

# Neuromorphic computing, a better solution for a host of AI applications?

Adrien Sanchez, Pierre Cambou

Yole Développement

November 2021

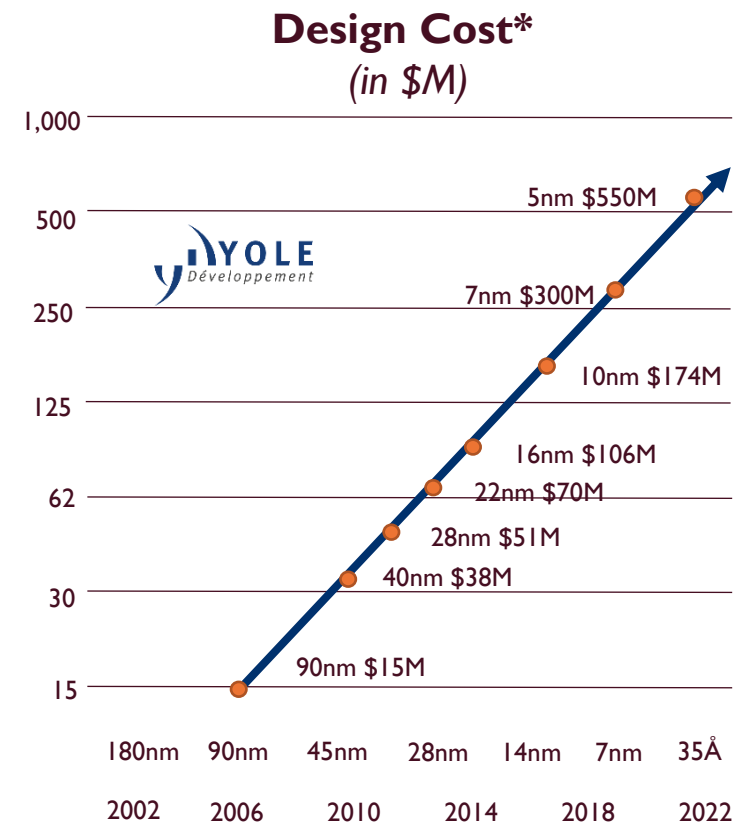
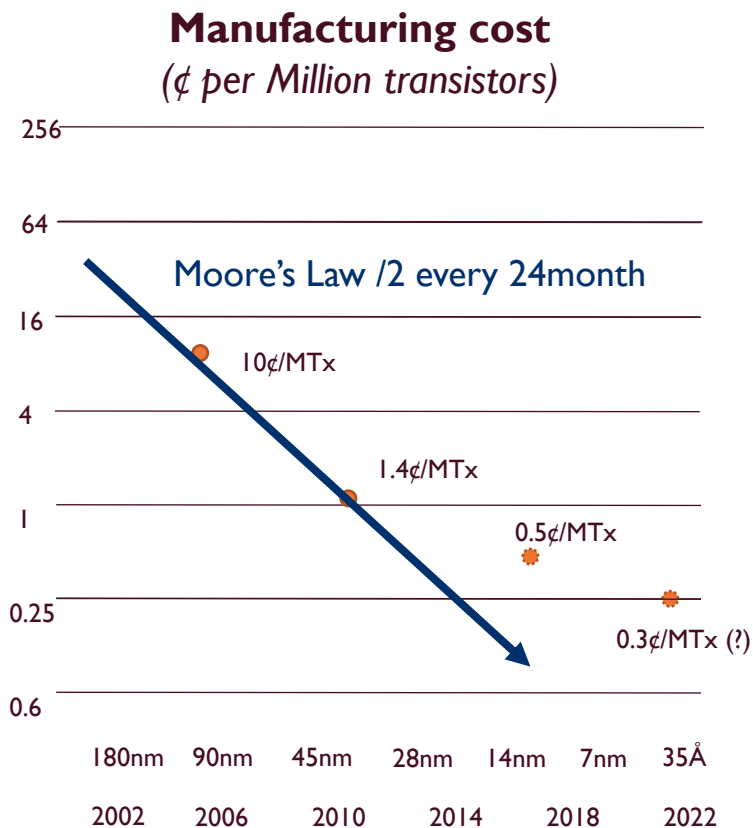
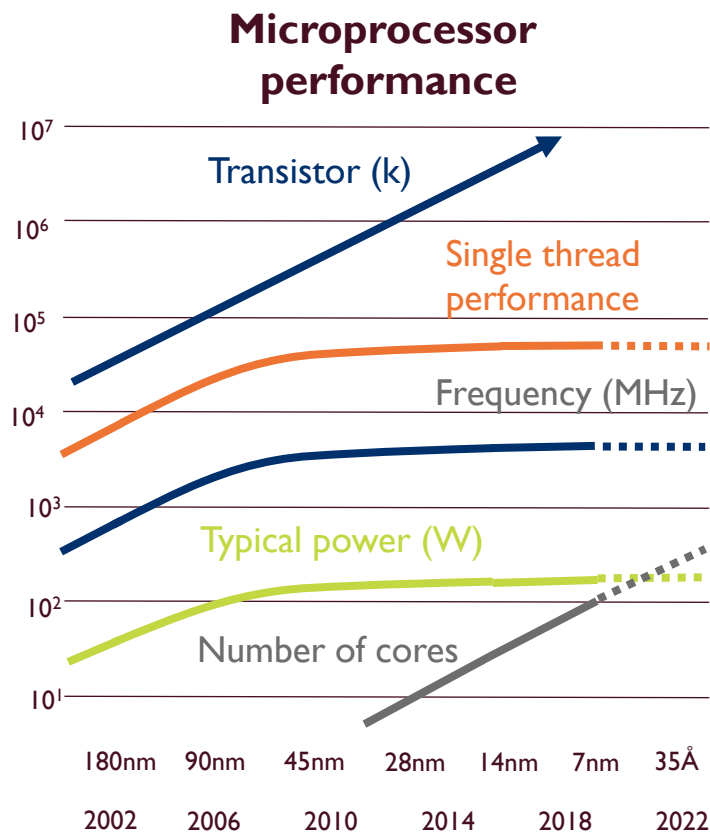


Neuromorphic sensing and computing advances are accelerating

- October 27 **AlpsenTek** present 8Mp event driven image sensor sensing
- October 20 **Brainchip** open orders for Akida computing
- October 15 **Synsense & Prophesee** partnership computing & sensing
- October 14 **Rain neuromorphics** demo presentation computing
- October 03 **Intel** Loihi 2 and LAVA software suite announcement computing
- September 20 **GrAI Matter Labs** and **Adlink** partnership computing
- September 9 **Sony** releases 2 stacked event based vision sensors sensing
- July 14 **Innatera** unveils neuromorphic AI chip computing
- July 03 **Prophesee** investment from Sinovation sensing
- April 25 **Xperi** develops world first in-cabin monitoring sensing
- February 25 **Terranet** and **Daimler** announce joint project sensing

