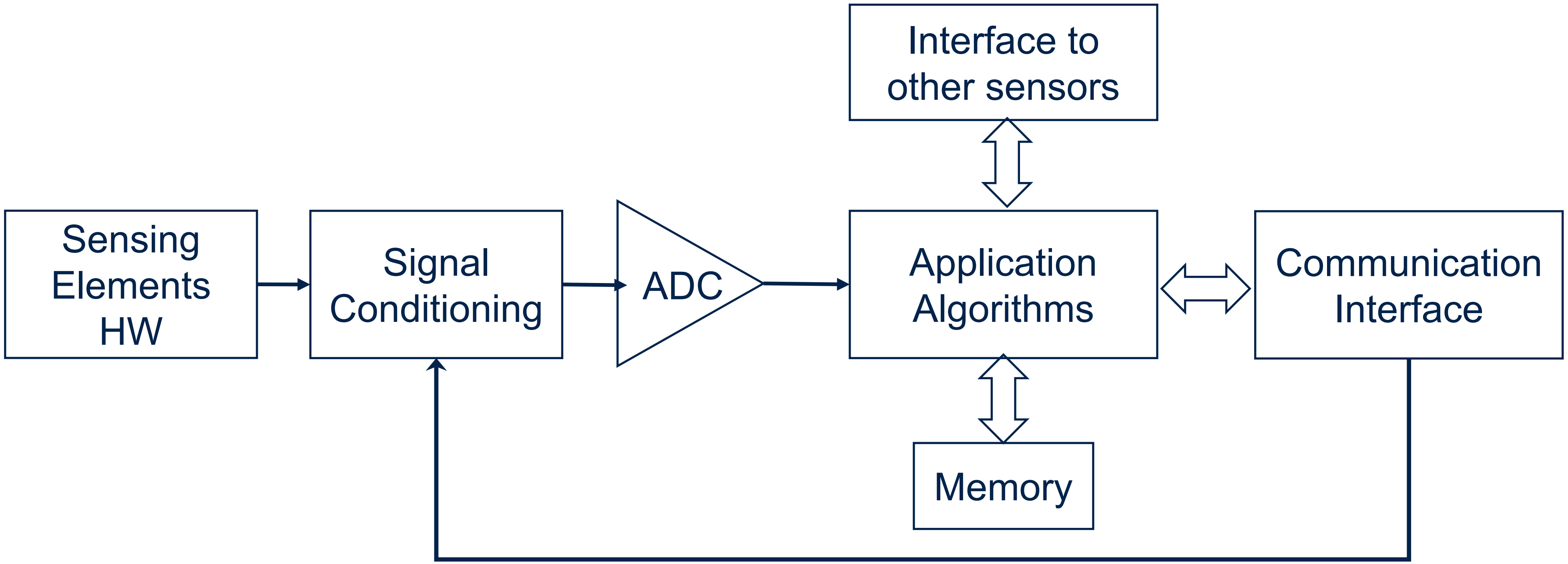
Intelligent sensors will become more autonomous and adaptable. Sensor would be able to adjust their sensing and operating parameters and behaviors based on changing conditions

- This adaptability will improve their performance in dynamic environments and enable them to meet specific application needs more effectively



Future Intelligent Sensors:
More computational power

- Intelligent sensors will incorporate more computational power and onboard artificial intelligence capabilities
- This trend is driven by the need for faster processing and decision-making at the edge of networks, reducing latency and reliance on cloud-based systems



