CHRONOCAM®

A NEW NEUROMORPHIC STRATEGY FOR THE FUTURE OF VISION FOR MACHINES

June 2017

–

Xavier Lagorce – Head of Computer Vision & Systems

Imagine meeting the promise of...

- **Restoring** sight to the blind
- **Accident-free** autonomous vehicles
- **High-speed** collision avoidance
- **Harmonious** human/robot collaboration
- **Surveillance** without power drain

This is reality for...

A paradigm shift is coming to **computer vision**

A 4th disruption in image sensors

SENSING

(not solely related to 'Pretty Picture' parameters)

MARKET

Film Photography | Digital Photography | Mobile Photography

1865 — 1945 — 2005 — 2015 — 2020

TECHNOLOGY

TUBES | CCD | CMOS | CMOS+ (Enhanced 3D Stacking focusing on full solution at edge)

Frame-based → **Event-based**

From Imaging «frames»...

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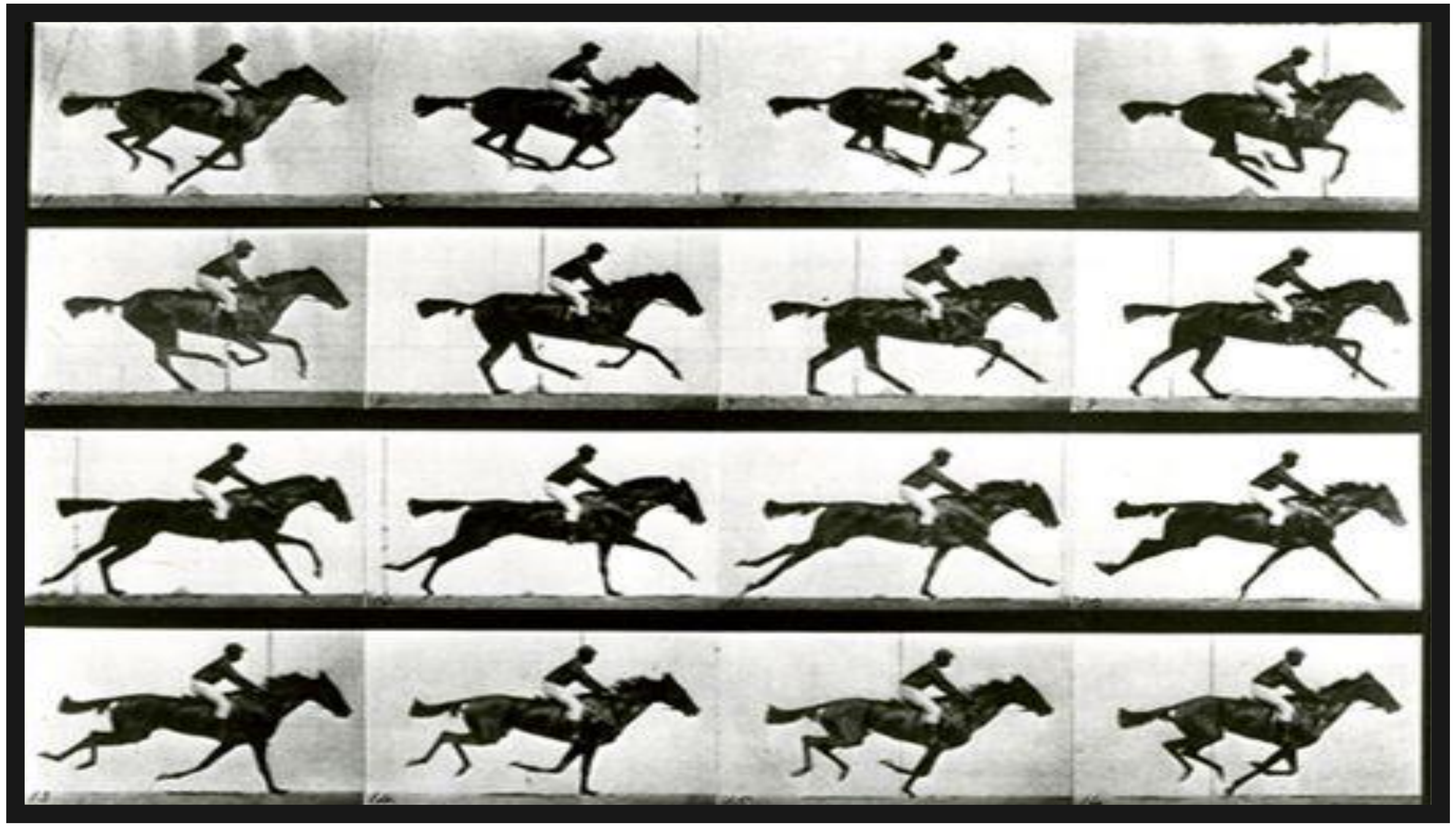
Adapted for static images, an impossible trade off – power vs frame rate

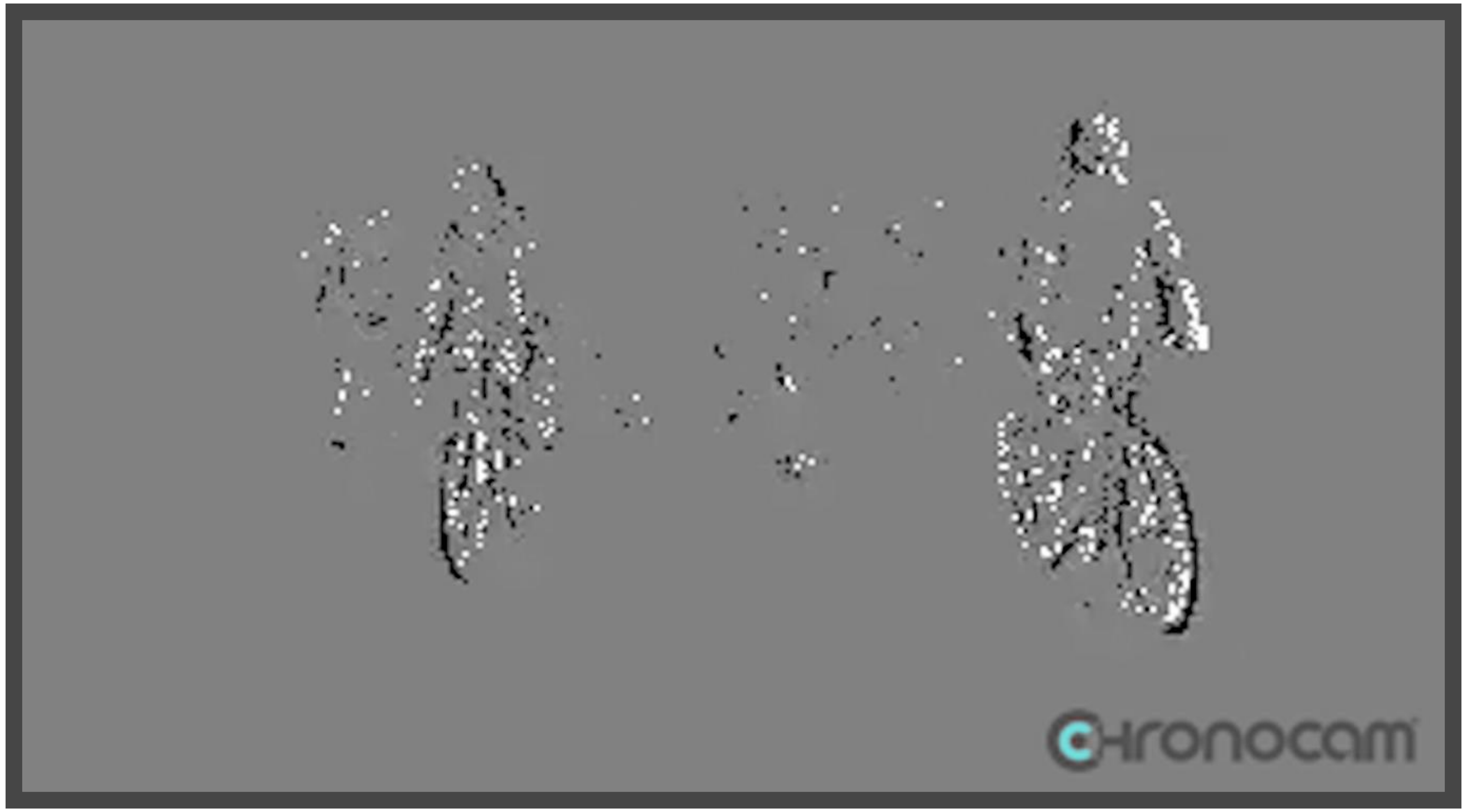


- **Data redundancy**
- **Information loss**
- **Light-dependent**

...to Sensing « events »

–

By capturing only changes in a scene,
event-based computer vision is optimized for dynamic applications



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- Redundancy-free 1000x less data
- Ultra high speed Microseconds precision
- Wide dynamic range 140+ dB

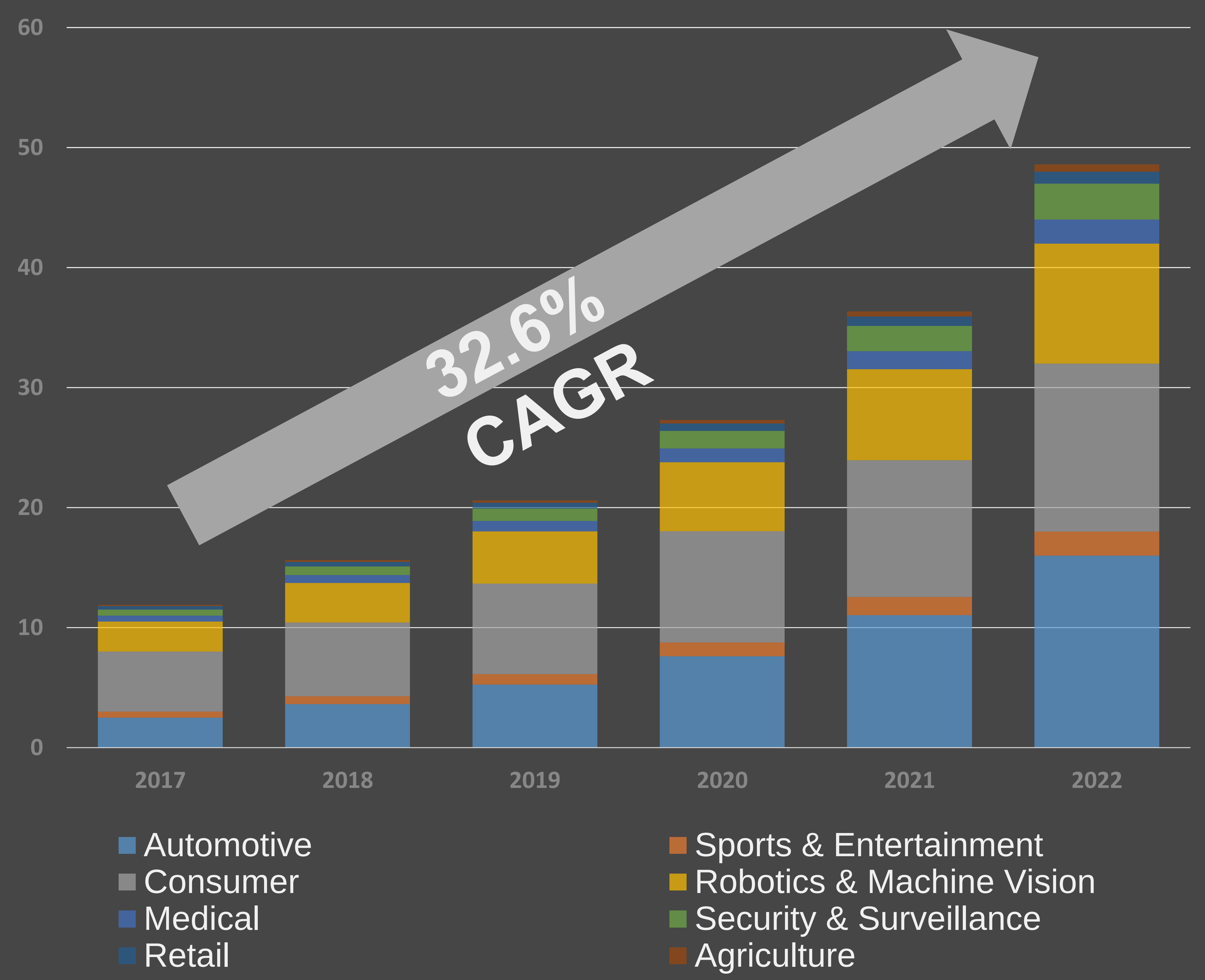
Computer vision market: ~$50B by 2022

TOTAL UNITS(*)