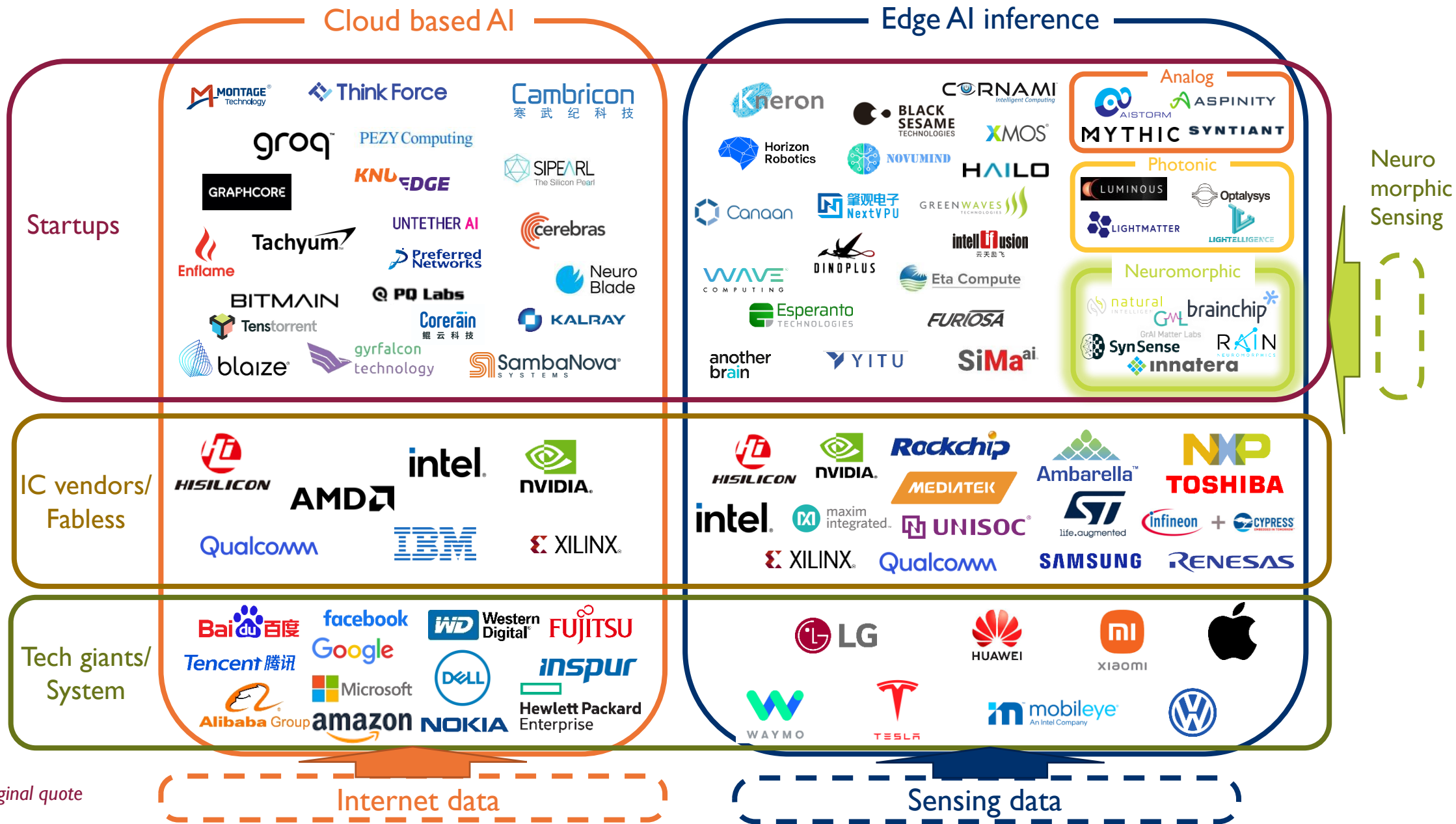
# NEUROMORPHIC SENSING AND COMPUTING

The end of Moore's law economics?



Moore law is pushed to its limits, questions arise about sustainability of cost to performance /2 every 24 month. Ever-larger markets must be found to justify the initial investment. Brute force computing will lose its best ally : the Moore's law

# CAMBRIAN EXPLOSION OF AI\*



\*Jensen Huang original quote

# THE PATH TOWARDS MARKET ADOPTION OF NEUROMORPHIC TECHNOLOGIES

## Neuromorphic beachheads will motivate the first players to invest

### \$ Investments

Some players which definitely need the benefits **won't have the choice** and will chose to bet on this technology and to **make the necessary investments**, as they will see it as the only way to overcome their technical challenges and to meet their objectives.

### Develop maturity

The development of the technology in niche applications will **increase the maturity** of the technology and **the associated ecosystem**.

### Disruptive technology

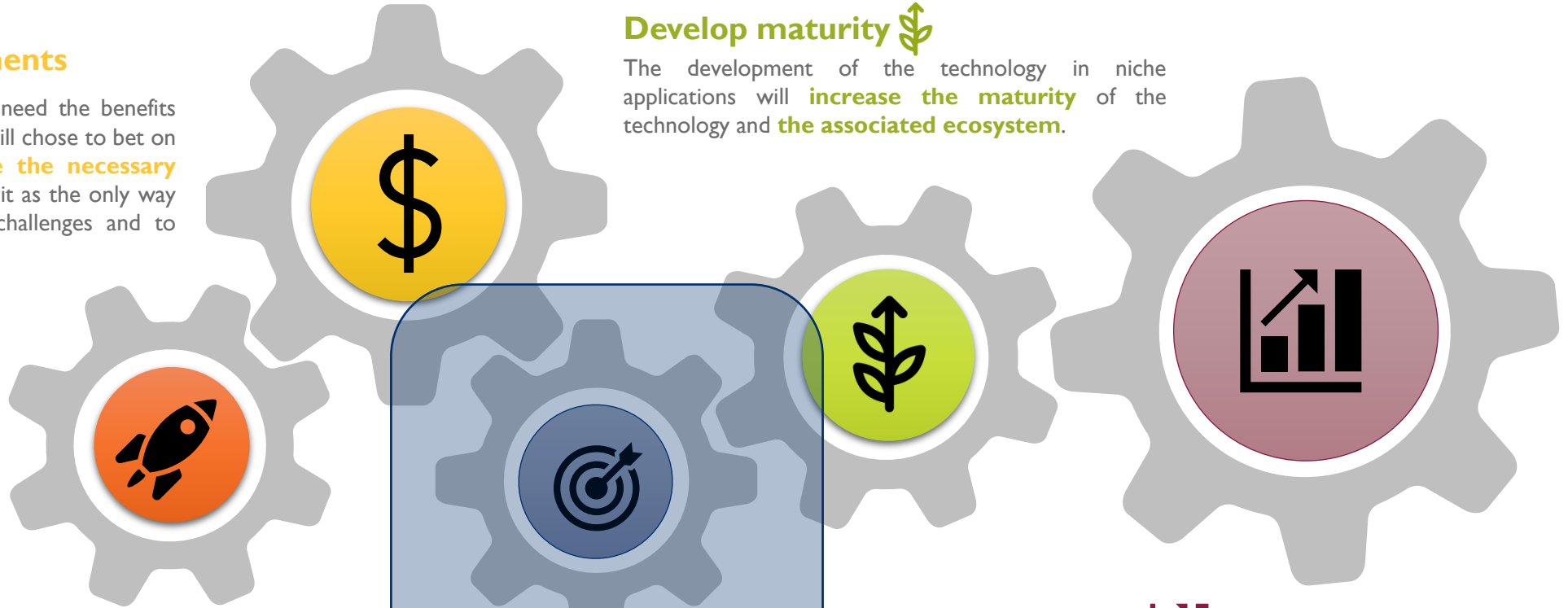
The technology will be complex, with lower levels of performance and higher prices. But they will **bring key specificities**, which can not be found in the market with other products.

### Niche applications

It will first concern only a **few niche markets**.

### Large diffusion

Once the ecosystem has been developed and the technology is sufficiently mature, it will **rapidly spread to other markets**, boosted by its solid achievements.



