LEARNING FROM EVENTS:

ON THE FUTURE OF MACHINE LEARNING FOR EVENT-BASED CAMERAS

Second International Workshop on Event-based Vision and Smart Cameras

June 17, CVPR 2019, Long Beach

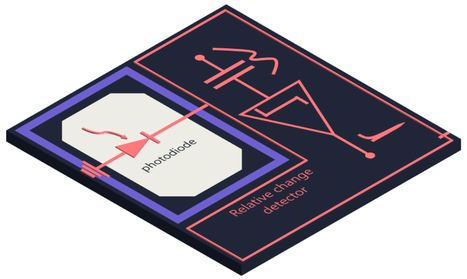
AMOS SIRONI

PROPHESEE

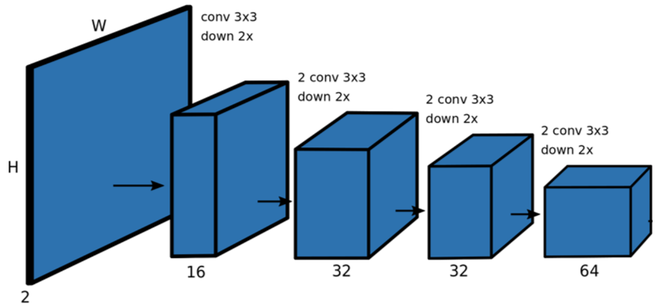
METAVISION FOR MACHINES

LEARNING FROM EVENTS: OUTLINE

THE SENSOR



THE PRESENT



THE FUTURE

LEARNING FROM EVENTS

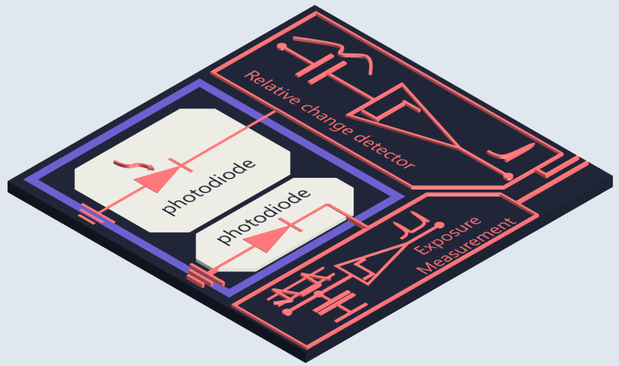
THE SENSOR

PIXEL EVOLUTION

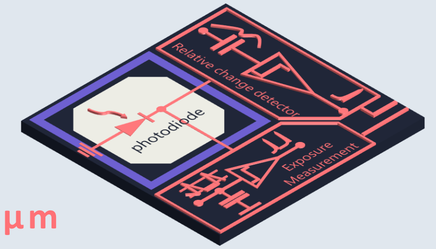
GEN 1	GEN 2	GEN 3	GEN 4
2014	2016	2017	2018

ATIS

ATIS 30 µm
180nm CMOS
304 x 240



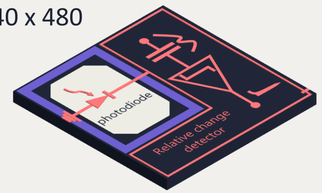
ATIS 20 µm
180nm CIS
480 x 360
20% fill factor
Single photodiode



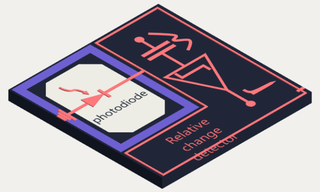
ATIS

CD

CD 15 µm
180nm CMOS
640 x 480



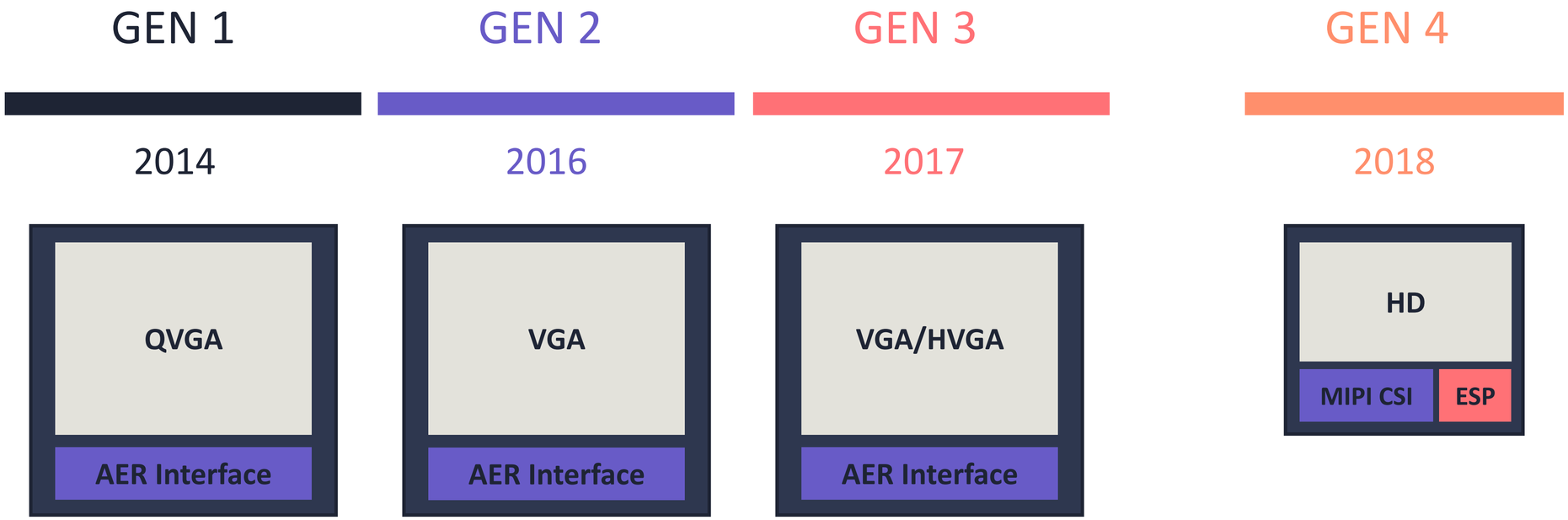
CD 15 µm
180nm CIS
640 x 480
25% fill factor