Mobile	6B
Automotive	300M
Consumer	200M
Industrial Automation	150M
Wearable	150M
Surveillance	125M
Robotics	20M
Medical Devices	6M

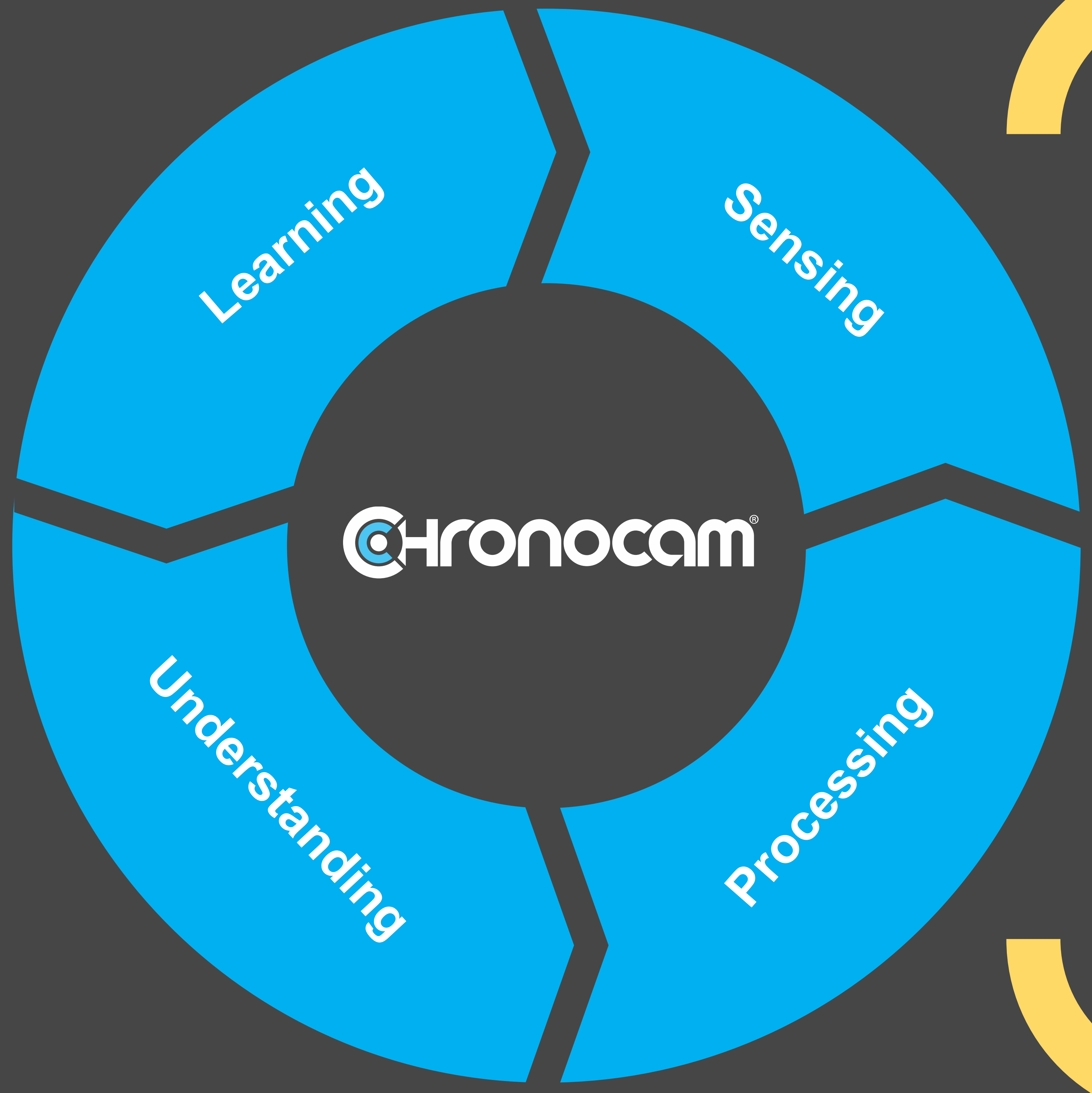
(*) vision sensors in units sold in 2020

PROJECTED REVENUE GROWTH ($B)



Sources: Tractica, Yole, M&M, Internal Analyses

A complete event-based computer vision solution



AUTOMOTIVE:
$8B in 2020

5Y CAGR: **44.8%**

Examples:
Collision Warning
Line Warning Detection
Sign Recognition
Driver Assistance & Monitoring

INDUSTRIAL:
$6B in 2020

5Y CAGR: **31.1%**

Examples:
Inspection
Autonomous Guided Vehicles
Collaborative Robots
Pick & Place

SMART IOT:
$10B in 2020

5Y CAGR: **33.2%**

Examples:
Smart City - monitoring
Smart Home – wake-up
Smart workplace – security & surveillance

PROSUMER:
$6B in 2020

5Y CAGR: **22.5%**

Examples:
AR/VR/MR
Wearables
Health Monitoring

Sources: Tractica, Yole, M&M, Internal Analyses

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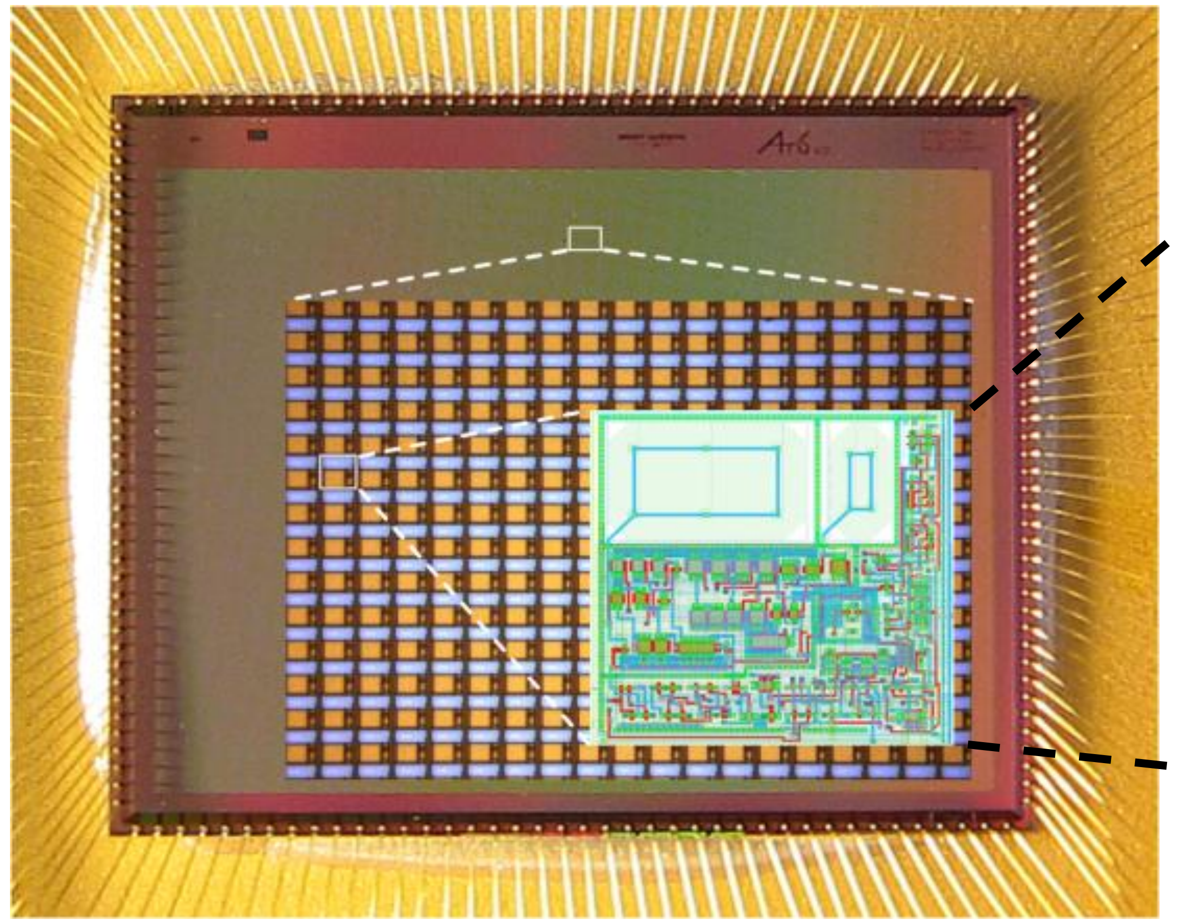
Event-based computer vision

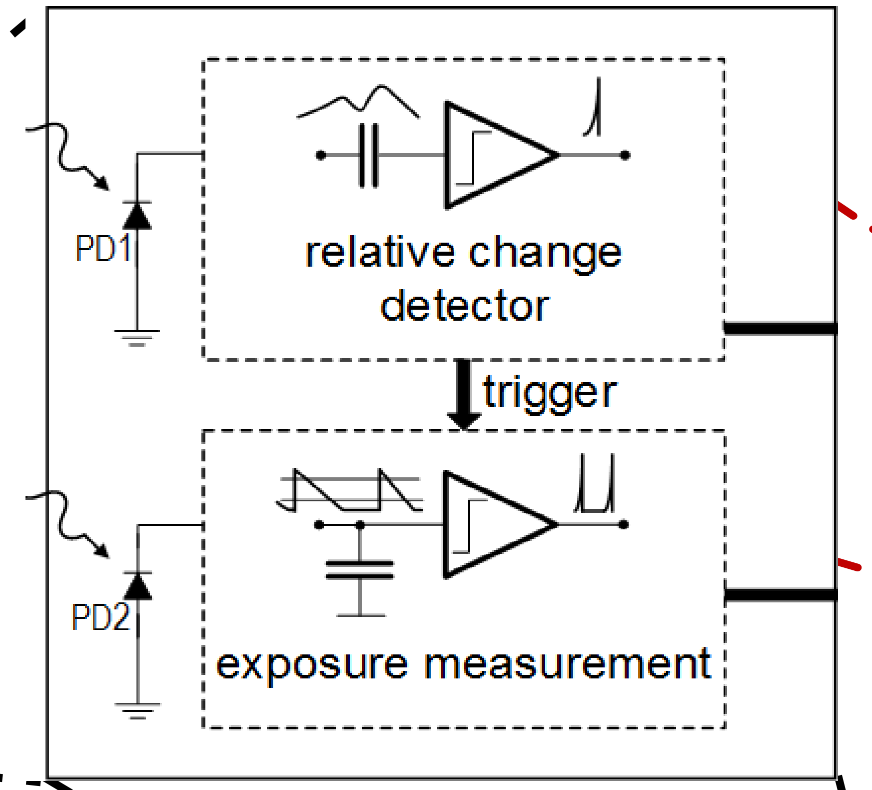
Computer vision: Inspired by Biology

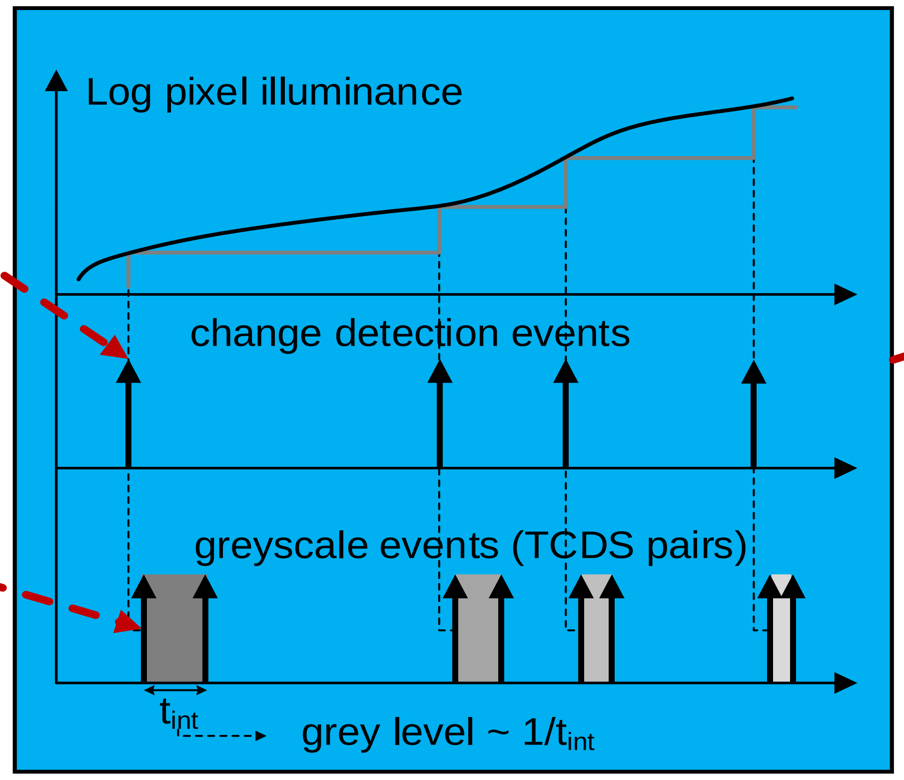
More efficient visual information acquisition

