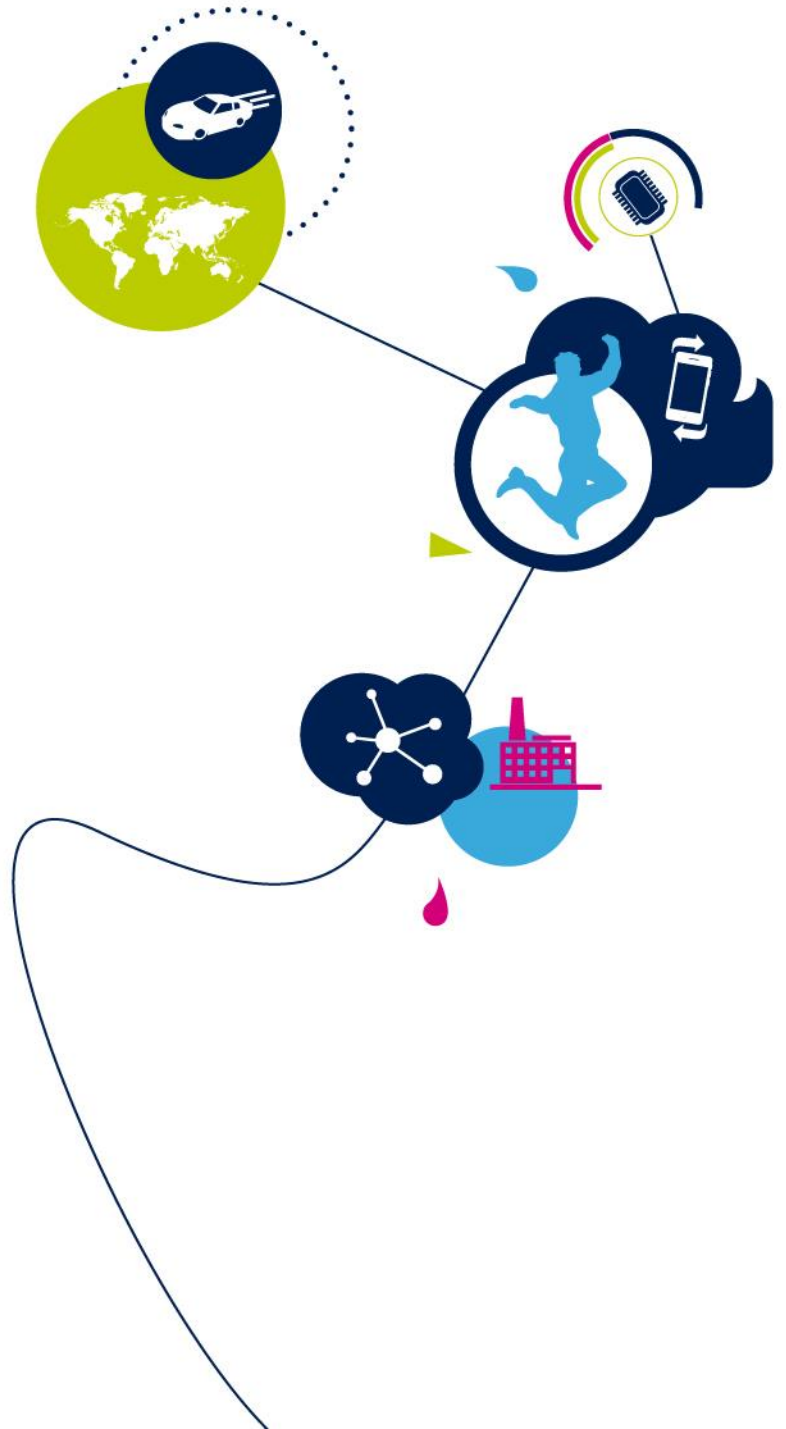
Automotive In-cabin Sensing Solutions

Nicolas Roux
September 19th, 2018



Smart Driving

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Impact of Drowsiness

Drive tired and you may never wake up. THINK!