CD

PROPHESEE

SENSOR EVOLUTION



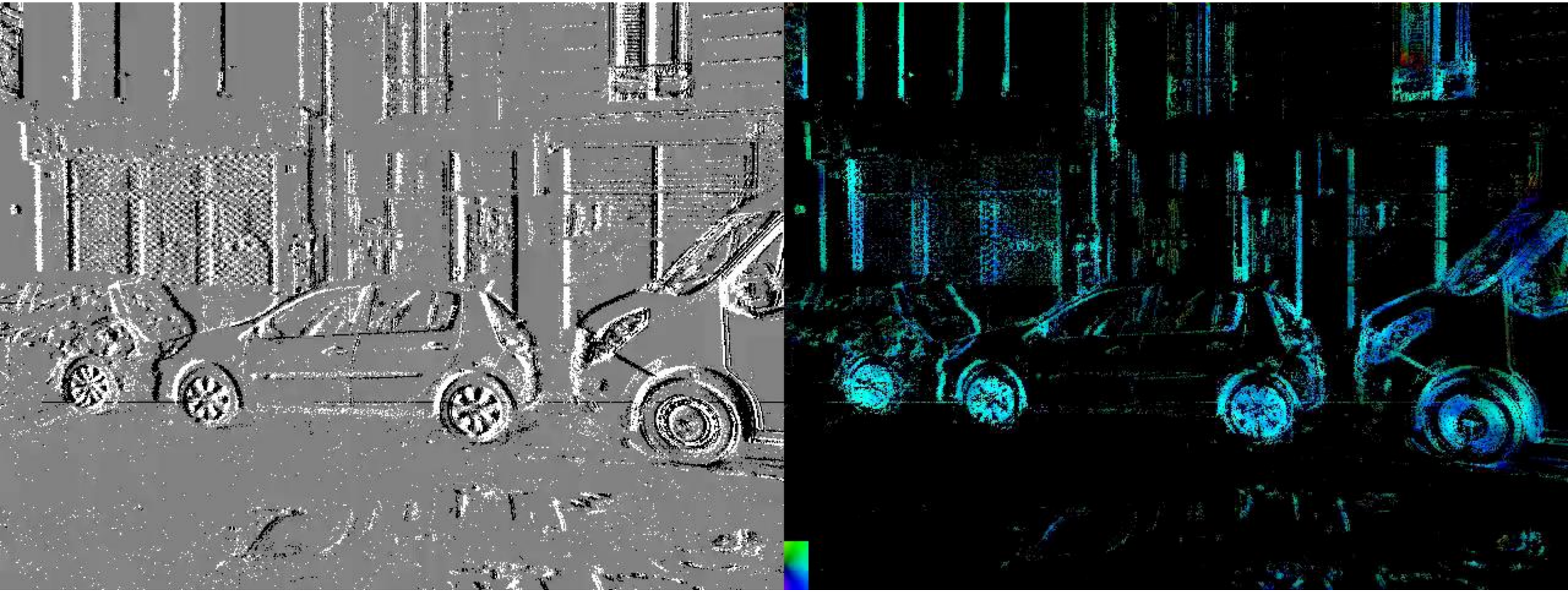
From custom interface to industry standard MIPI CSI

From raw data to pre-processed data with dedicated Event Signal Processor (ESP)