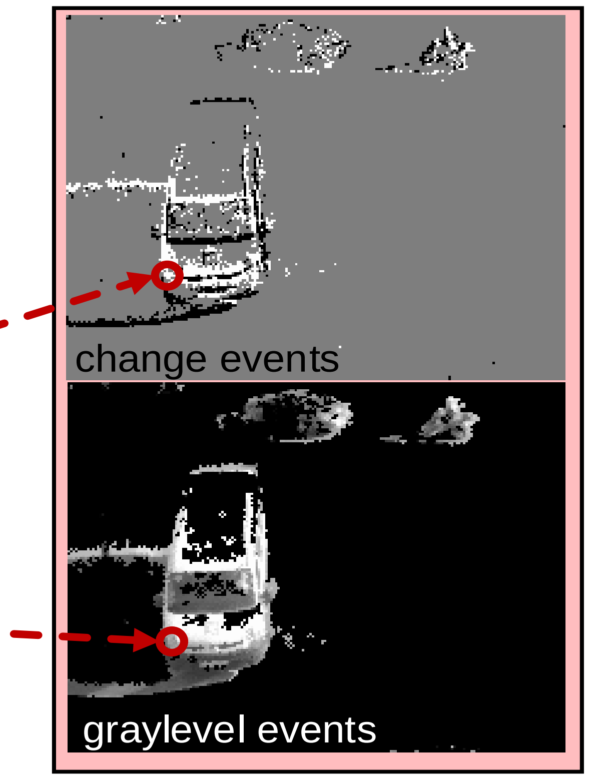
- Biological vision does not use “images” to see
- Machine vision needs “vision”, not “images”
- Event-based vision uses pixels to capture relevant information and only the changes in a scene

Pixel controlled sensor: adapted for dynamic scenes



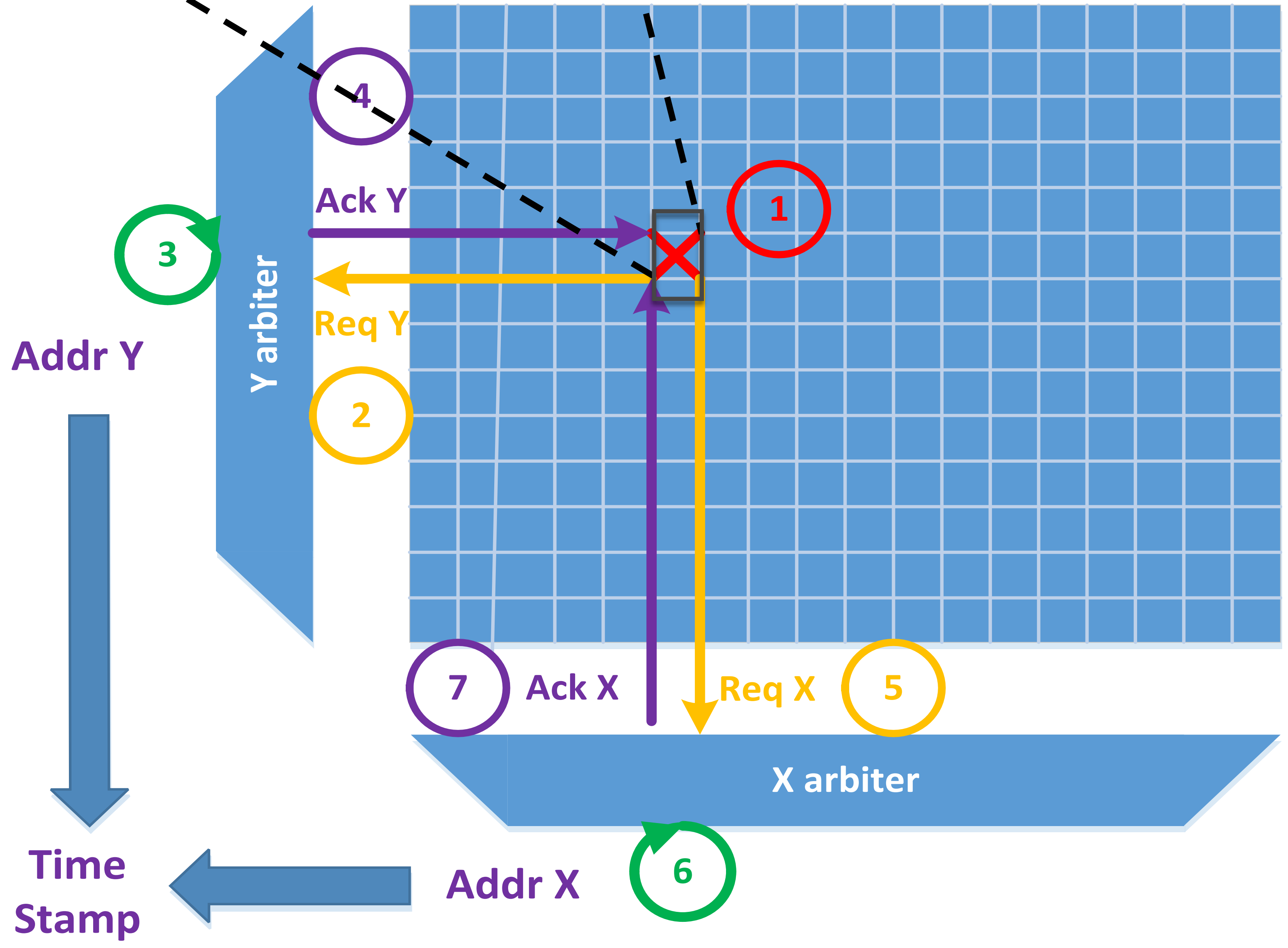






Each pixel individually controls its own sampling rate

- "Active" when signal changes
- "Inactive" when no changes



What this means:

- Auto-sampling of pixels
- Pixel-individual optimization of sampling
- Zero-redundancy sampling
- Time-domain encoding of exposure

Results

- High-speed response (sub-millisecond)
- Low data rate (10-1000x less data)
- Wide dynamic range (120-140 dB)
- Low-power operation (<10mW, QVGA)

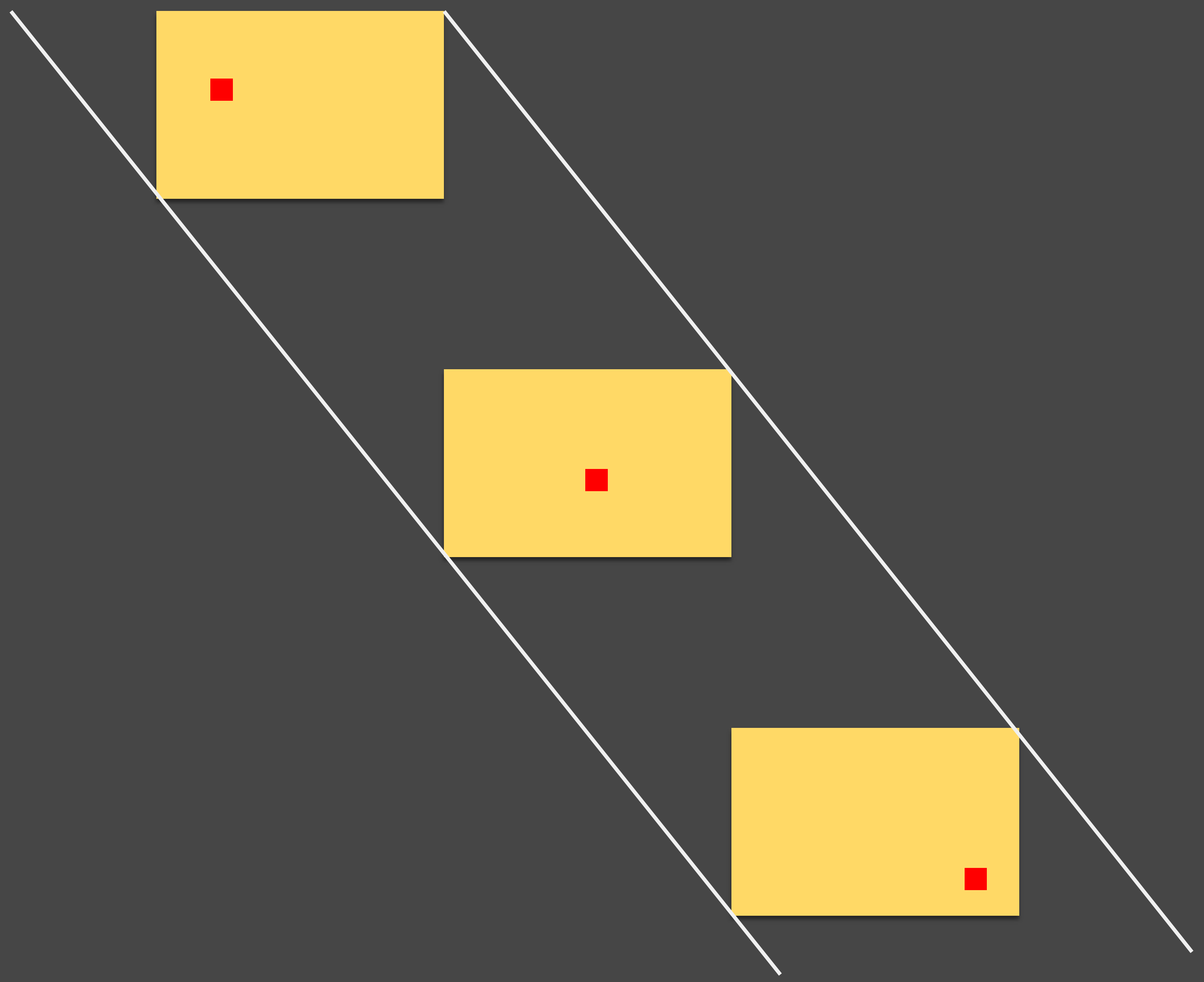
Benefits

- Real-time vision processing: tracking, motion flow, 3D reconstruction, … with millisecond to microsecond update rates