➡ **Drowsiness responsible for 20% to 25% of car crashes in Europe** (INVS/AFSA)

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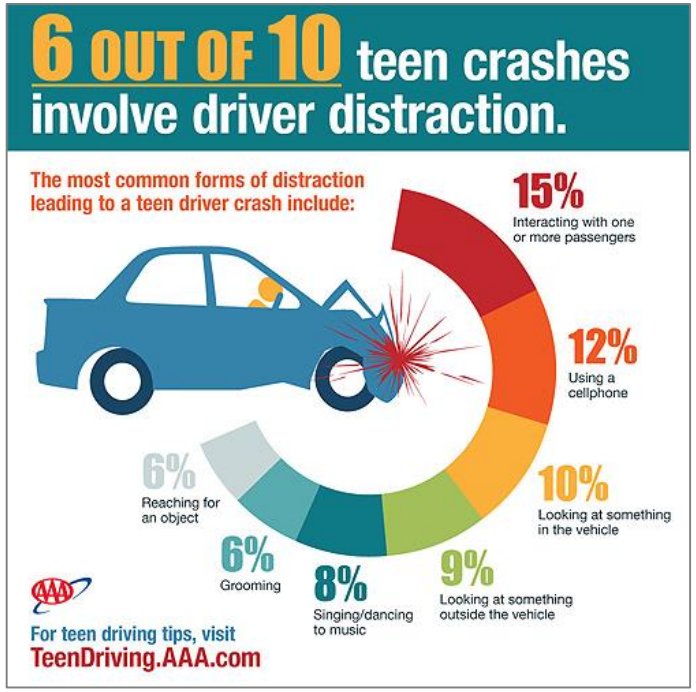
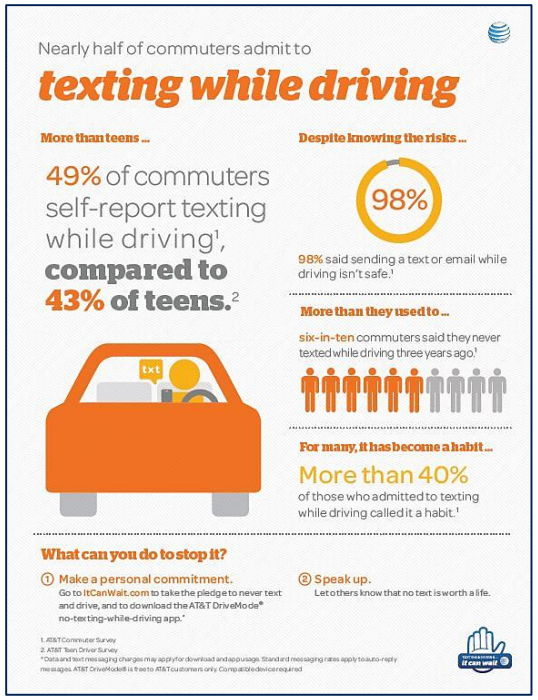
Beyond Drowsiness