LEARNING FROM EVENTS

THE PRESENT

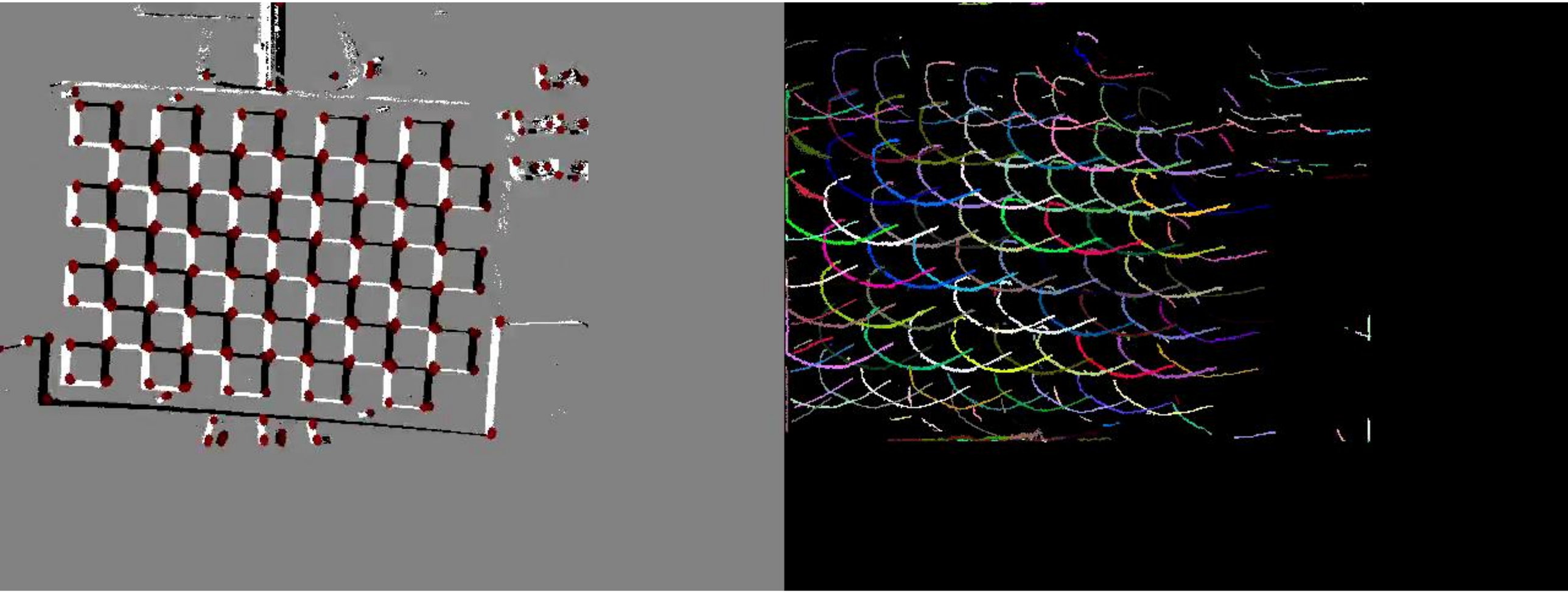
LEARNING OPTICAL FLOW



- 50HZ INFERENCE ON VGA SENSOR ON LAPTOP GPU
- 3.2M PARAMETERS (CFR. EV-FLOWNET 36M [1])

[1] ZHU, A. Z., YUAN, L., CHANEY, K., & DANIILIDIS, K. (2018). EV-FLOWNET: SELF-SUPERVISED OPTICAL FLOW ESTIMATION FOR EVENT-BASED CAMERAS

LEARNING FEATURE POINTS



- 1.6MEV/S ON HVGA SENSOR ON LAPTOP CPU
- DATASET AVAILABLE ONLINE: PROPHESEE.AI/HVGA-ATIS-CORNER-DATASET/

POSTER SESSION 3.1. MANDERSCHEID, J., SIRONI, A., BOURDIS, N., MIGLIORE, D., & LEPETIT, V. (2019). SPEED INVARIANT TIME SURFACE FOR LEARNING TO DETECT CORNER POINTS WITH EVENT-BASED CAMERAS.

PROPHESEE

OBJECT DETECTION

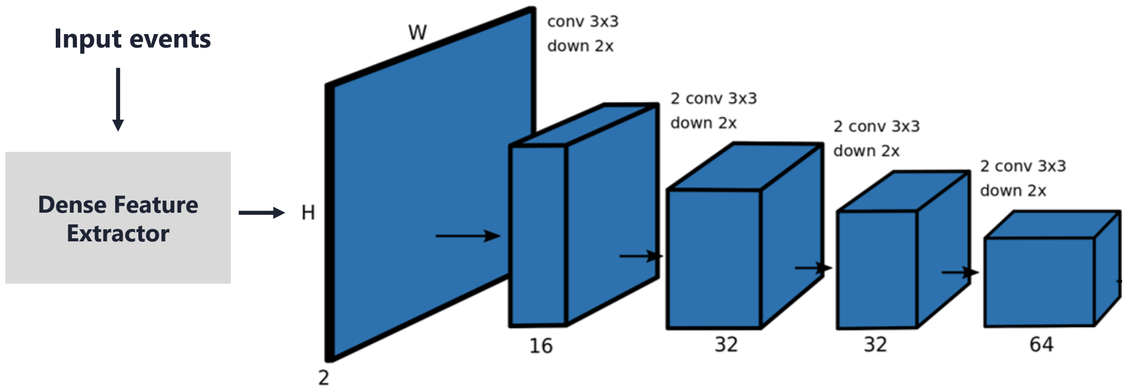
- 50HZ INFERENCE VGA SENSOR ON MOBILE PHONE (CFR. MOBILENET-V2 13HZ)
- 7.1M PARAMETERS

LEARNING FROM EVENTS: TODAY

TWO MAIN APPROACHES

DENSE

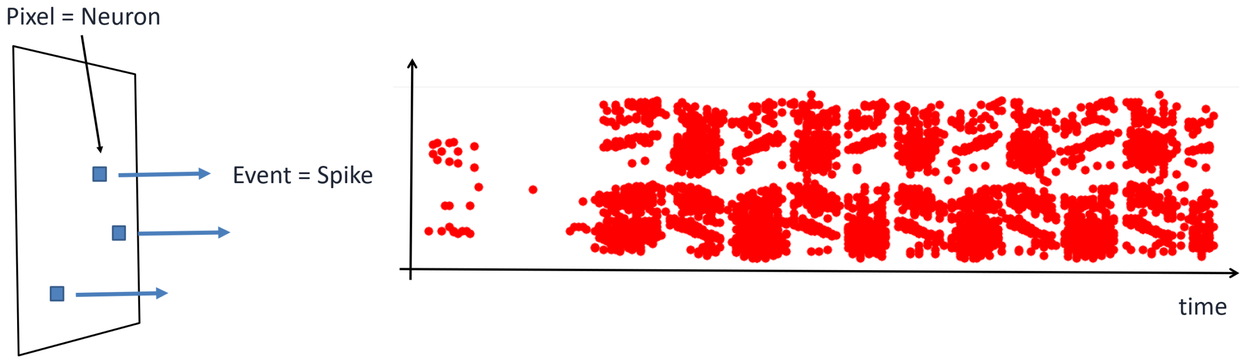
- Example: histograms, time surfaces, ...