CCAM High Speed Tracking

Event imaging // Frames are absent from the acquisition process

STANDARD CAMERA



FIXED SAMPLING RATE

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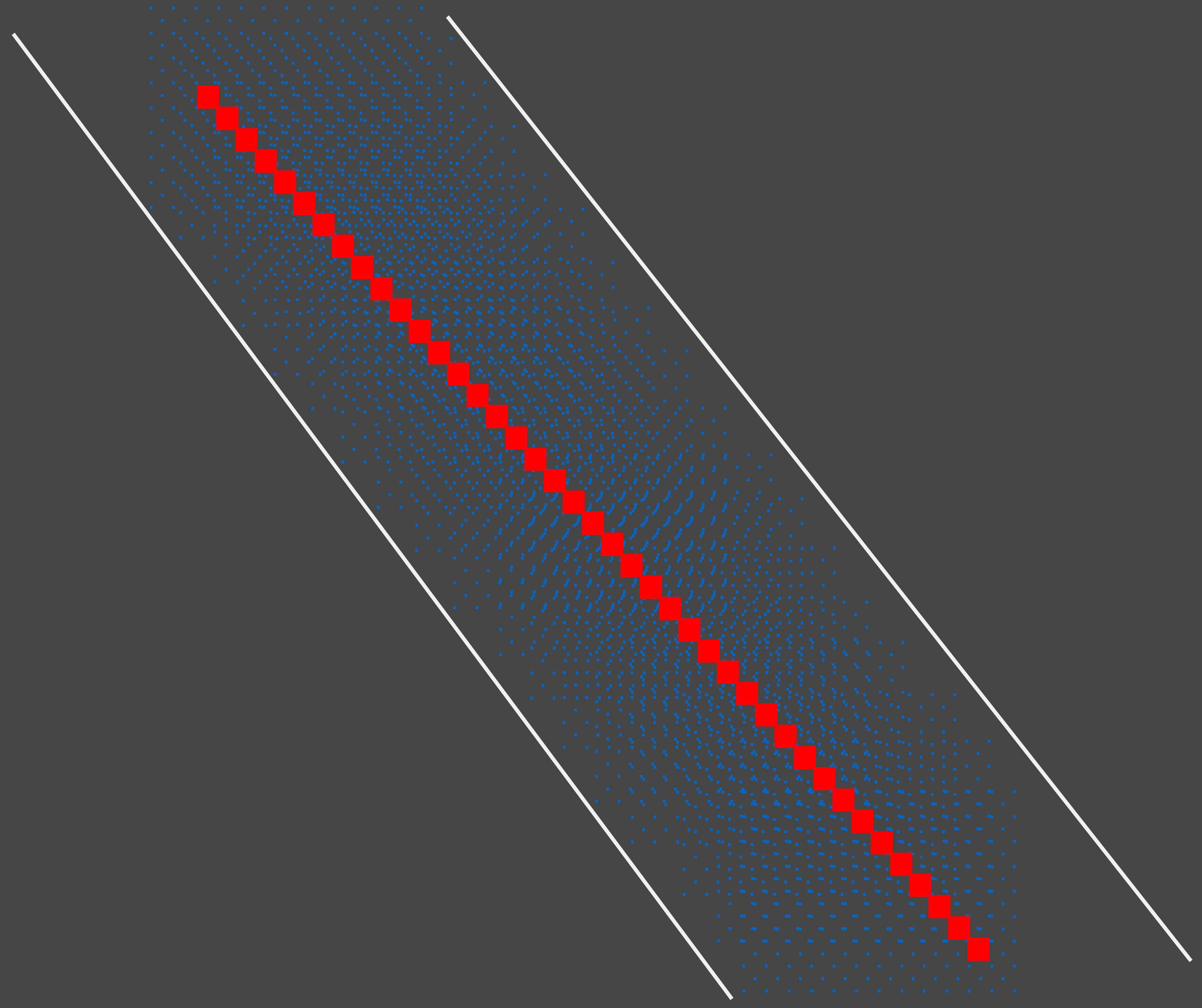
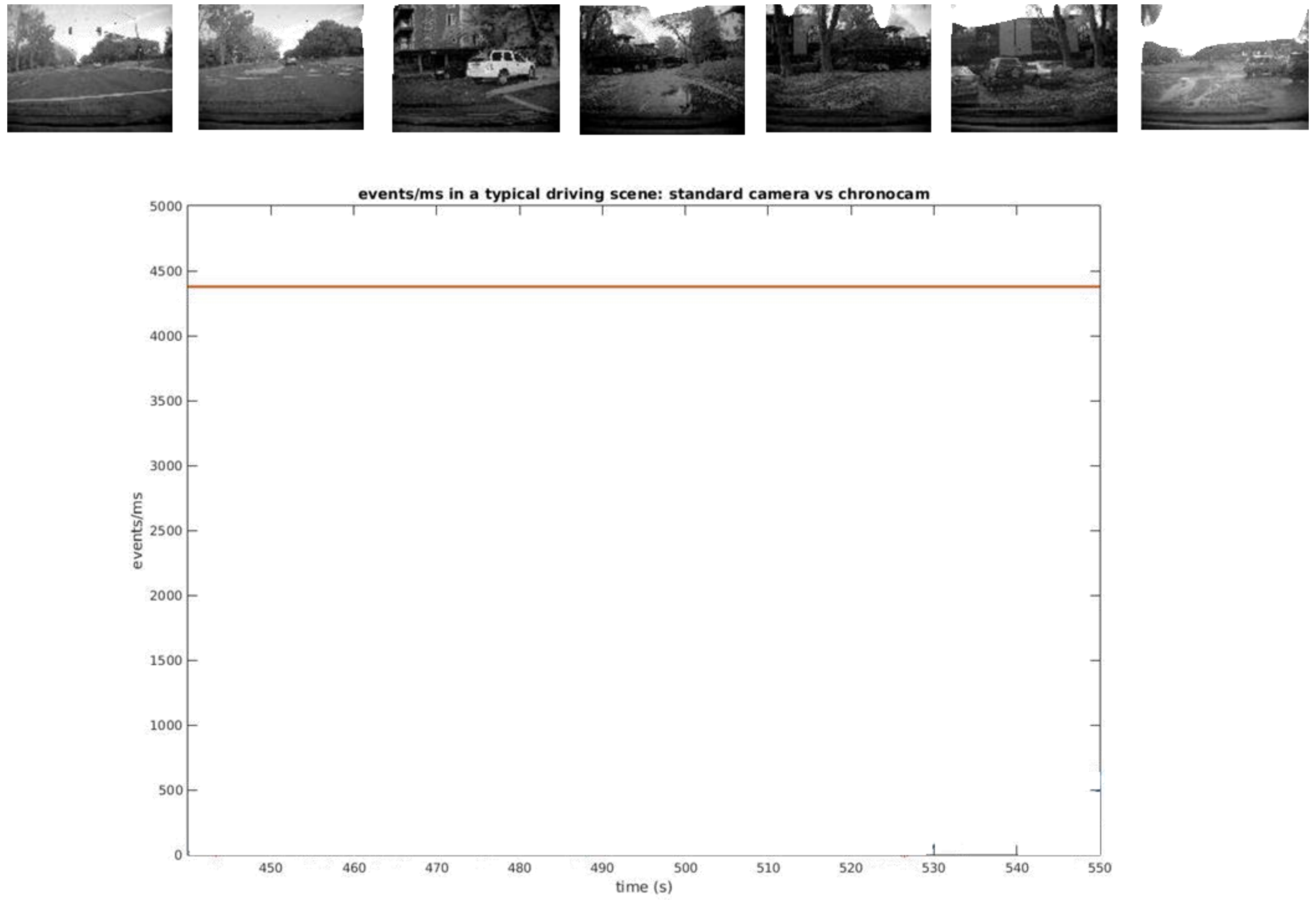


µS EVENTS SAMPLING

Event imaging impact: Low Bandwidth

STANDARD CAMERA



CONSTANT HIGH BANDWIDTH
NEEDS DECODE/ENCODE TO STREAM

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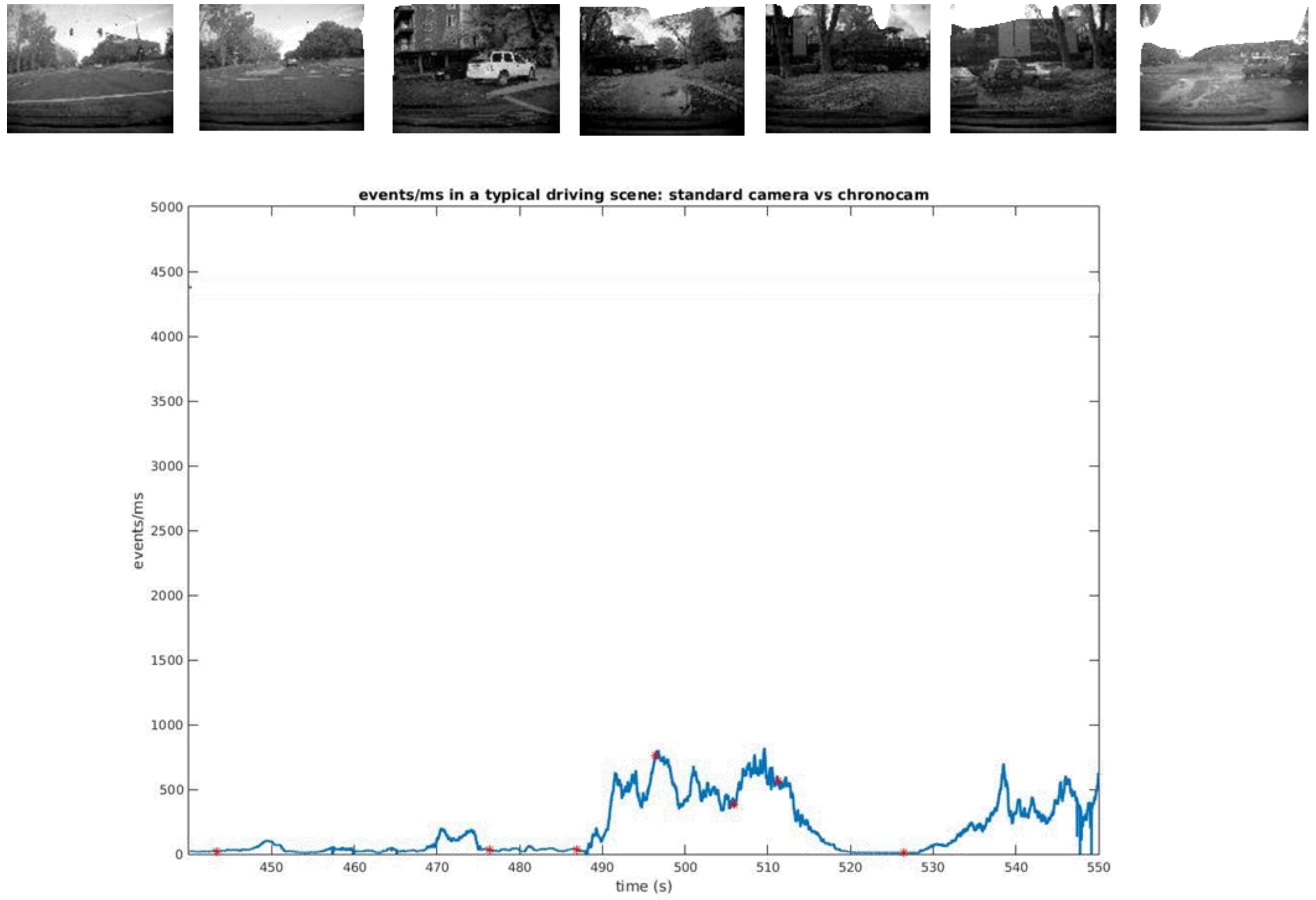
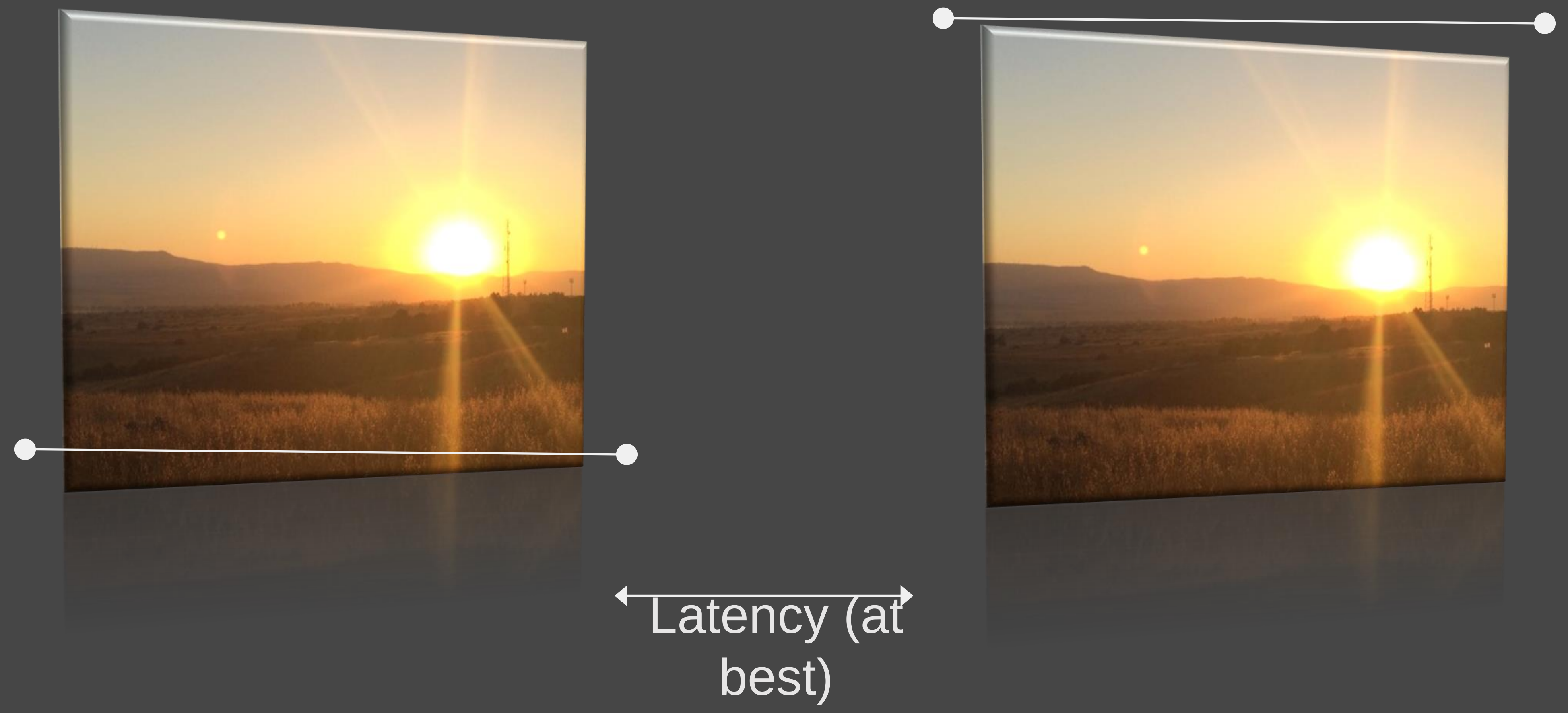