Driver Distraction



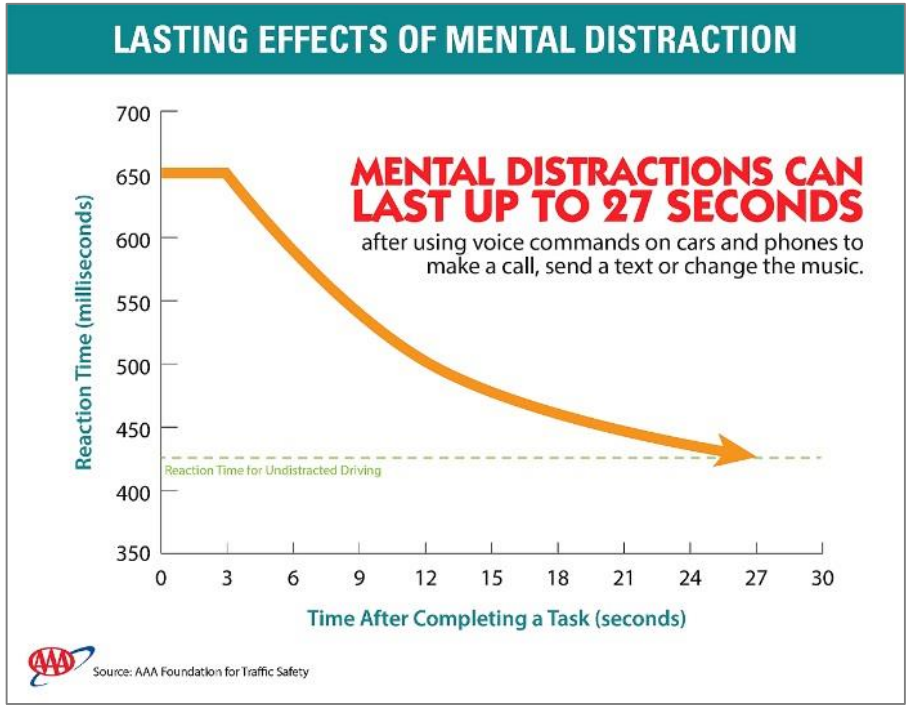
Driver distraction is highly Implicated in accidents

Young drivers are particularly affected



Mobile used during driving

About 50% drivers are texting, while on the road



Mental distraction lasts long after the eye distraction time

~50% of drivers text. Cars have features close to smartphones.

→ Drivers are much more distracted than before

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Driver Monitoring

a Must Have for Car Automation

Levels	0 Human only	1 Assisted driving	2 Partial automation	3 Conditional automation	4 High automation	5 Full automation
Foot off	No	Temporary	Temporary	Temporary	Within use cases	Always
Hands off	No	No	Temporary	Temporary	Within use cases	Always
Eyes off	No	No	No	Temporary	Within use cases	Always

Driver monitoring is key for a safe **co-driving**

Driver Monitoring
a Must Have for Car Automation

Would you be relaxed being a passenger in a car with two drivers?

The Machine must sense the Human driver to understand his behavior, release the car control upon driver request, while keeping safety assistance

Safety but Also Beyond

Euro NCAP 2025 Roadmap

The Overall Safety Rating

PRIMARY SAFETY

Driver Monitoring (2020)

Automatic Emergency Steering (2020, 2022)

Effective driver monitoring will also be a prerequisite for automated driving, to make sure that, where needed, control can be handed back to a driver who is fit and able to drive the vehicle.

Driver Monitoring - DMS

- Attention, distraction, drowsiness
- Health status, heart rate, breathing
- Gaze direction
- Head orientation
- Identification (immobilizer)
- Hands position
- Recording (legal aspect)
- ADAS interaction management