- ⊕ Can leverage Frame-based Algorithm and Hardware
- ⊖ Latency, Power Consumption, Lose Sparsity

SPARSE

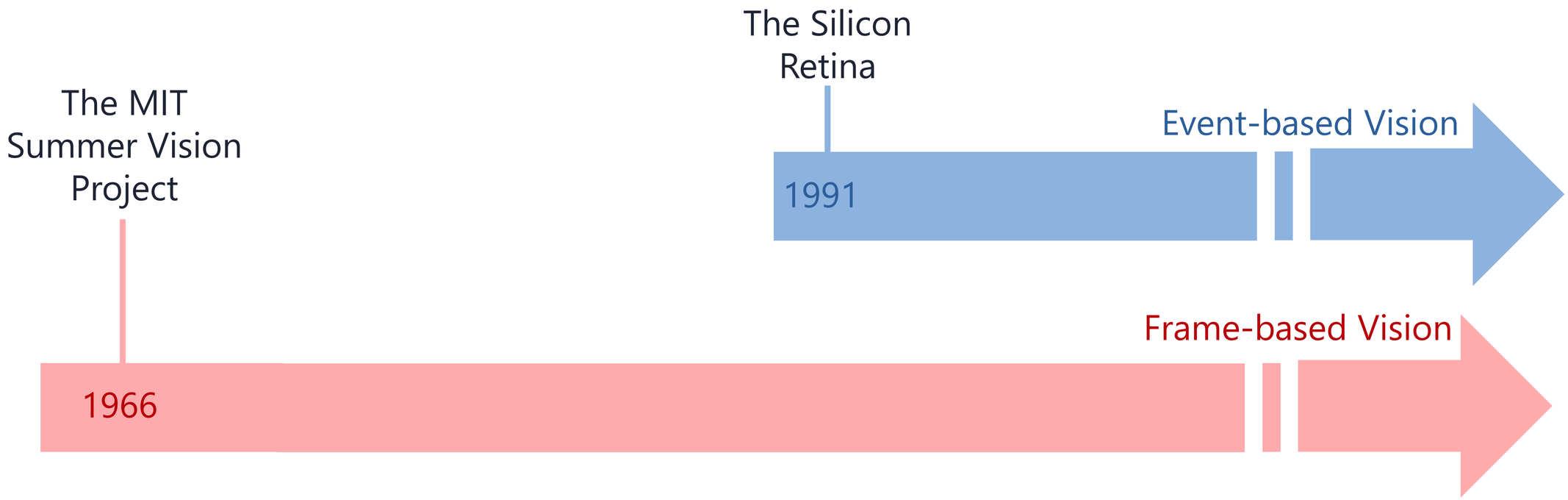
- Example: Spiking Neural Networks



- ⊕ Low latency, Low Computation
- ⊖ Limited in Size and Resolution, Limited by Hardware

LEARNING FROM EVENTS: TODAY

EVENT-BASED VISION IS STILL AT ITS EARLY STAGES

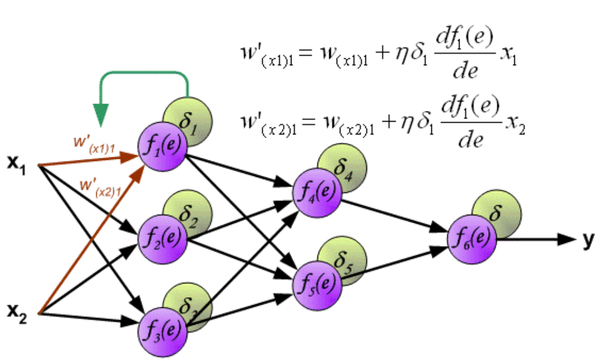


LEARNING FROM EVENTS

THE FUTURE

LESSONS FROM FRAME-BASED AI

WHAT MADE SUCCESS OF MODERN AI?