2015

2020

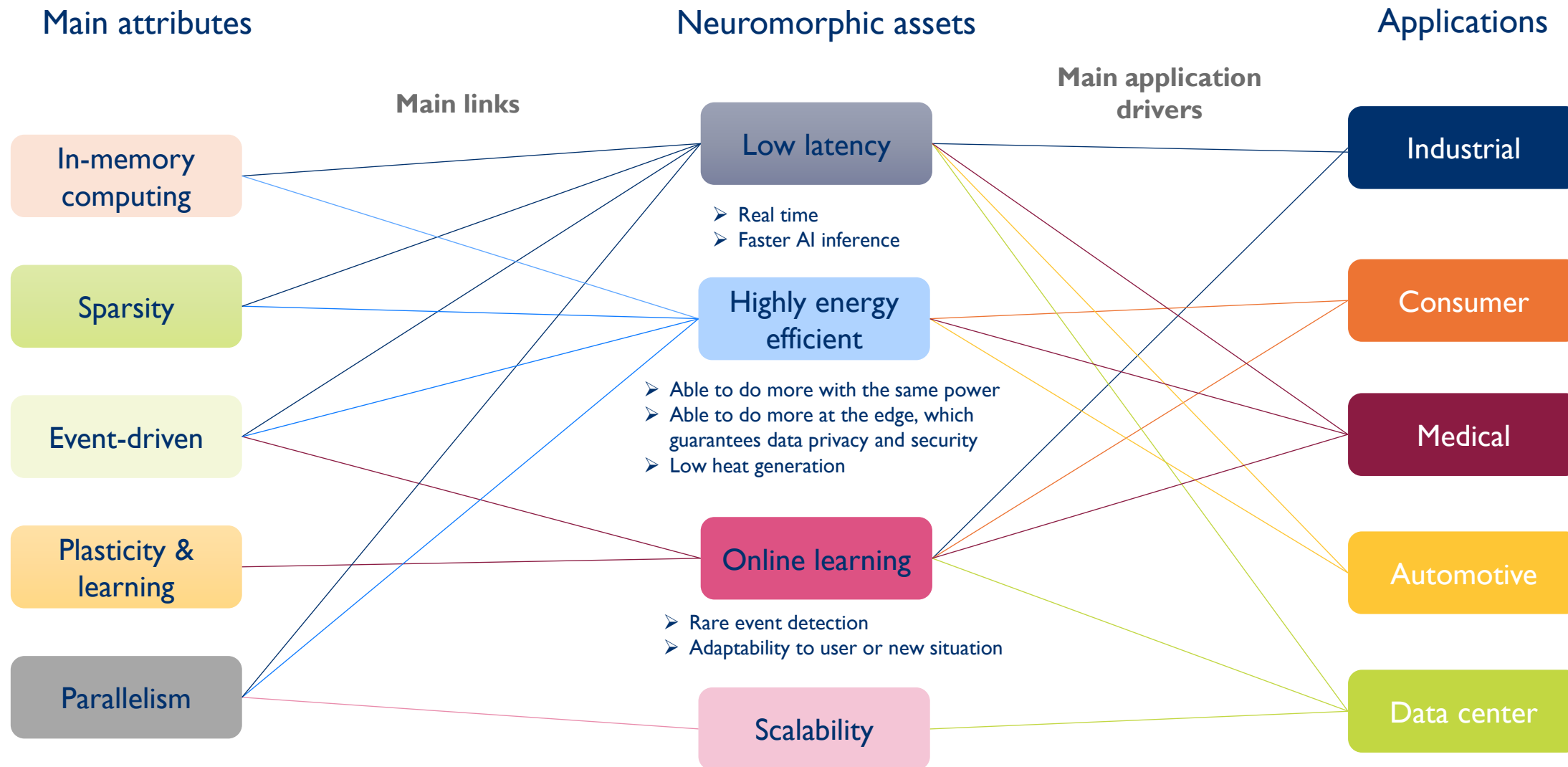
2025

2030

Time

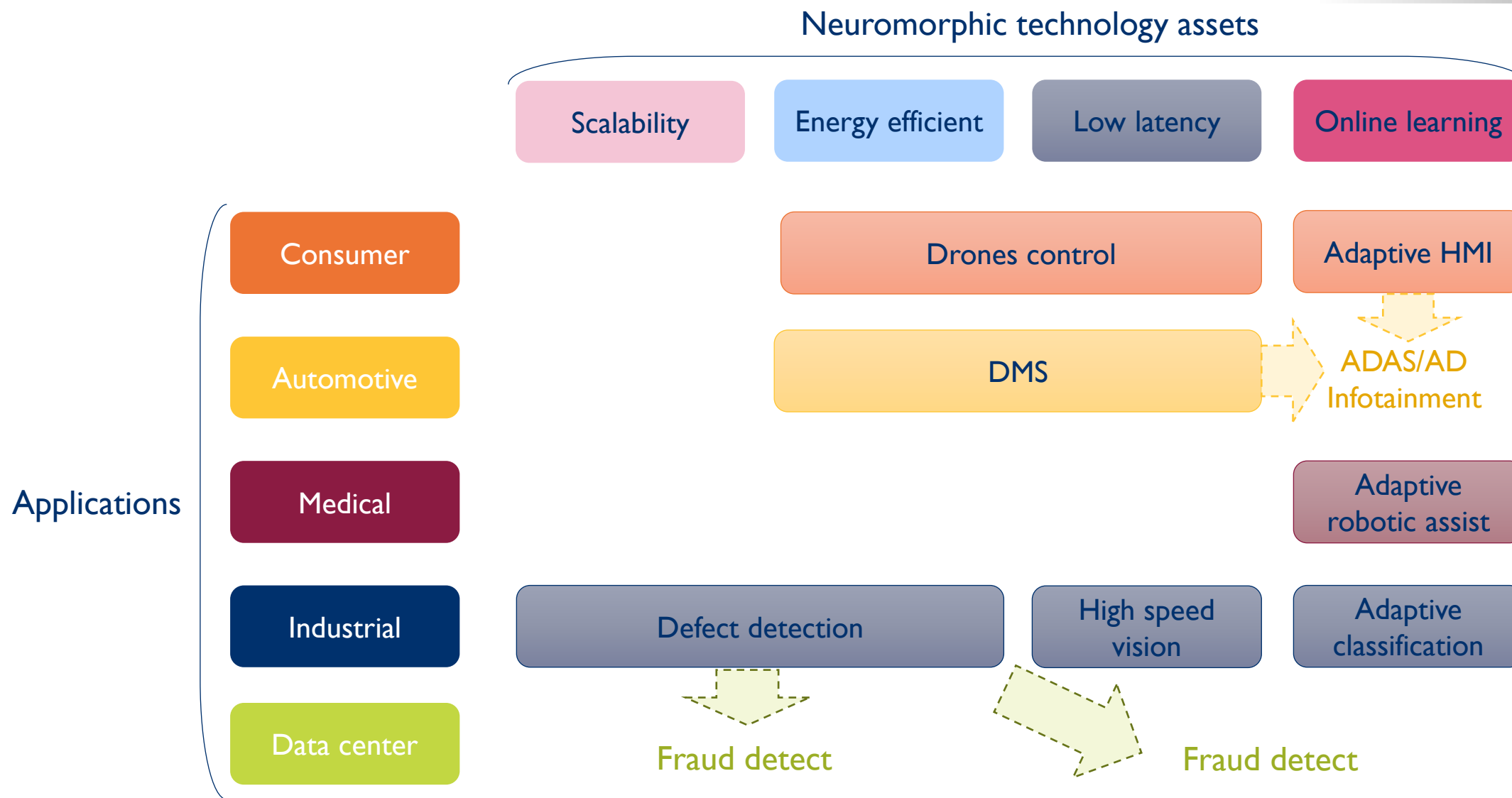
# NEUROMORPHIC APPLICATION DRIVERS

## Neuromorphic attributes, assets and application



# NEUROMORPHIC APPLICATION DRIVERS

## Neuromorphic attributes, assets and application





# Neuromorphic Sensing

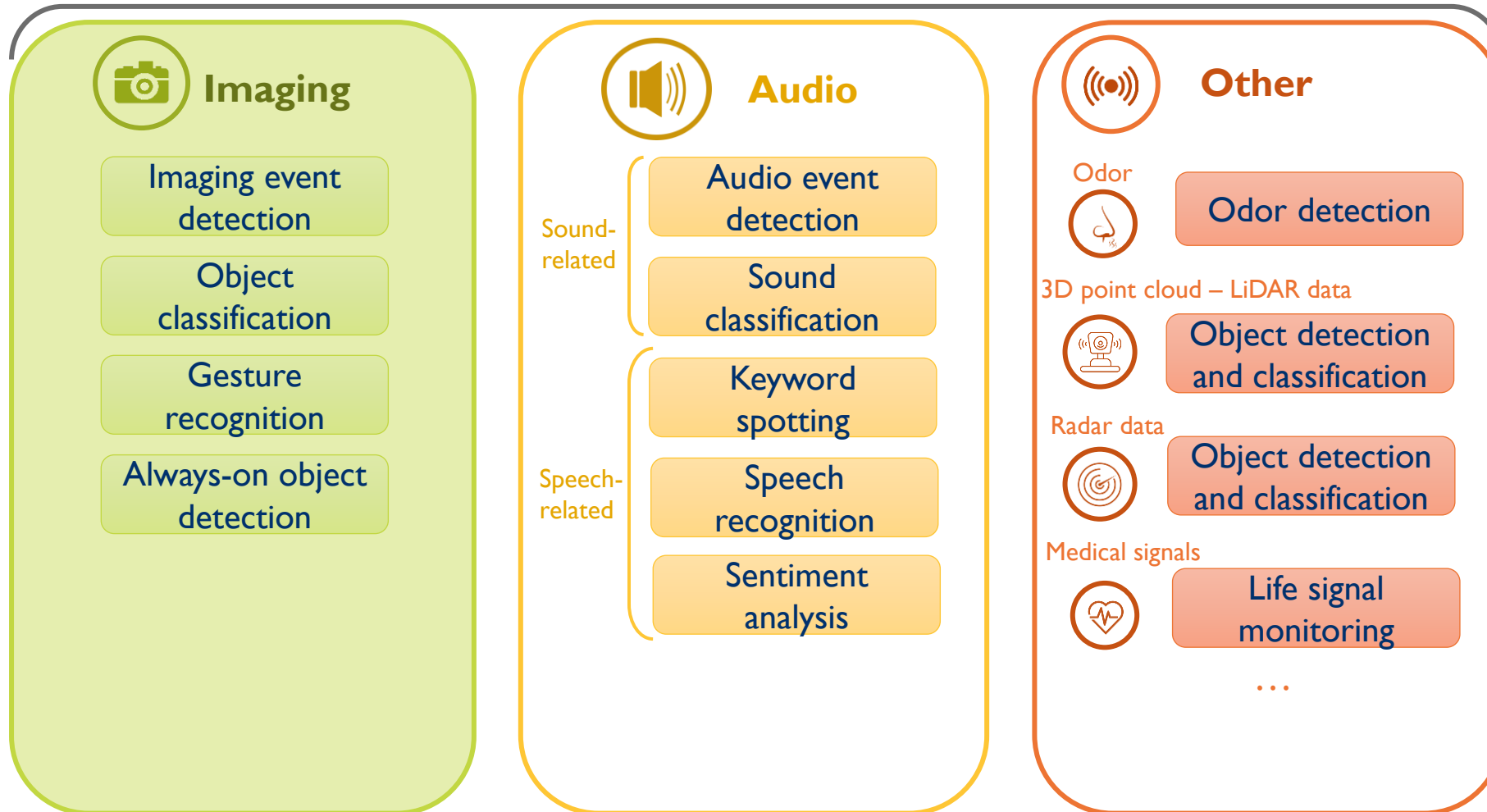
---



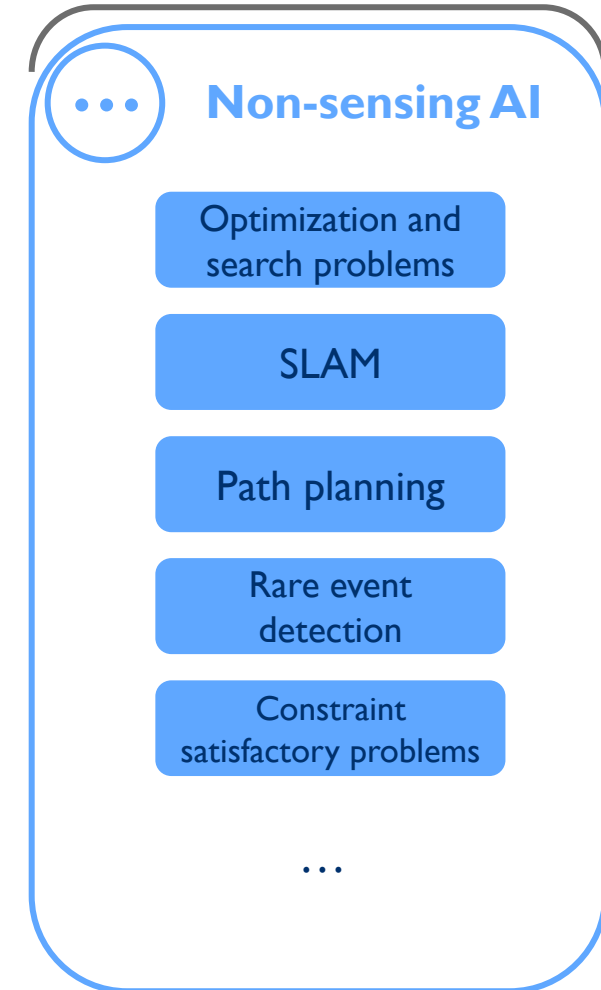
# NEUROMORPHIC SENSING AND COMPUTING APPLICATIONS

## Key AI applications by function

### Sensing related applications



### Non-sensing related applications



# NEUROMORPHIC SENSING

1992 - Invention of the bio-inspired silicon retina.