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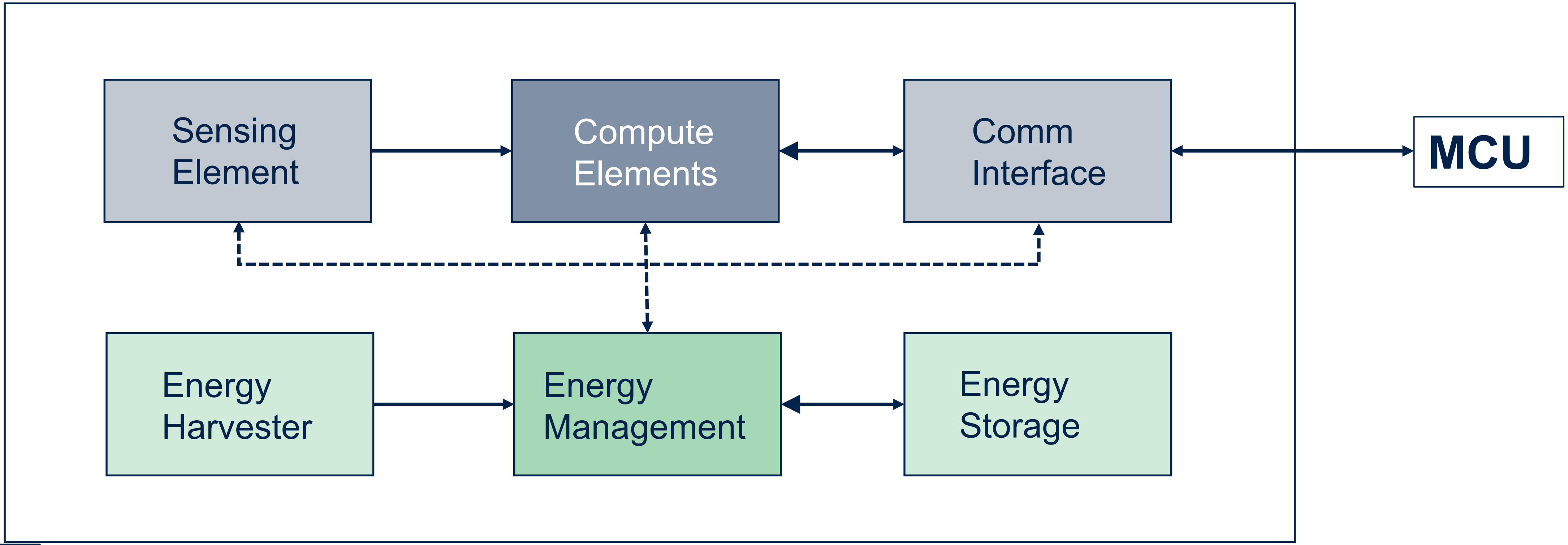
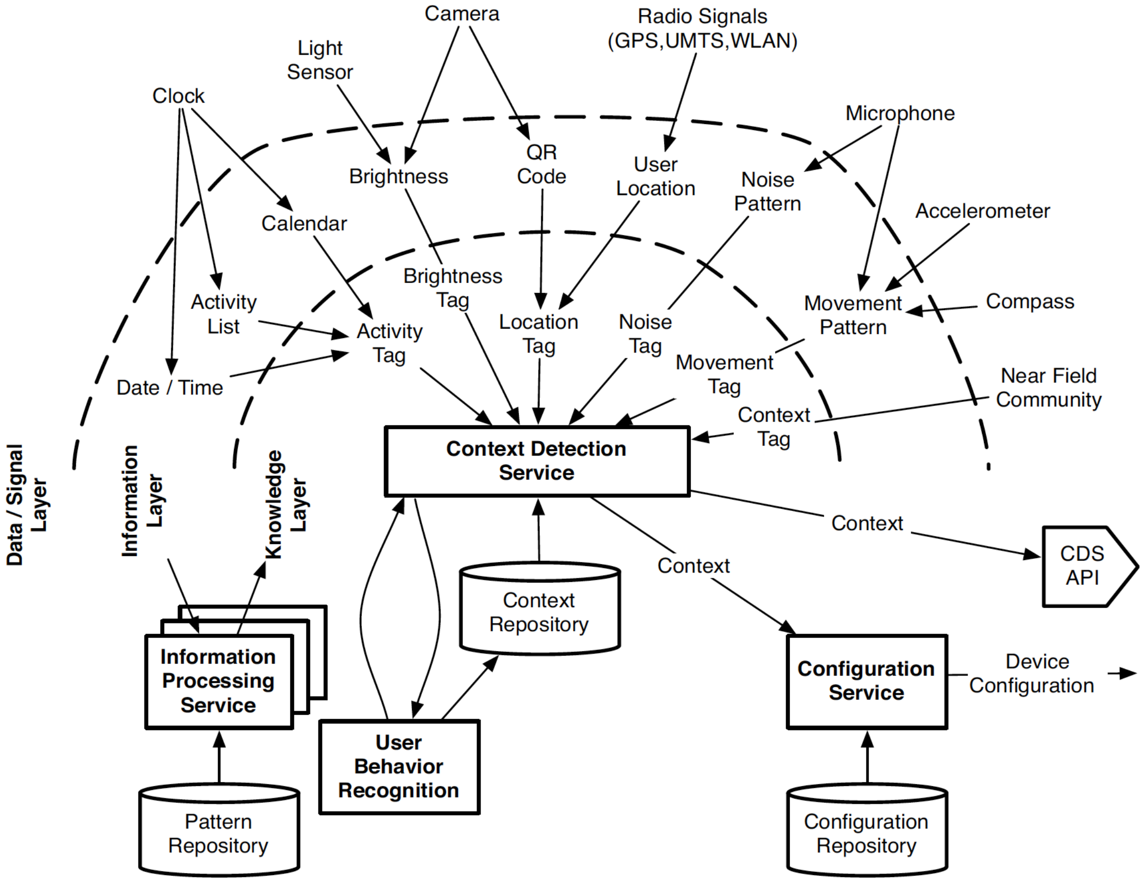
Future Intelligent Sensor: Improved energy efficiency