SCENE-OPTIMIZED BANDWIDTH
STREAM CAN BE PROCESSED DIRECTLY

Event Imaging impact: Ultra-High Speed

STANDARD CAMERA



THE SLOWEST PIXEL ACQUISITION

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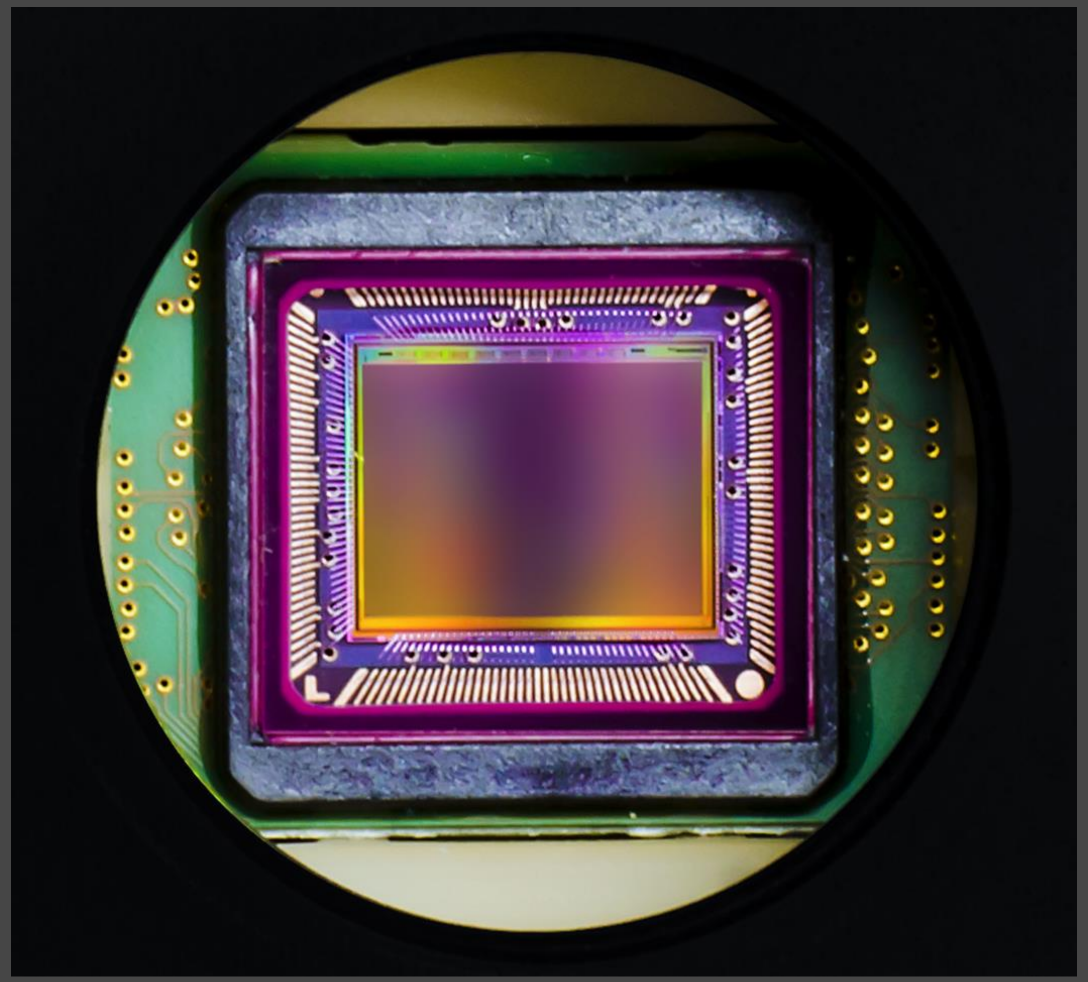
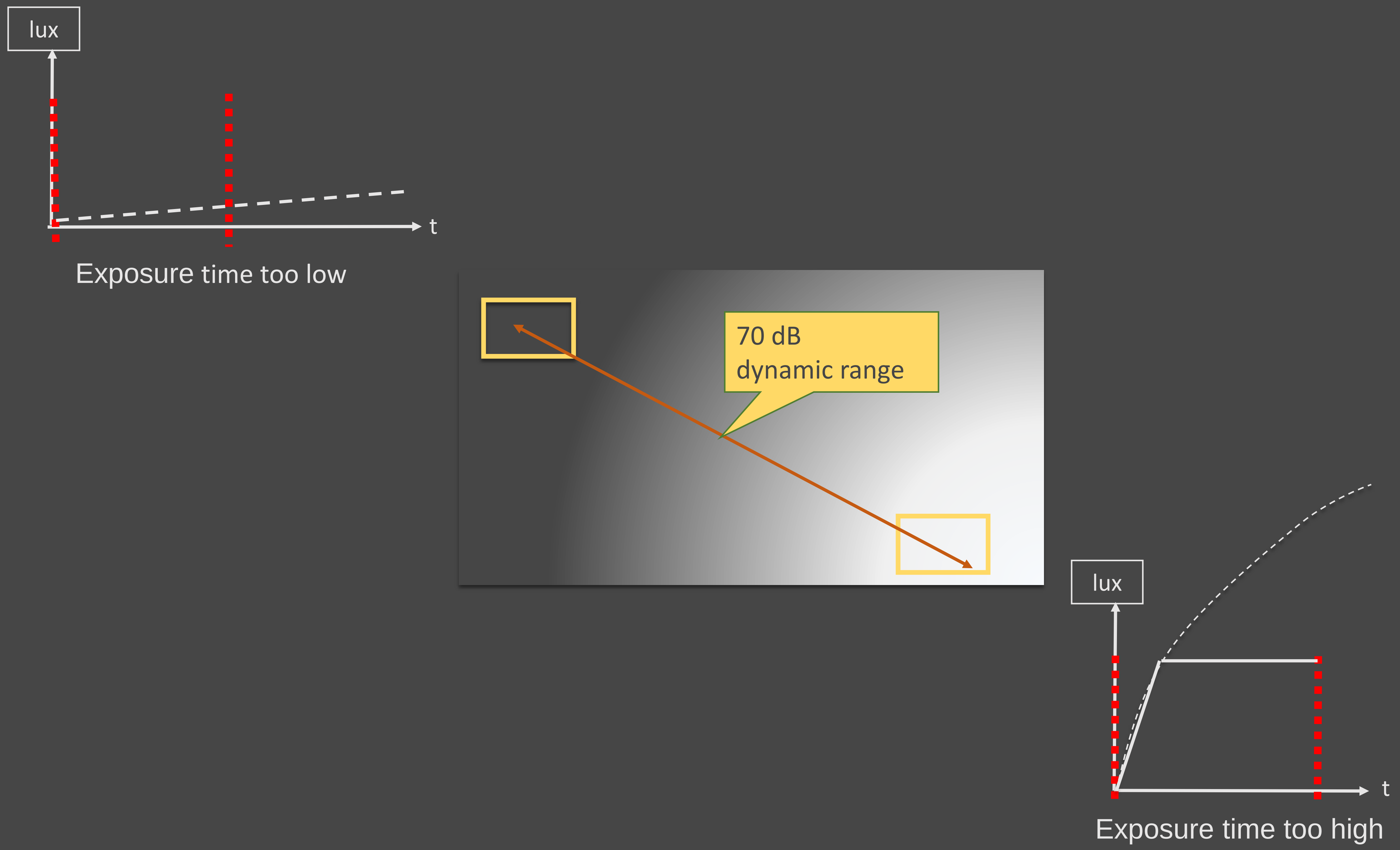