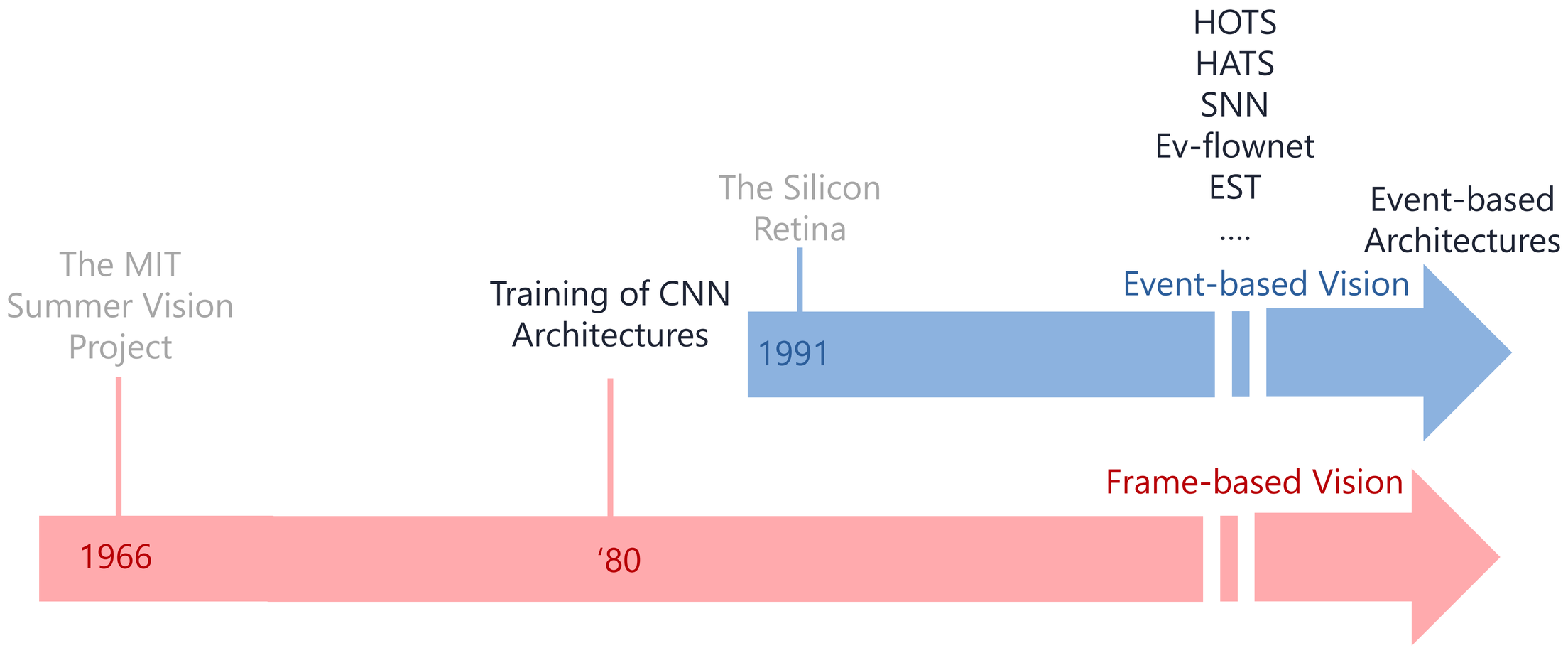
Learning Algorithms

Dedicated Hardware

Large Datasets

EVENT-BASED VISION SHOULD MOVE IN SAME DIRECTION, BUT FASTER

FUTURE EVENT-BASED AI:
ALGORITHMS



FUTURE EVENT-BASED AI:
ALGORITHMS

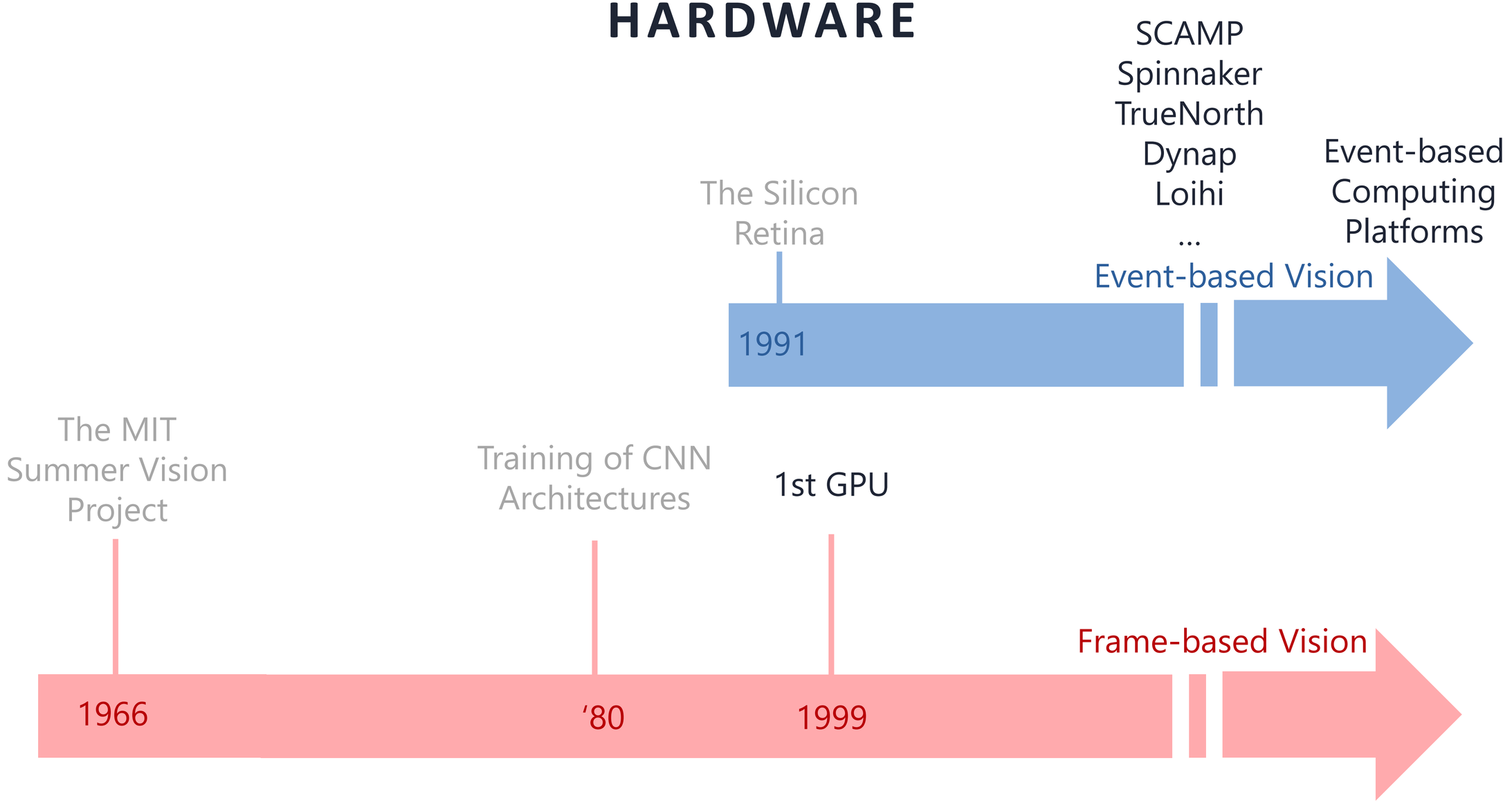
EVENT-BASED AI SHOULD FOCUS ON SENSOR SPECIFIC ADVANTAGES

- Exploit sparsity