PhD student at Caltech under Carver Mead in the 80's.

**Dr. M. Mahowald** invented a retina made from silicon, using analog electrical circuits to mimic the biological functions of rod cells, cone cells, and other non-photoreceptive cells in the retina of the eye.

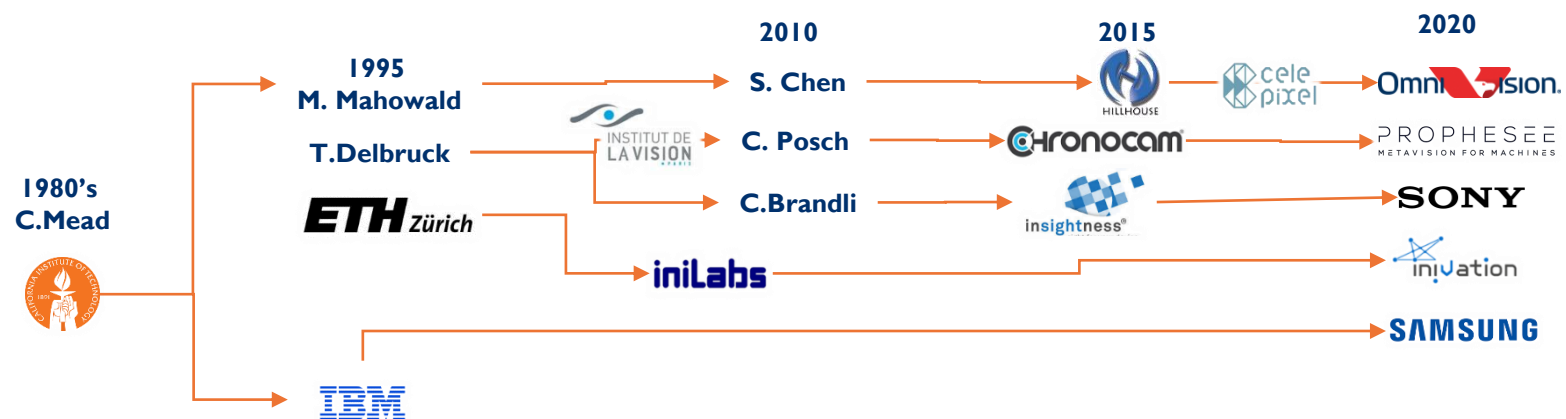
Her work was published in Scientific American and Nature.

She relocated to the University of Oxford and then to Zurich to help found the Neuroinformatics Institute.

She became a member of the 'Women in Technology' hall of fame in 1996 the year of her premature death at age 33.