Latency of **~1ms** based on sensor's acquisition speed

ASYNCHRONOUS PIXEL

Pixel exposure impact: High Dynamic Range

STANDARD CAMERA



UNIFORM EXPOSURE

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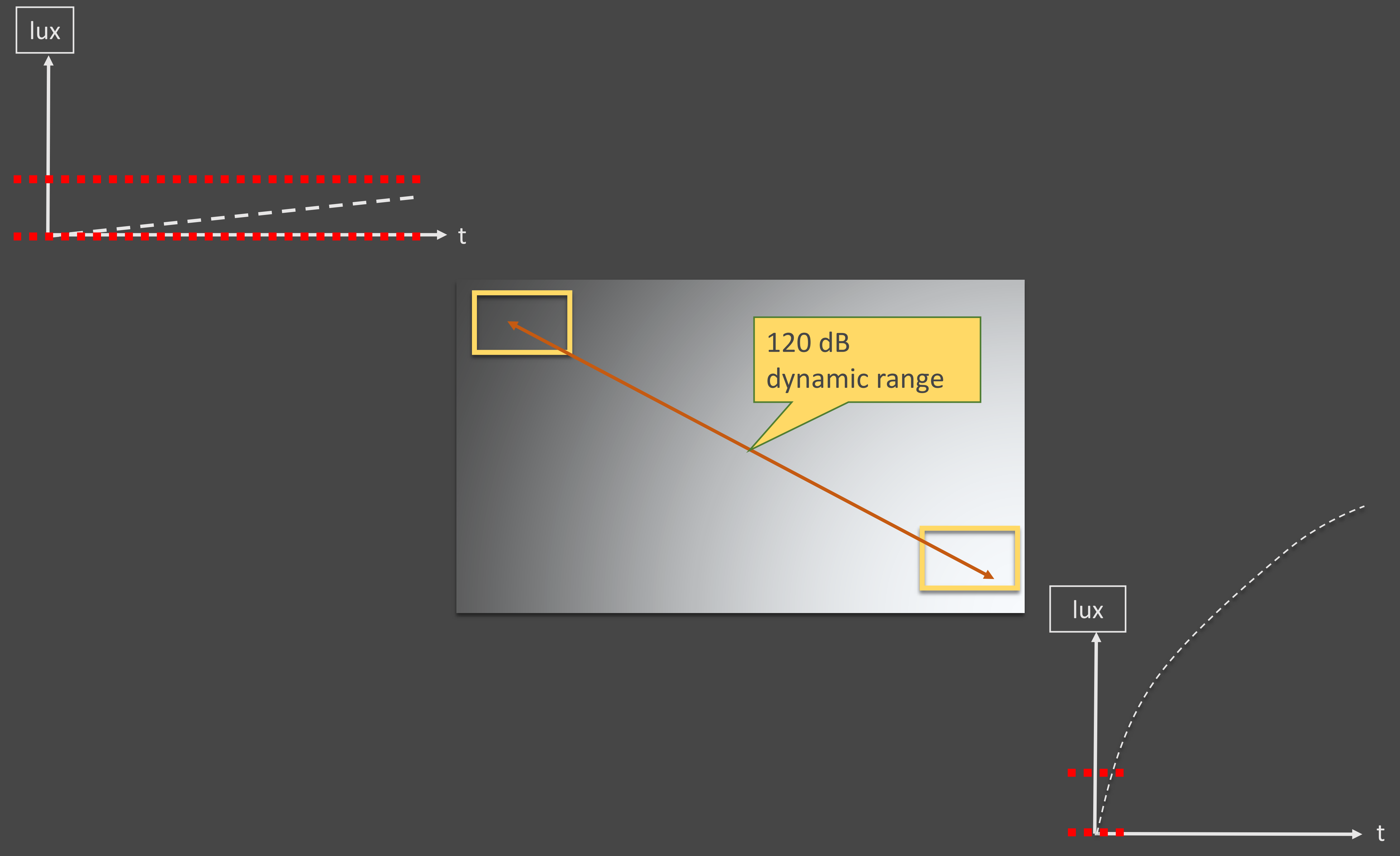
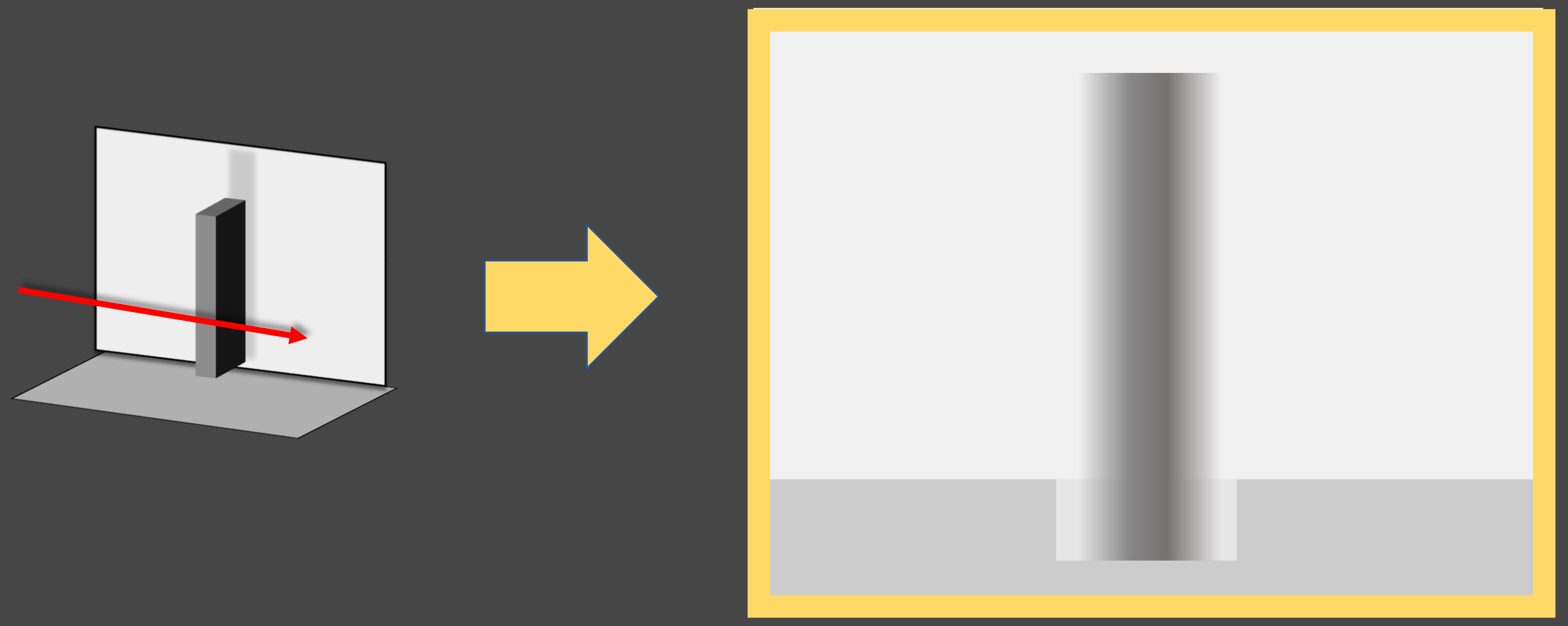


PER-PIXEL SELF-ADJUSTED EXPOSURE

Pixel exposure impact: No Motion Blur

STANDARD CAMERA



UNIFORM EXPOSURE SET ON THE SCENE
-> HIGH COMPARED TO SPEED

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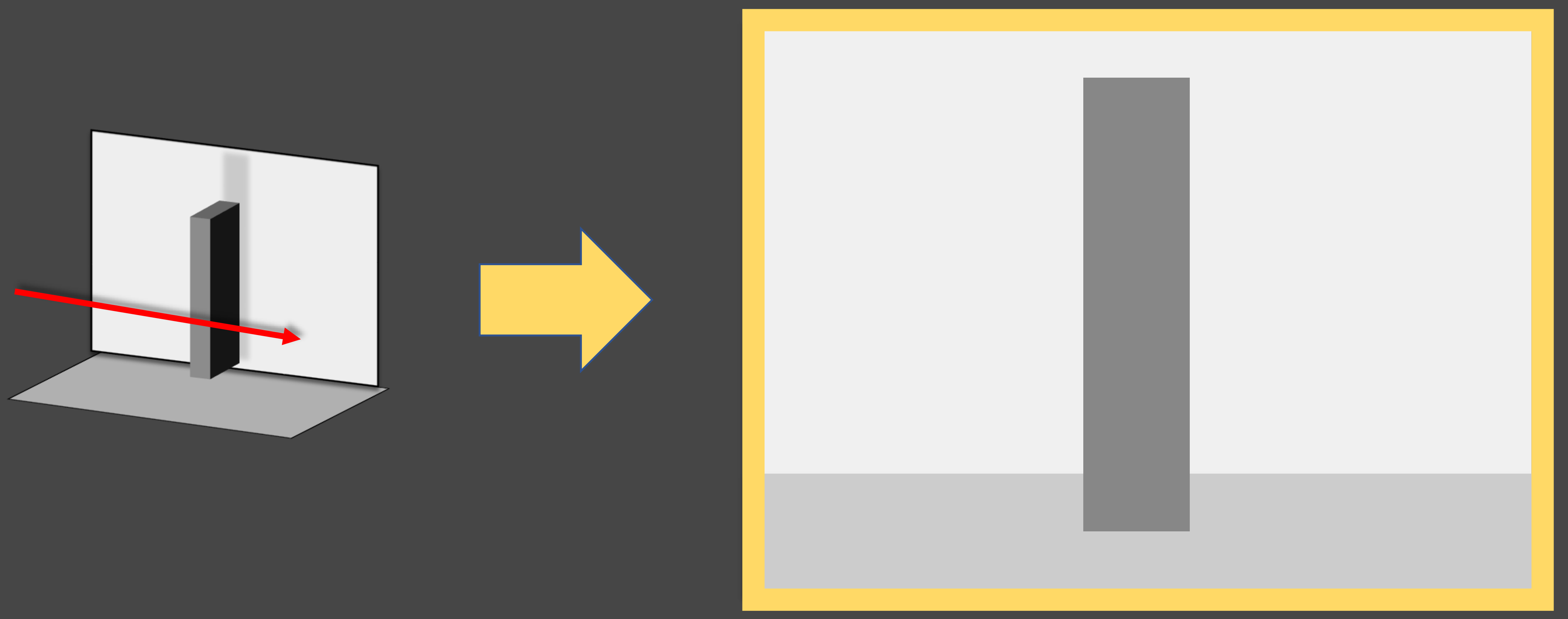
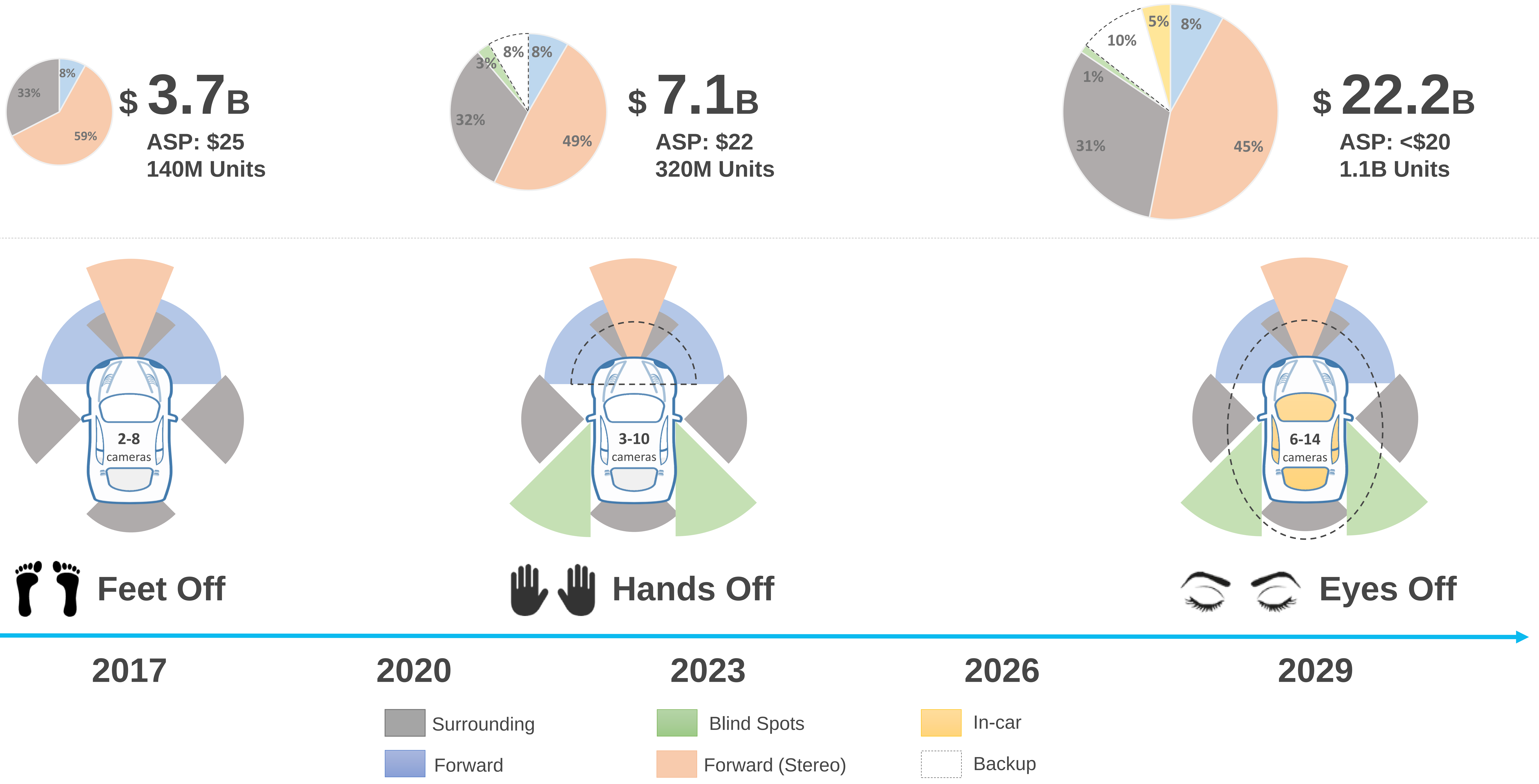


ASYNCHRONOUS PER-PIXEL EXPOSURE

Event-based technology enables **embedded-AI**

in objects, devices & machines

Vision trends – creating 360° awareness



Event-based technology as key enabler of low-latency detection and fast classification of obstacles

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Respond to any imminent danger in real-time