Longer battery life, reduced power consumption, and potentially the integration of energy harvesting technologies will be utilized to power the sensors

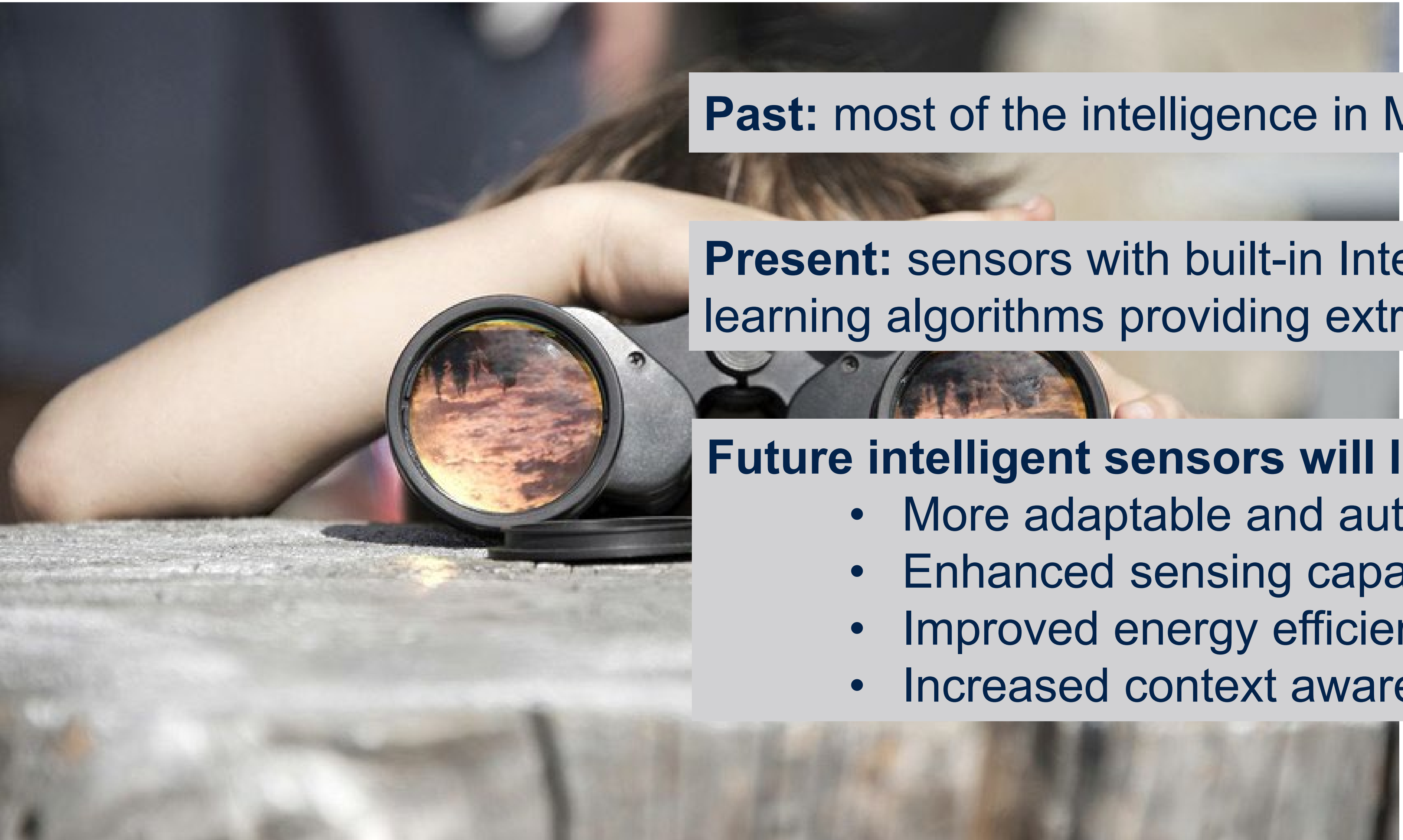


Future Intelligent Sensor: Increased contextual awareness

- Future intelligent sensors will have the ability to understand and interpret the context in which they operate
- These sensors will gather data also from external sources to maintain and provide a comprehensive view of environment
  - Environmental factors
  - Spatial awareness
  - Temporal context
  - User context
  - Networked context
  - Task context



Takeaways



Past: most of the intelligence in MCU or cloud

Present: sensors with built-in Intelligence run machine learning algorithms providing extreme power efficiency

Future intelligent sensors will likely have:

- More adaptable and autonomous capabilities
- Enhanced sensing capabilities through fusion
- Improved energy efficiency
- Increased context awareness

Our technology starts with You

Find out more at www.st.com/MEMS

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