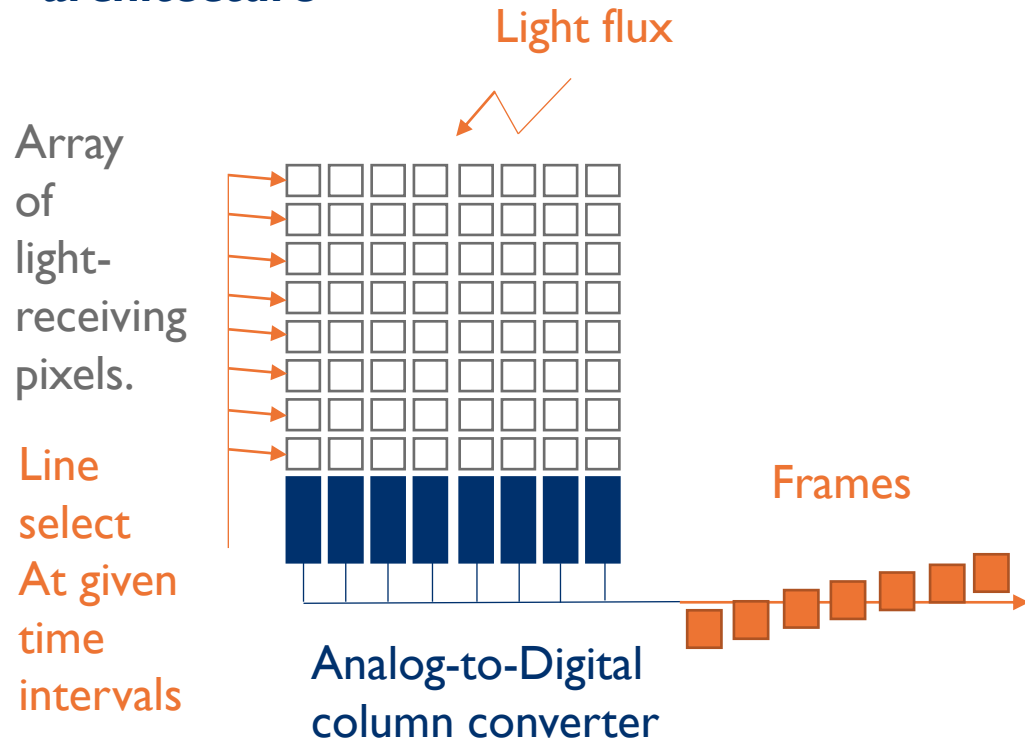
Dr. M. Mahowald



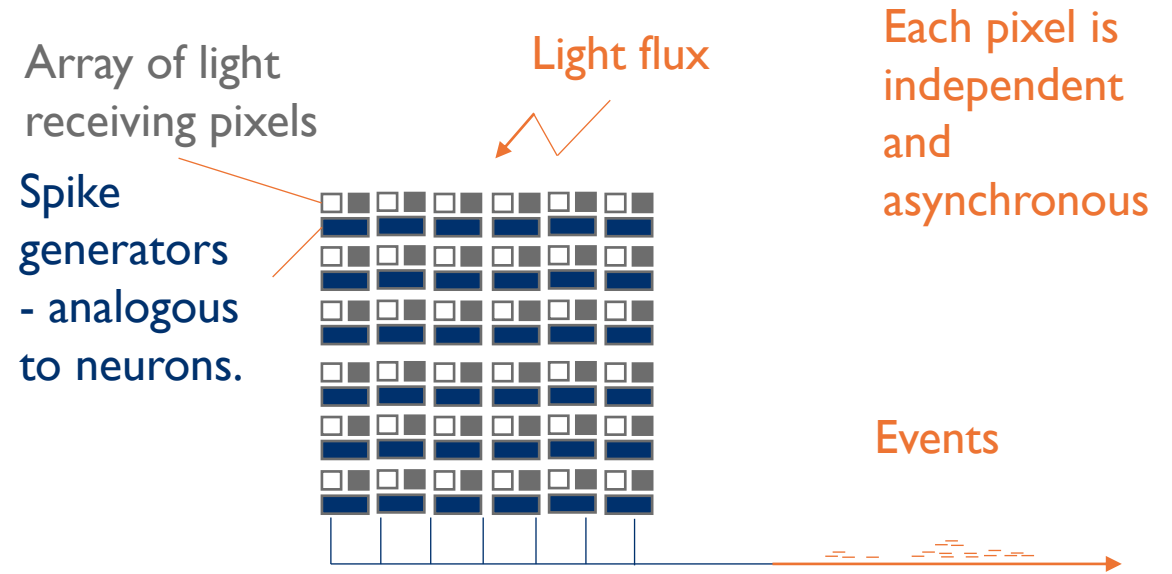
# EVENT-BASED/NEUROMORPHIC IMAGE SENSORS



## Conventional CIS architecture



## Neuromorphic 'event-based' CIS



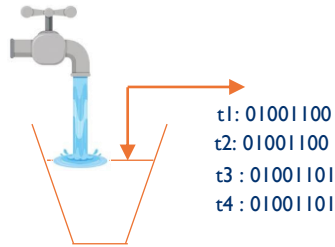
Video output is a matrix of data every 30fps = ~30 milli-seconds.



Video output is a continuous stream of "events"; time stamped location of the pixel which 'spiked' with time precision of 10ns

## Conventional CIS architecture

Hydraulic parallel

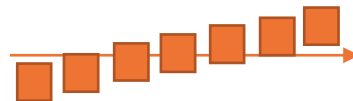


each pixel is a bucket

a measurement is performed for every given time interval. 8 to 10 bit data for each pixel is sent out at regular time interval

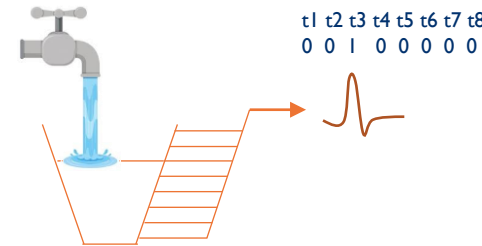


Von Neumann architecture  
1 image every 30ms coded with 10 to 20bits  
Resulting in 60dB to 120dB dynamics



## Neuromorphic 'event-based' CIS

Hydraulic parallel



each pixel is a bucket

a "spike" signal is sent only when a new increment level is reached.  
Only the dynamics of the image is sent out.