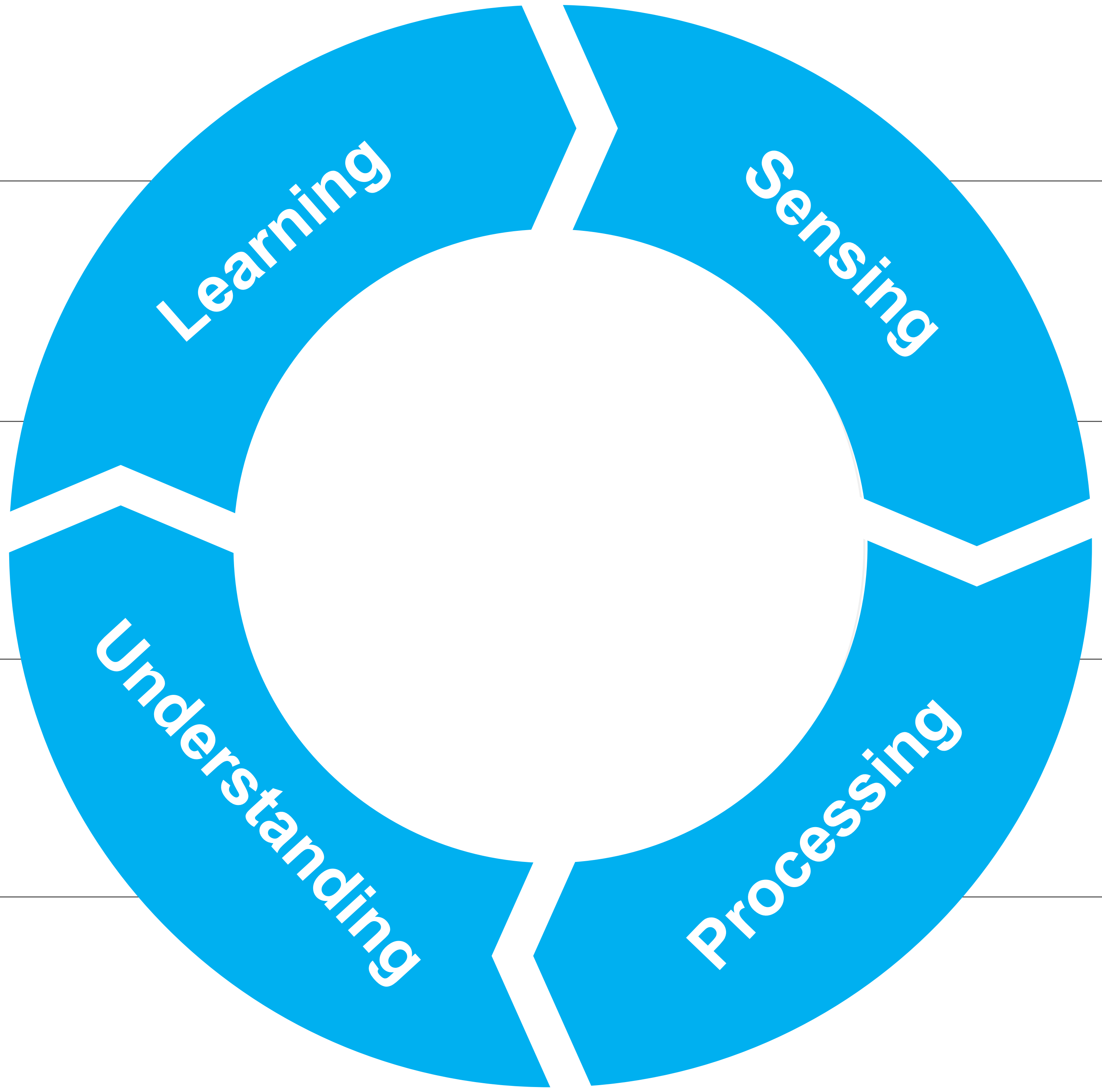
Efficient data acquisition, tailored for machines

Runtime inference

Smaller training datasets

Temporal & spatial precision

Native optical flow



Ultra-high speed

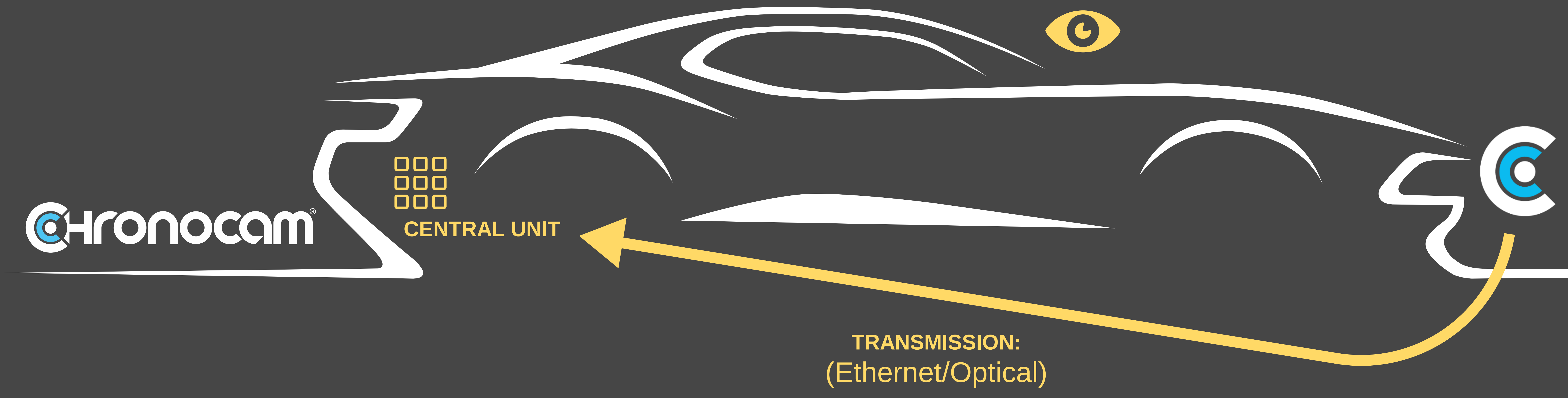
Relevant regions of interest

No sensor signal processing

Low bandwidth transmission

Provide advanced edge solution

E.G. PEDESTRIAN DETECTION



	LATENCY
CCAM (Event-based)	**<10ms**
Lidar	~30ms
Radar	~10ms
Frame-based	100+ ms

High Temporal Precision

- ✓ <10 ms latency for detection
- ✓ First-level classification
- ✓ Robustness to occlusion

Low Data Rate

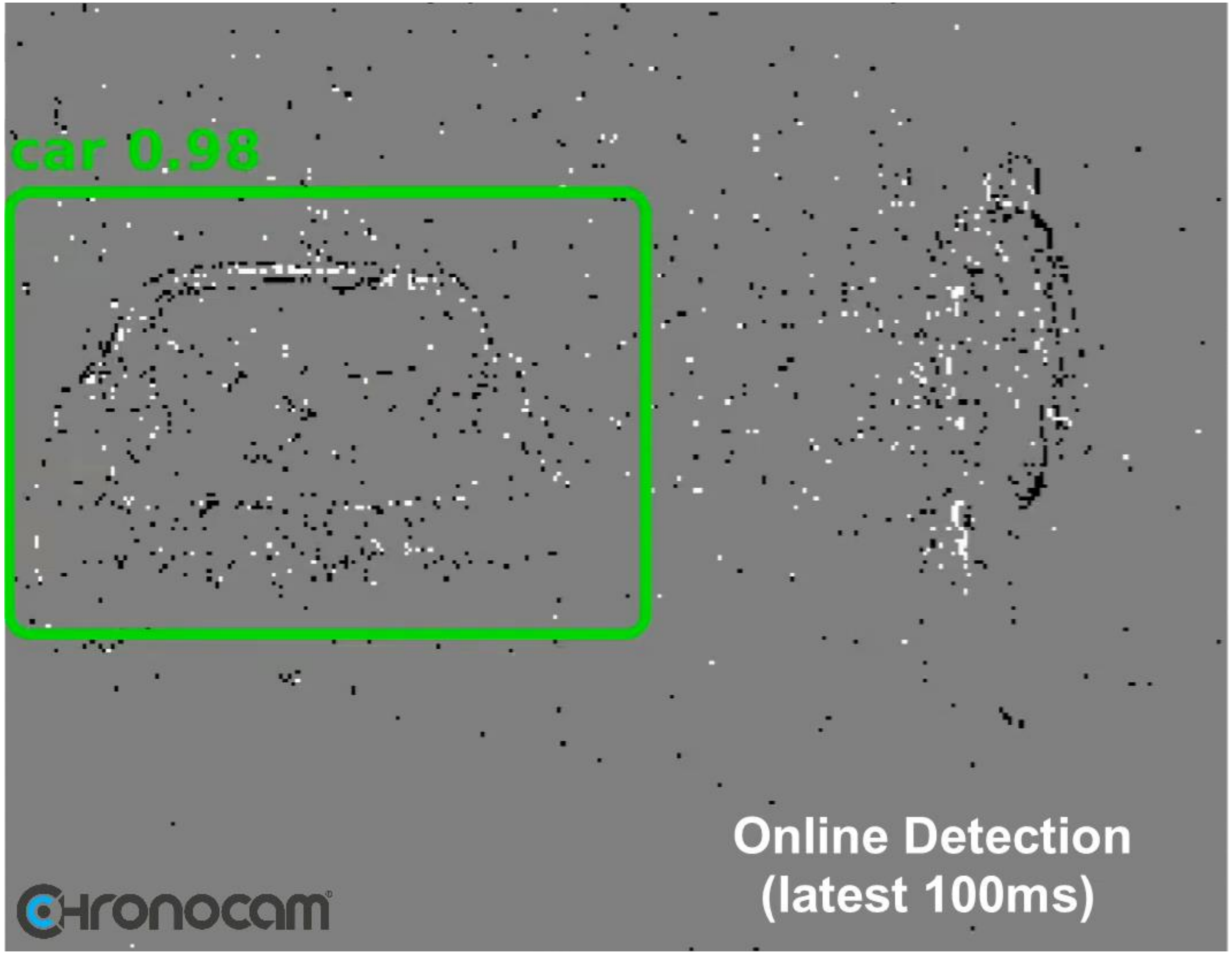
- ✓ Generates change events
- ✓ Edge classification
- ✓ Smart Compression

Reduced Computation

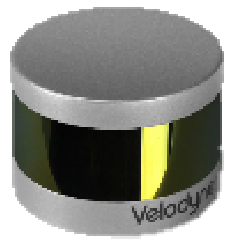
- ✓ Edge processing
- ✓ Relevant regions of interest
- ✓ No ISP required (signal processing)

High Dynamic Range

- ✓ 140+ dB
- ✓ Self-adjusted exposure


car 0.98
Online Detection
(latest 100ms)

Introducing unprecedented safety capabilities

	 Radar	 Lidar	 Ultrasound	 Frame-Camera	Event-Camera
Light Independent	✓	✓	✓	✗	✓
Computational Cost	=	−	=	✗	✓
Detection Speed	✓	−	✗	−	✓
Optical Information	=	✗	=	✓	✓
Passive	✗	✗	✗	✓	✓