- Temporal Information

FUTURE EVENT-BASED AI:
ALGORITHMS

EVENT-BASED MODELS WILL LEARN WITH MEMORY

FUTURE EVENT-BASED AI:
HARDWARE



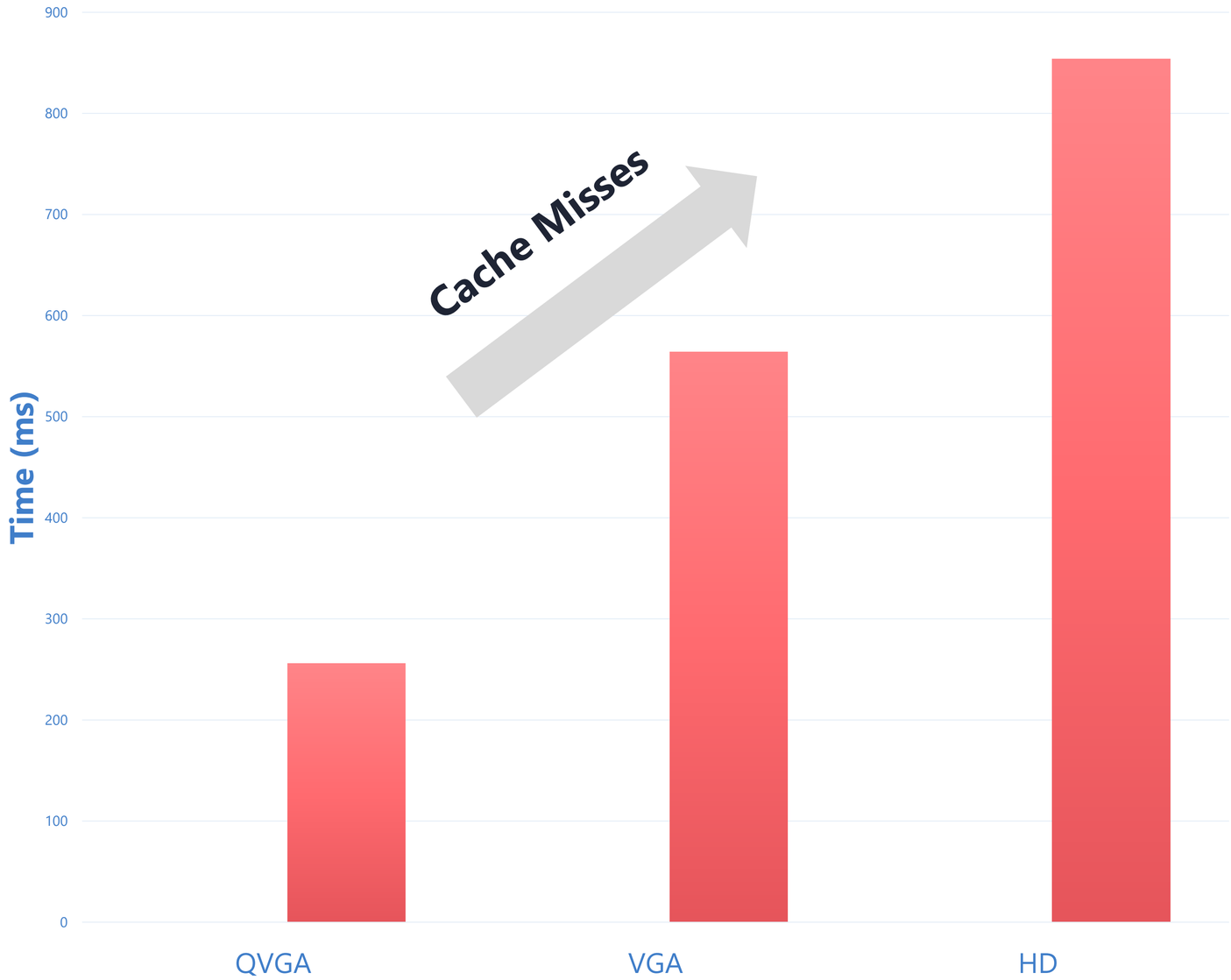
FUTURE EVENT-BASED AI:
HARDWARE

Build histogram H:

for each $e = (x, y, p, t)$

$$H(x, y) \mathrel{+}= 1$$

- Fixed number of events
- Change resolution of H (from QVGA to HD)