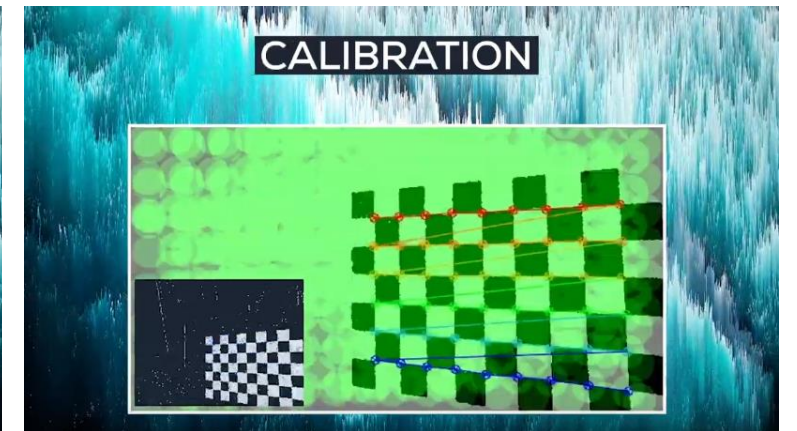
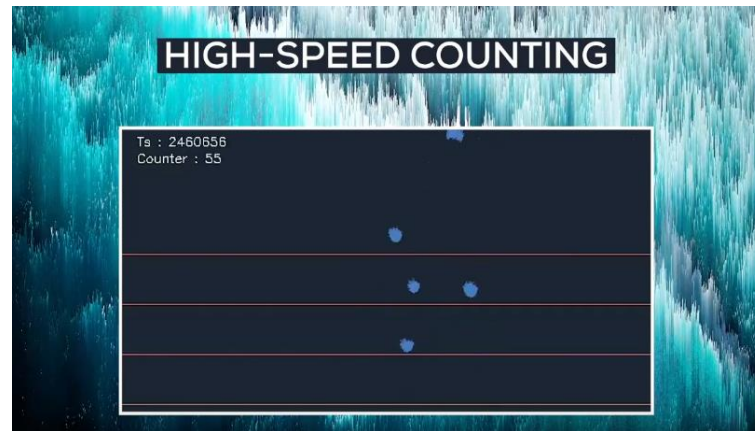
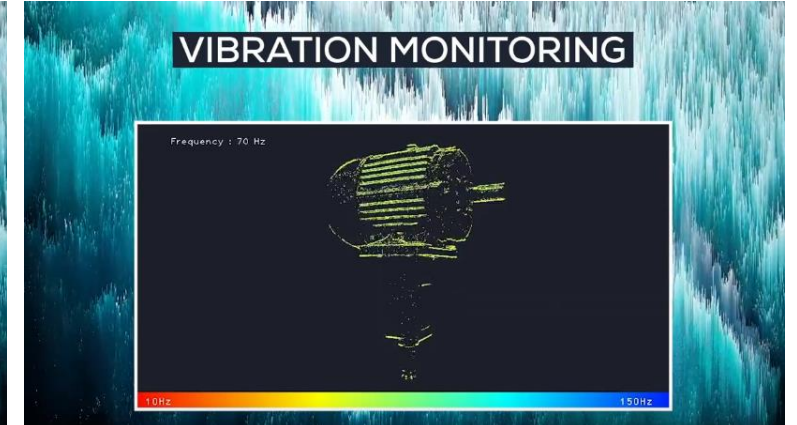
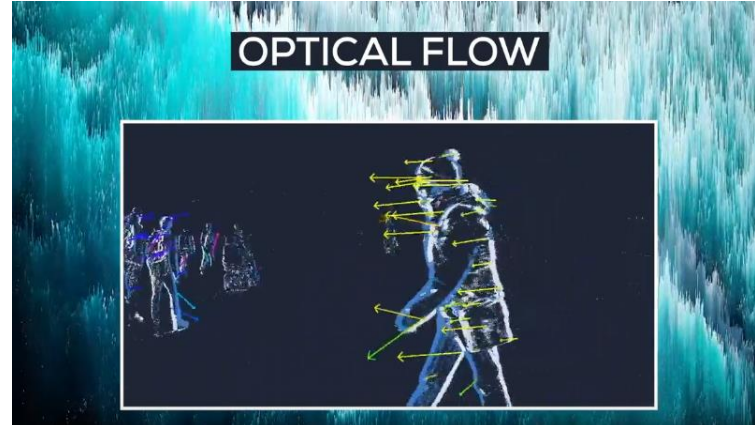
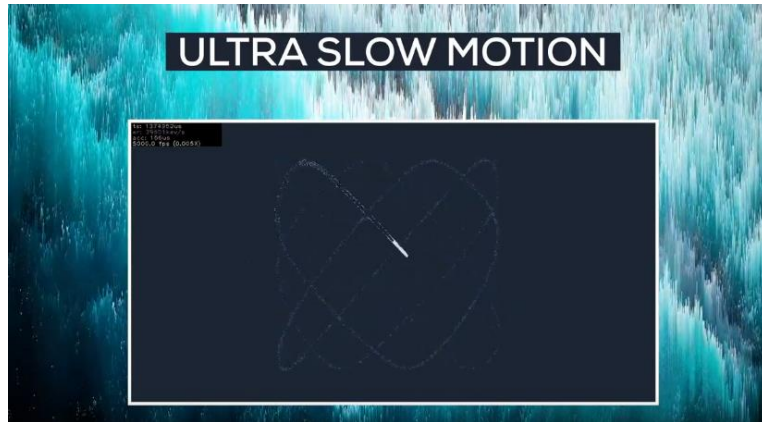


- Asynchronous
- 10 ns latency
- Sparse data
- Dynamics is defined by triggering increment ~120dB and beyond



# EMERGING IMAGE SENSOR TECHNOLOGIES

Event-based imaging is going beyond current frame-based machine vision



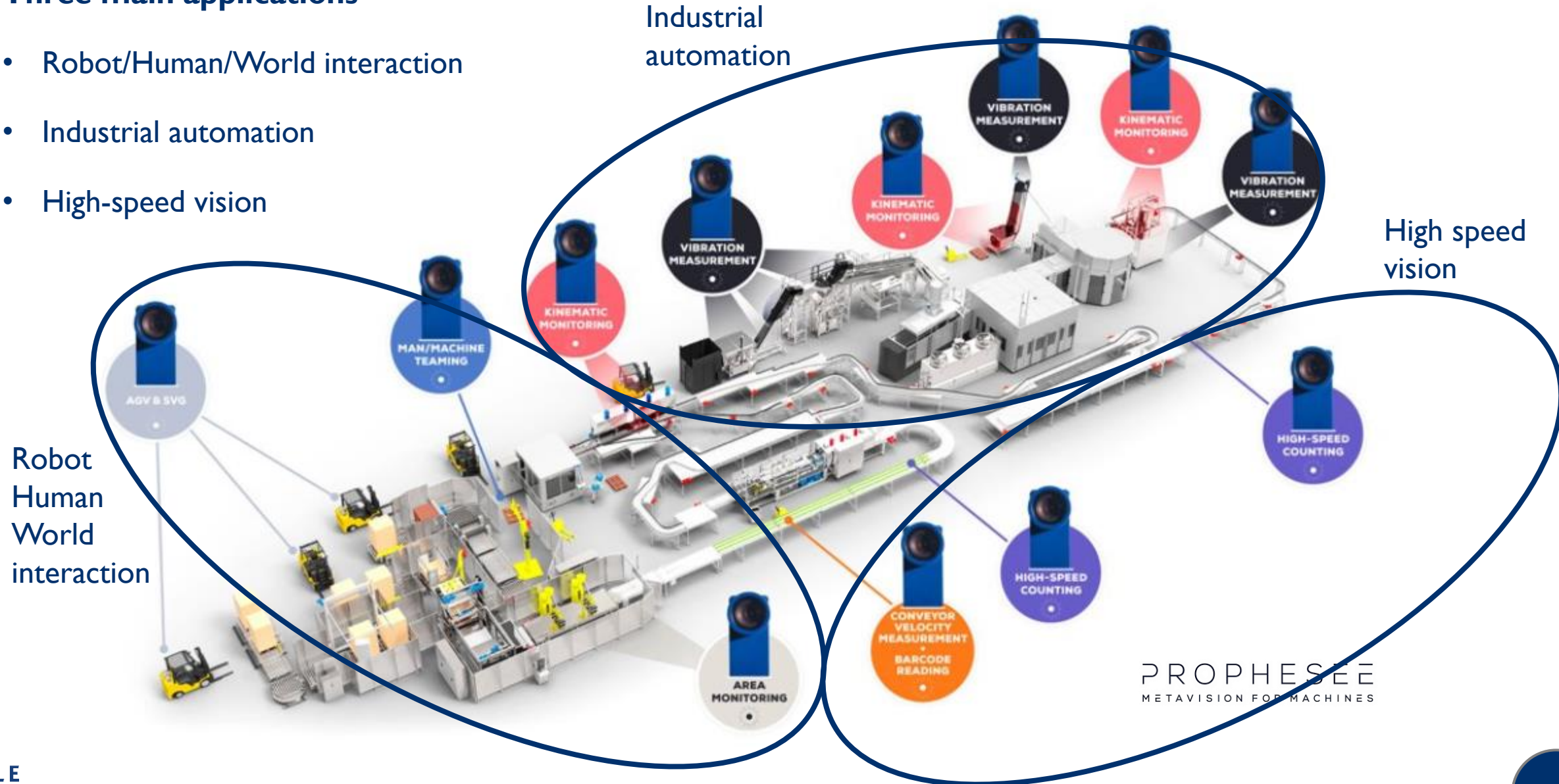
Courtesy of Prophesee

- Event-based technology resolves many of the current limitations of a frame-based approach to machine vision.
- The next step for event-based imaging is to demonstrate it is a superior visual input for machine learning and perception.



## Three main applications

- Robot/Human/World interaction
- Industrial automation
- High-speed vision



## Driver Monitoring Solution from Xperi

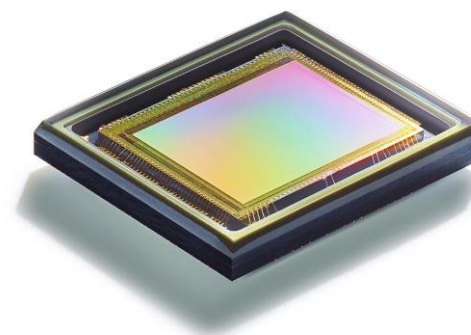
- In April 2021, a **hybrid DMS** powered by the Prophesee **neuromorphic vision sensor** is announced by XPERI.
- **Better low-light and high dynamics performance** in very constrained in-cabin automotive condition for driver monitoring.
- **Fatigue monitoring** must count eye blinks therefore >100fps and intense image processing loads. Event cameras detect all blinks at low power.