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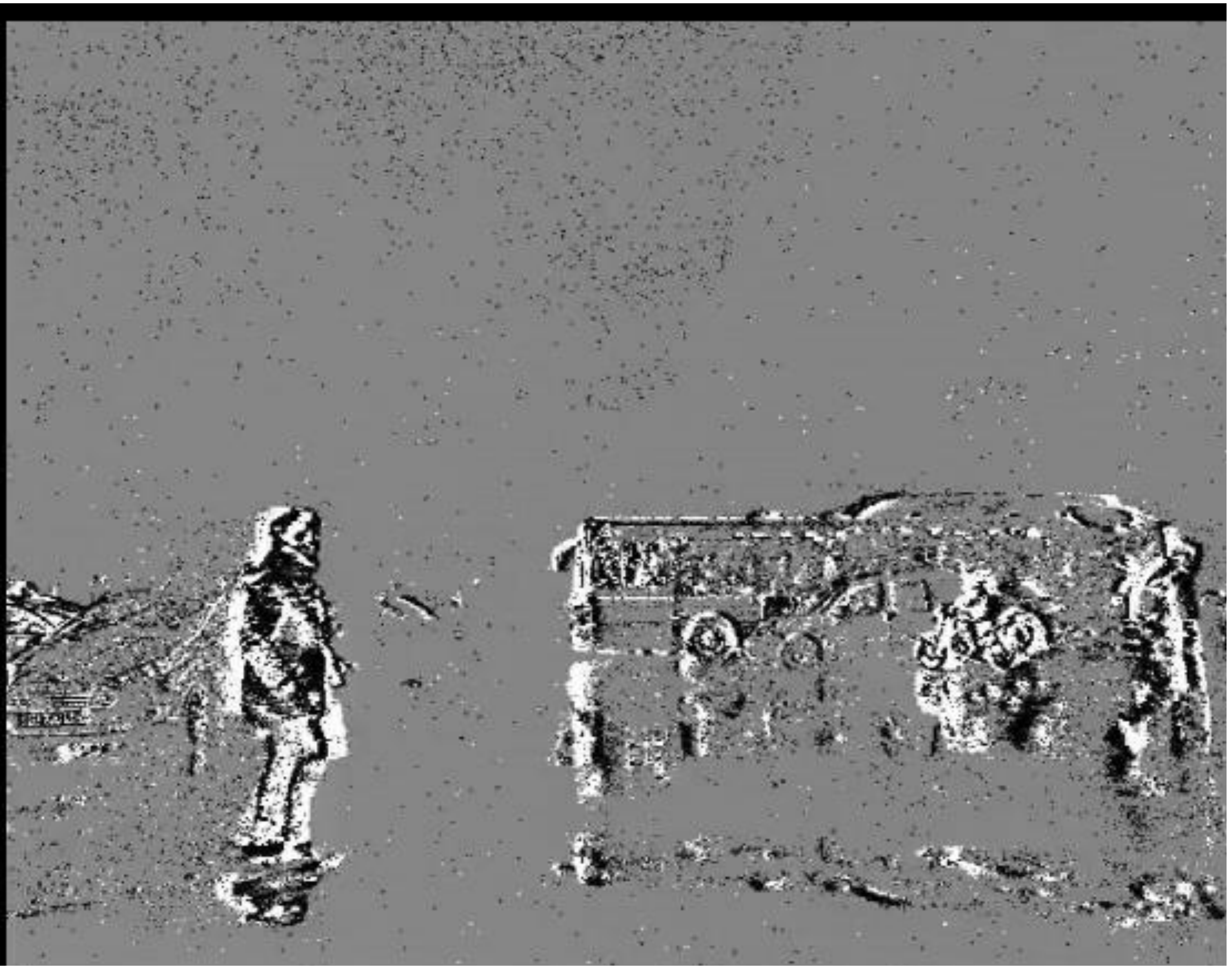
Standard Camera (HD 30fps)



CCAM (VGA)

Rethinking in-car monitoring

At low power with fast, accurate image sensing

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3D Tracking

Enhanced driver monitoring

E.G. EYE TRACKING & GESTURE CONTROL

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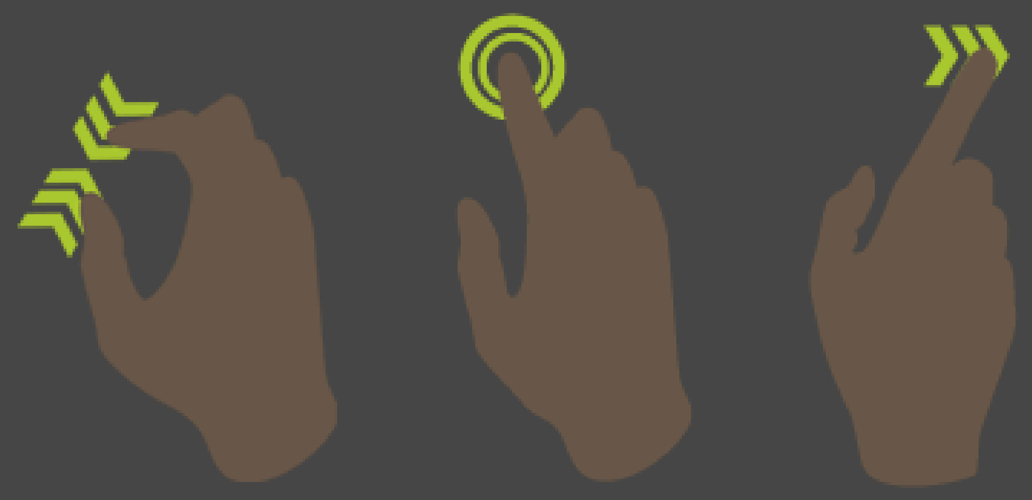


	LATENCY	TEMPORAL ACCURACY
CCAM (Event-based)	**<1ms**	**>1kHz**
Frame-based	~4-8ms	<250Hz

High Temporal Precision

- ✓ <10 ms latency for detection
- ✓ Faster data fetching
- ✓ No motion blur

Low Data Rate

- ✓ Graphic rendering efficiency
- ✓ Adjusted image output

Low Power

- ✓ Edge processing (remove all clutter that does impact downstream processing)
- ✓ Relevant regions of interest

High Dynamic Range

- ✓ 140+ dB
- ✓ Self-adjusted exposure

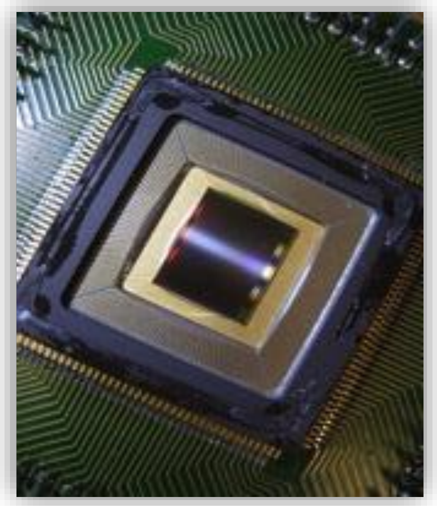
CCAM - Eye Tracking (VGA)

A **solid team** to lead the shift in technology

Leading the event-based **computer vision (r)evolution**

2010

First ATIS
Event-based Sensor



2011

FIRST PRODUCT

Pixium vision

2014

CHRONOCAM
+20 Patents in HW & SW

2015

CLOSED 1M€ FUNDRAISING

cea investissement AMORÇAGE TECHNOLOGIQUE
BOSCH Invented for life

Collaborations
Horizon 2020,
ANR, RAPID, DARPA
CNRS, UPMC, CSIC,
U of Illinois, U of Madrid

2016

CLOSED 15M€ FUNDRAISING

intel Capital
BOSCH Invented for life
RENAULT NISSAN
360 CAPITAL PARTNERS
iBIONEXT
cea investissement AMORÇAGE TECHNOLOGIQUE

Partnership
Renault-Nissan
(ADAS systems)

2017

TOP 100 AI
CB INSIGHTS

COOL VENDOR
AI CORE TECHNOLOGY
Gartner

TOP COMPUTER VISION INNOVATOR
FROST & SULLIVAN

IS EUROPE AWARDS

Collaborations
DARPA

2018

Chronocam®

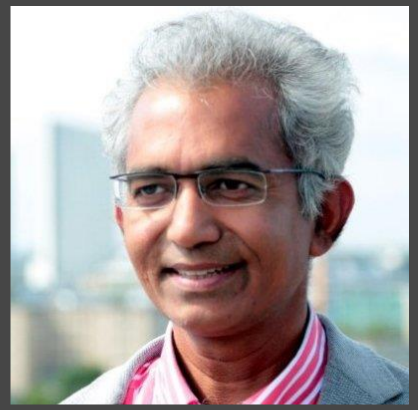
Founders & Senior Management

Luca Verre
Co-founder & CEO

Bernard Gilly (PhD)
Co-founder & Chairman

Christoph Posch (PhD)
Co-founder & CTO

Ryad Benosman (PhD)
Co-founder & Advisor



Atul Sinha
Board of Directors & Advisor

Jean-Luc Jaffard
VP Sensors Engineering & Operations

Geoff Burns (PhD)
VP Products & Vision Systems

Stephane Laveau (PhD)
VP Computer Vision & Software

40 Employees in Paris

14 Nationalities

36 Average Age

16 PhDs

37 Engineers

38 R&D

4 G&A

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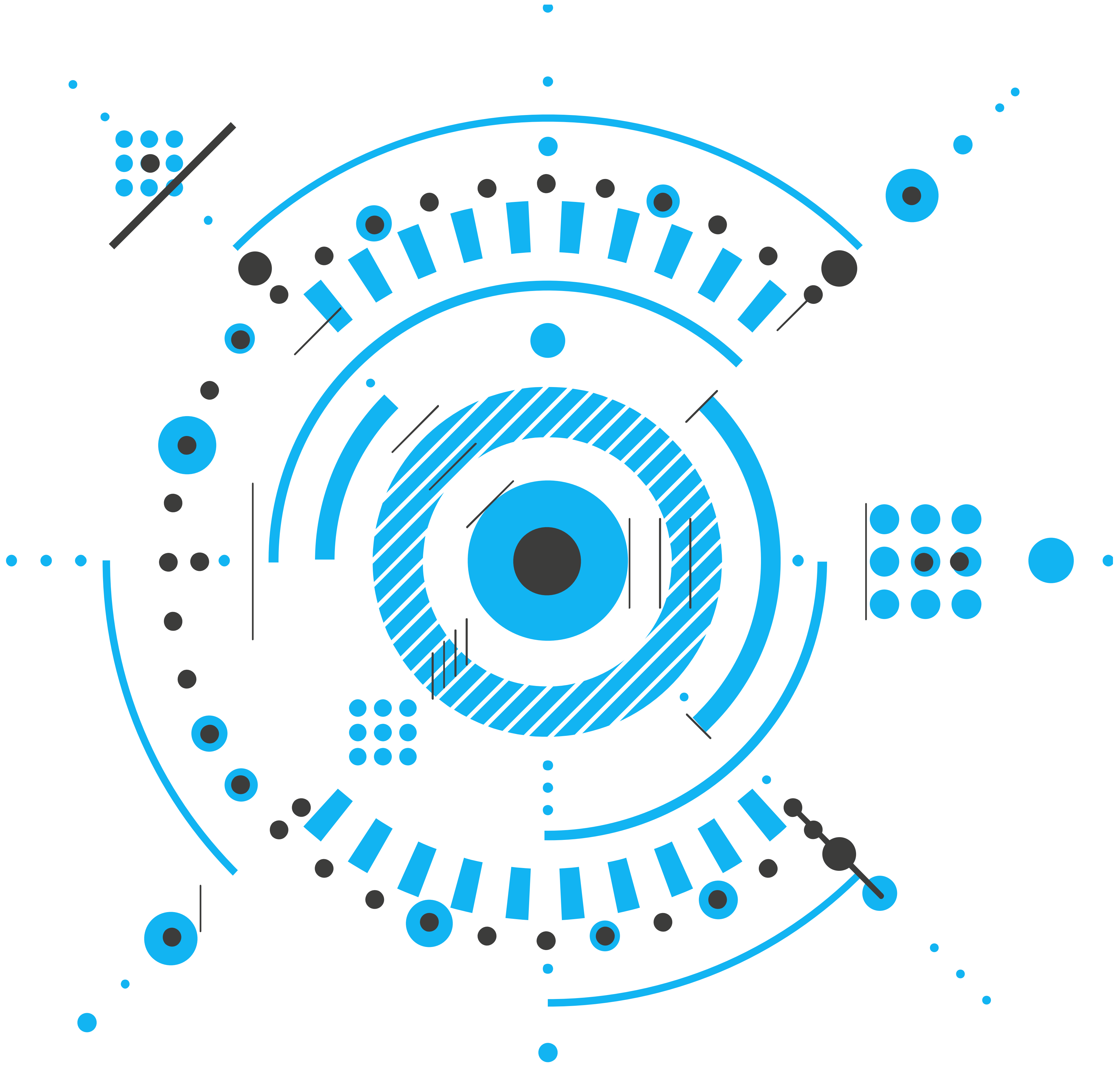

THANK YOU!

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www.chronocam.com