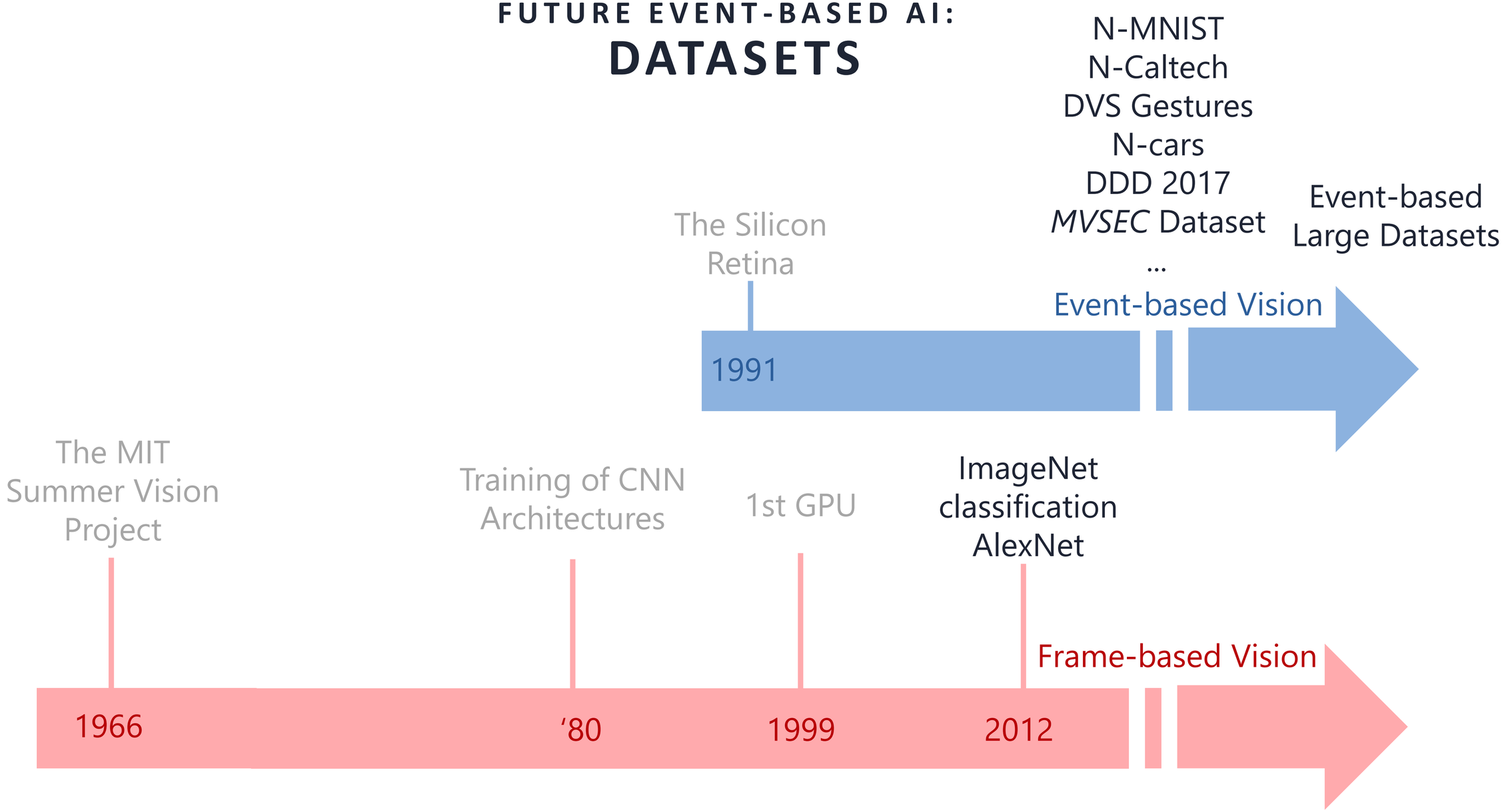


FUTURE EVENT-BASED AI:

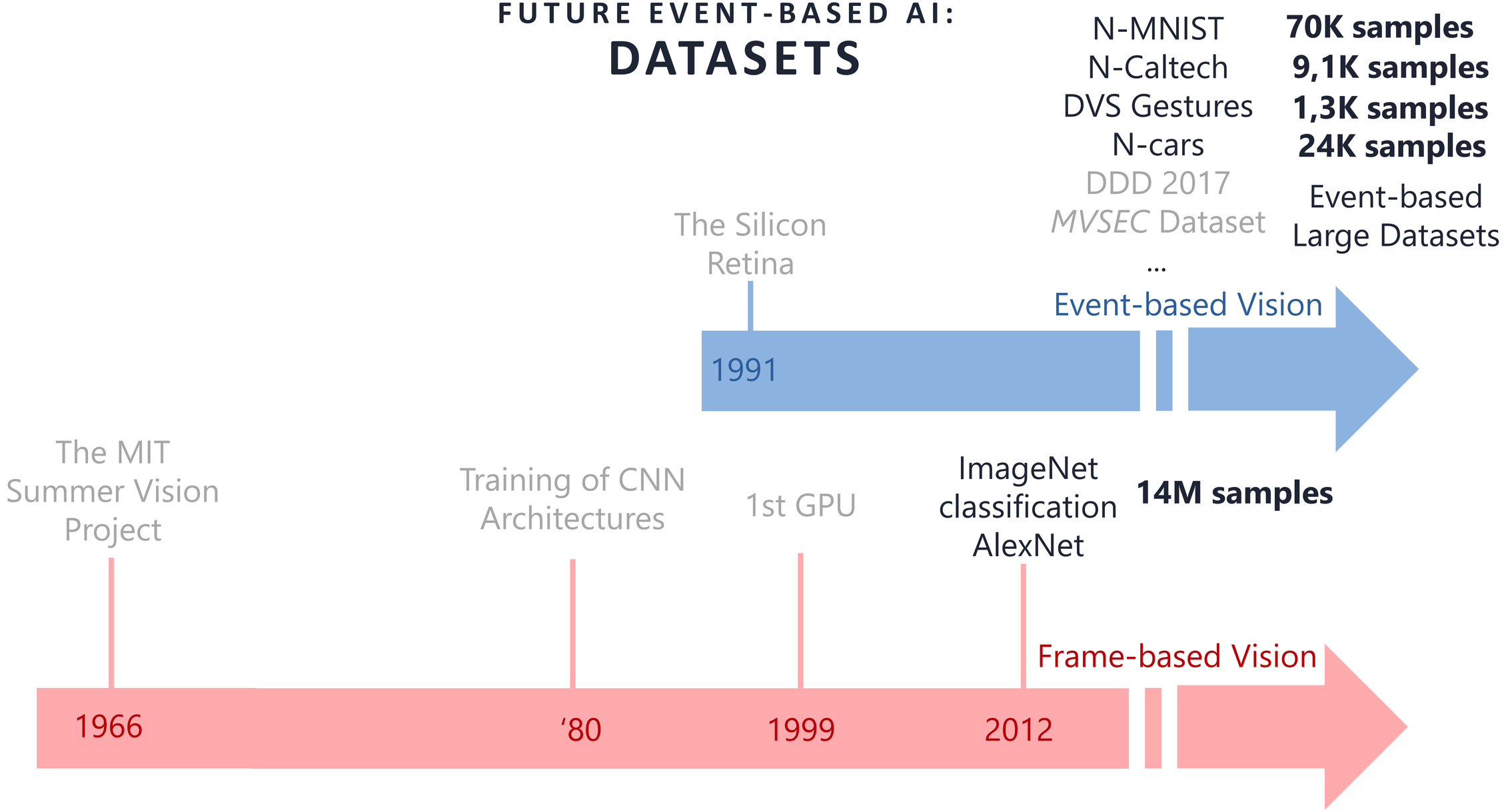
HARDWARE

AFTER THE SILICON RETINA WE NEED A SILICON VISUAL CORTEX (V1)

FUTURE EVENT-BASED AI:
DATASETS



FUTURE EVENT-BASED AI:
DATASETS



FUTURE EVENT-BASED AI:
DATASETS

- CVPR'18: PROPHESEE N-CARS DATASETS

- CVPR'19: PROPHESEE HVGA CORNER DATASET

RELEASE: Q4 2019

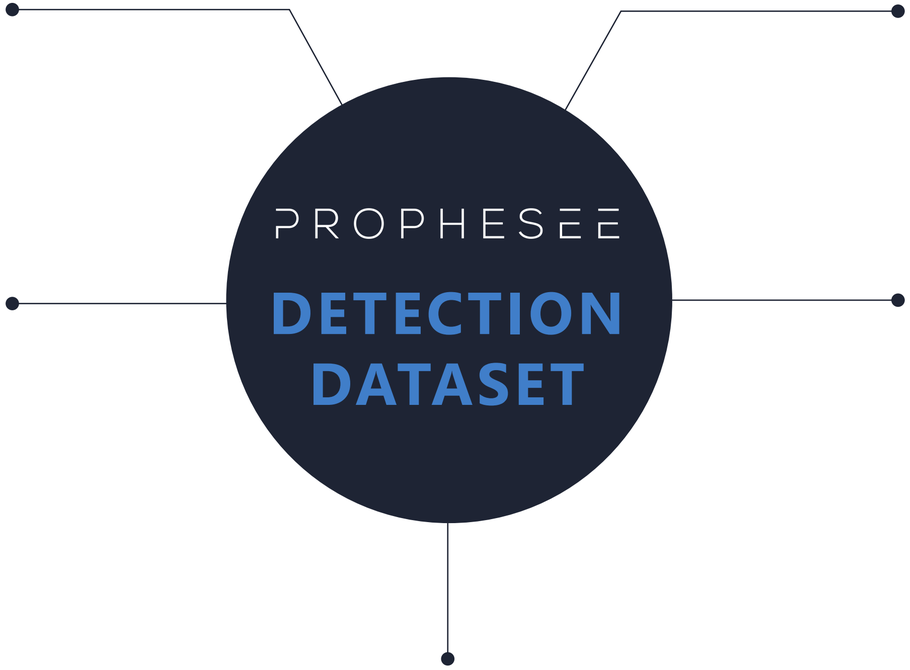
PROPHESEE

DETECTION DATASET

FUTURE EVENT-BASED AI:
DATASETS

10 HOURS
of recording

EQUIPMENT
ATIS (QVGA)
Events + Gray Levels



177,000
CARS and PEDESTRIANS
Bounding Boxes

DRIVING SCENARIOS
Urban, Highway, Countryside

RELEASE: Q4 2019

LEARNING FROM EVENTS:
CONCLUSION

RESOLUTION	ARCHITECTURE	HARDWARE	DATASET
Event-Based sensor resolution is increasing	Event-Based architectures will use memory	Event-Based AI will run on dedicated hardware	Training and validation is done on large dataset

COME VISIT US

BOOTH: 1752

POSTER SESSION:

THURSDAY

10.00 – 12.45

PROPHESEE

METAVISION FOR MACHINES