Low latency

Highly energy efficient



DTS Driver Monitoring Solution *Courtesy of DTS*



*Courtesy of Prophesee*

Prophesee event-based Metavision sensor

PROPHESÉE

DTS and Xperi announced a neuromorphic-based DMS.

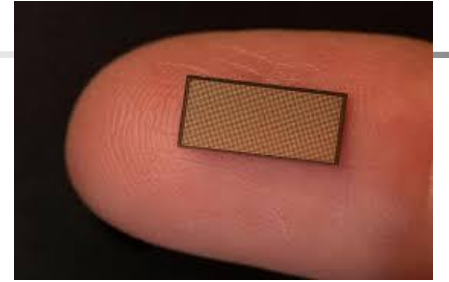


# Neuromorphic Computing

---



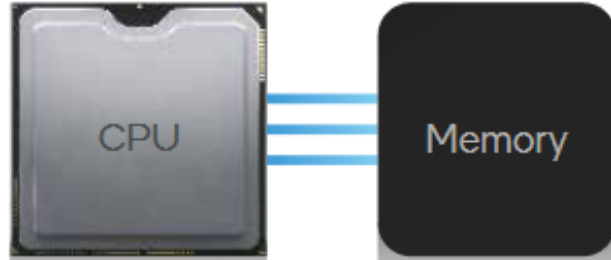
# NEUROMORPHIC COMPUTING TECHNOLOGY



intel

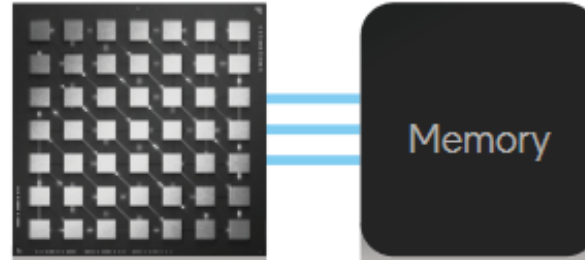
## Today's Computing Architectures

### Conventional Computing



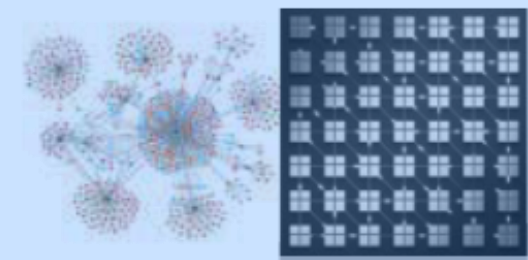
- Programming by Encoding Algorithms
- Synchronous Clocking
- Sequential Threads of Control

### Parallel Computing



- Offline Training Using Labeled Datasets
- Synchronous Clocking
- Parallel Dense Compute

### Neuromorphic Computing



- Learn On-the-Fly Through Neuron Firing Rules
- Asynchronous Event-Based Spikes
- Parallel Sparse Compute

Courtesy of Intel

# FACTORY AUTOMATION – VISUAL INSPECTION



Neuromorphic can be implemented to improve existing performance

- BMW is currently doing **visual inspection** tests to identify and discard errors in real-time on the production line, based on a U-Net neural network powered by GPUs.
- They developed a POC using neuromorphic computing and SNN to implement the same visual inspection functions.
- Results:
  - Comparable performance
  - A network with 10x fewer parameters
  - Joules per inference level was reduced by 7x.



Courtesy of BMW

Highly energy  
efficient

Scalability

BMW  
developed  
neuromorphic  
POC for  
visual  
inspection on  
production  
lines

# VISION SYSTEMS

## Adaptive neuromorphic systems for fish sorting

- The system enables a classification into four different categories, which could be, for instance:
  - **Accept:** Right species correctly positioned
  - **Reject:** Damaged fish or wrong species
  - **Recycle:** Correct species but badly positioned, or several fish
  - **Empty:** No fish
- The training can be easily improved at any time by fisherman's using an easy-to-use API.
- The use of such systems enable a reduction of the number of crewmembers by up to 6 persons, and the time at sea has shortened by 15%.

Low latency

Online learning

Today tens of neuromorphic computing systems are being used on several fishing ships to classify and sort in real time fish on the boat.

The first systems were deployed in 2008.



Images from "Fish Inspection System Using a Parallel Neural Network Chip and Image Knowledge Builder Application", Anne Menendez, Guy Paillet



The Engey (Iceland) is operating seven neuromorphic systems



Pisces Industries integrated neuromorphic systems to its filleting machines



Well positioned mackerel



Damaged mackerel

# MEDICAL – DISABLE PEOPLE SUPPORT

Online learning enable to reach a new level of performances

Many POC are being developed in the Intel Neuromorphic Research Community

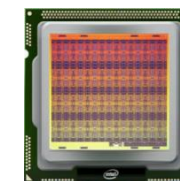
- The Open University of Israel in collaboration with Accenture developed a **wheelchair with a robotic arm to assist patients with performing daily tasks.**
- **Intel's Loihi chips** and **algorithms developed by Applied Brain Research** were used to create this Prototype.
- Results, versus traditional control methods:
  - **50% fewer errors**
  - **48% improvement in energy efficiency**



Courtesy of Accenture

Online learning

Highly energy efficient

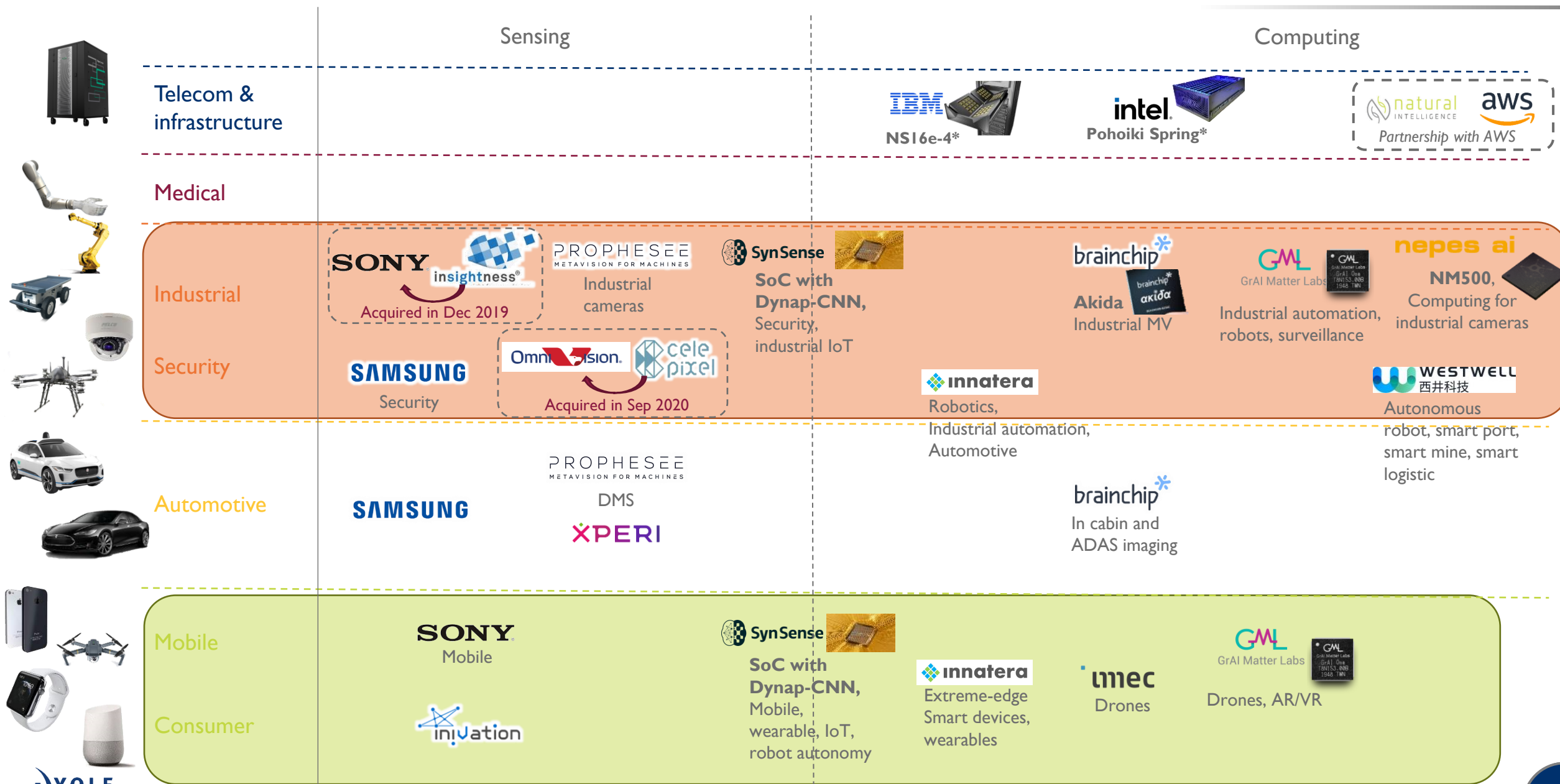


Loihi chip

intel.

# NEUROMORPHIC COMPANY MARKET POSITIONING

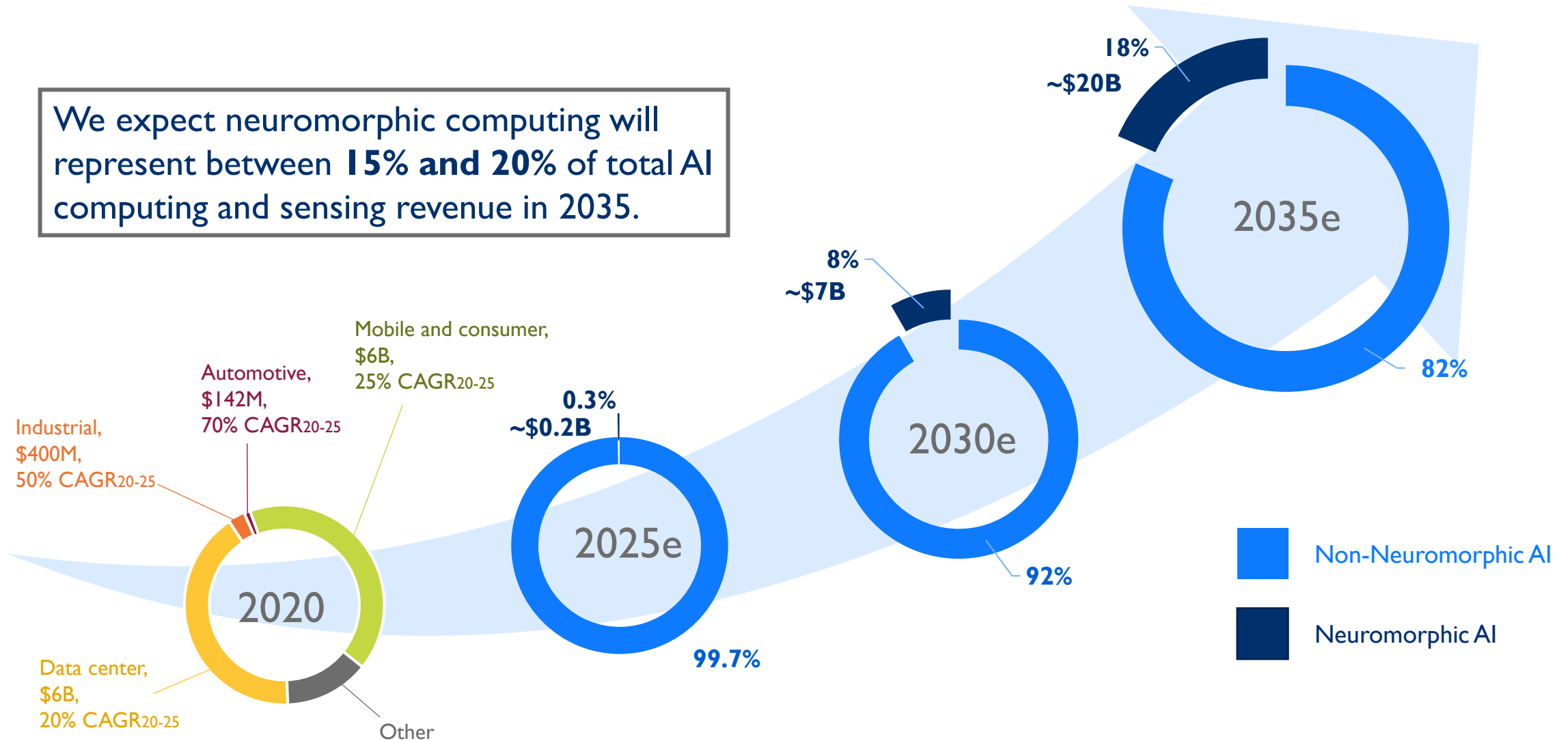
\*No commercial product today



# NEUROMORPHIC COMPUTING AND SENSING IN AI REVENUE

Evolution of the share of neuromorphic in AI chip revenue

We expect neuromorphic computing will represent between **15% and 20%** of total AI computing and sensing revenue in 2035.

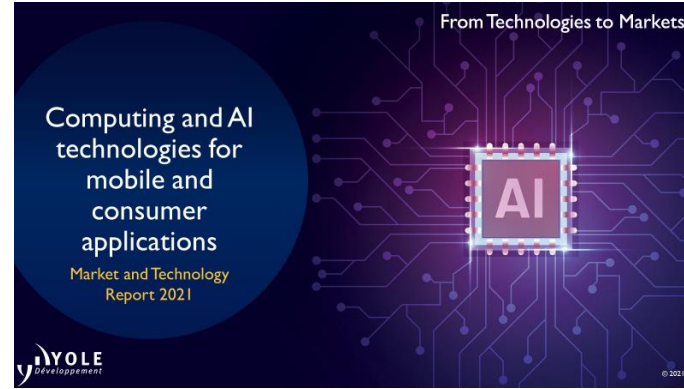




Thank you for your attention

---

# LATEST YOLE'S REPORTS RELATED



Any question, email us: [faycal.khamassi@yole.fr](mailto:faycal.khamassi@yole.fr)



# Empowering Product Creators to Harness Edge AI and Vision



The Edge AI and Vision Alliance ([www.edge-ai-vision.com](http://www.edge-ai-vision.com)) is a partnership of 100+ leading edge AI and vision technology and services suppliers, and solutions providers

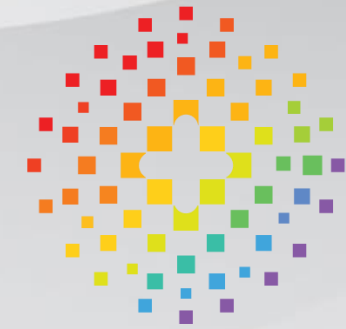
Mission: To inspire and empower engineers to design products that perceive and understand.

The Alliance provides low-cost, high-quality technical educational resources for product developers

Register for updates at [www.edge-ai-vision.com](http://www.edge-ai-vision.com)

The Alliance enables edge AI and vision technology providers to grow their businesses through leads, partnerships, and insights

For membership, email us: [membership@edge-ai-vision.com](mailto:membership@edge-ai-vision.com)



edge ai + vision  
ALLIANCE™



# Join us at the Embedded Vision Summit

May 17-19, 2022—Santa Clara, California



*The only industry event focused on practical techniques and technologies for system and application creators*

- *“Awesome! I was very inspired!”*
- *“Fantastic. Learned a lot and met great people.”*
- *“Wonderful speakers and informative exhibits!”*

## Embedded Vision Summit 2022 highlights:

- **Inspiring keynotes** by leading innovators
- High-quality, practical **technical, business and product talks**
- Exciting **demos, tutorials** and **expert bars** of the latest applications and technologies



Visit [www.EmbeddedVisionSummit.com](http://www.EmbeddedVisionSummit.com) to learn more