Cabin Monitoring - CM

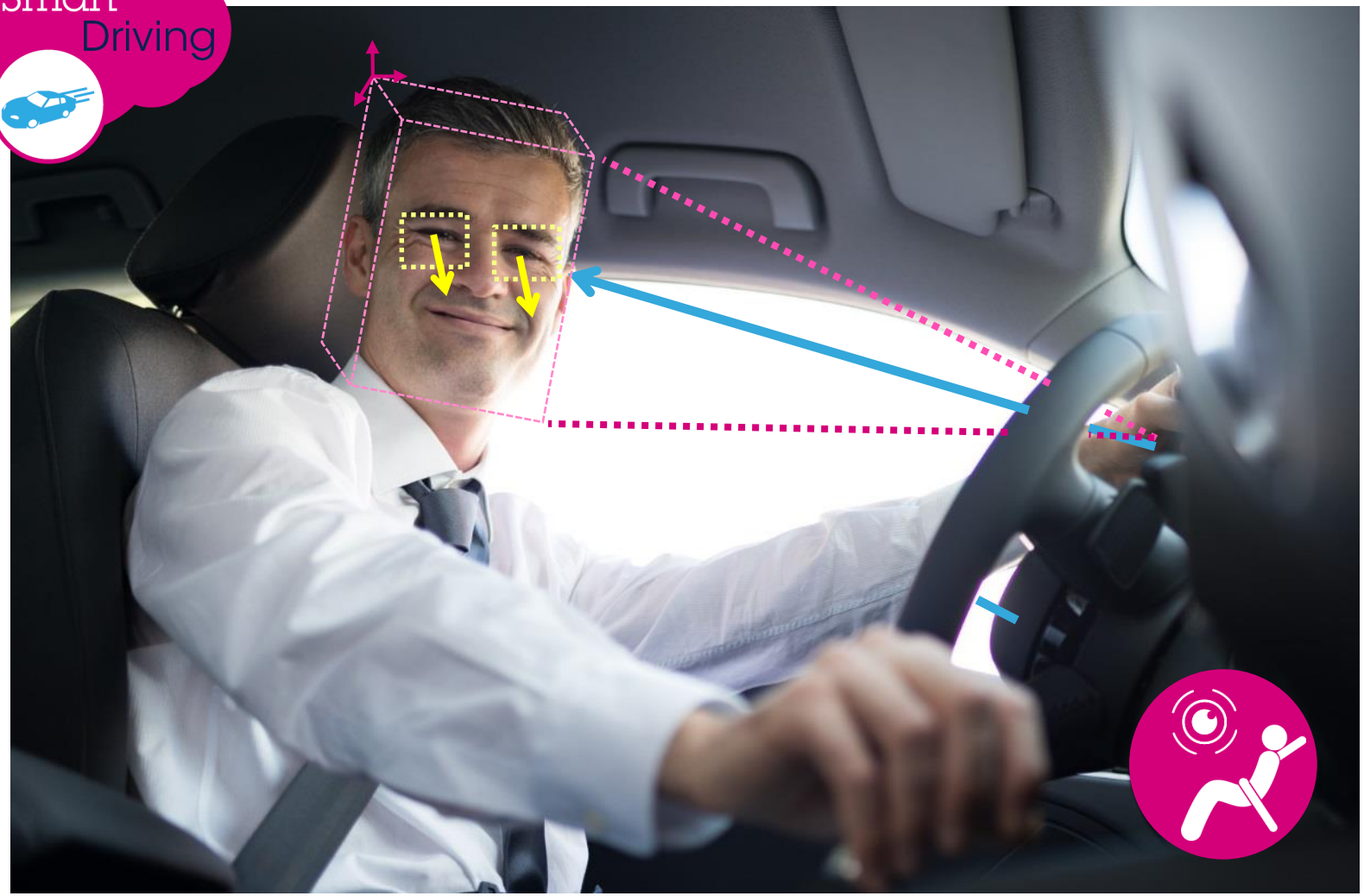
- Passengers detect/classify
- Passenger/child surveillance,
- Airbags adaptation
- Passengers identification
- Autonomous taxi
- Accident recording
- Intruder detection, recording,
- Left child detection

Comfort Functions - CF

- Gestures driver and passengers
- Air condition
- Personalization,
- Head up display eye box adjustment
- Display interactions, smart dashboard
- Video conferencing,
- Speaker detection
- Remote Cabin monitoring, lost items
- Cabin light management

Automotive In-cabin Camera

Smart Driving



HDR Global Shutter

Perfectly fitting with applications

- Head pose detection
- Eyelids analysis
- Accurate gaze direction
- Immune to ambient
- AEC-Q100 grade 2 and ASIL-B

Disruptive sensor technology

- 1.6Mpixels & 2.3Mpixels
- 98dB High Dynamic Range
- Background removal
- High effective resolution and contrast at near IR 940nm
- Very low noise at high temperature

Perfect use in a 3D sensing system

- Using *Stereo* or *Structured Light*
- Robust driver identification
- Head distance to dashboard
- Head position confirmation

Perfect for 2D + 3D depth map

- 2D High resolution
- Accurate Depth Map

➡ HDR Global Shutter
➡ With Stereo or Structured Light

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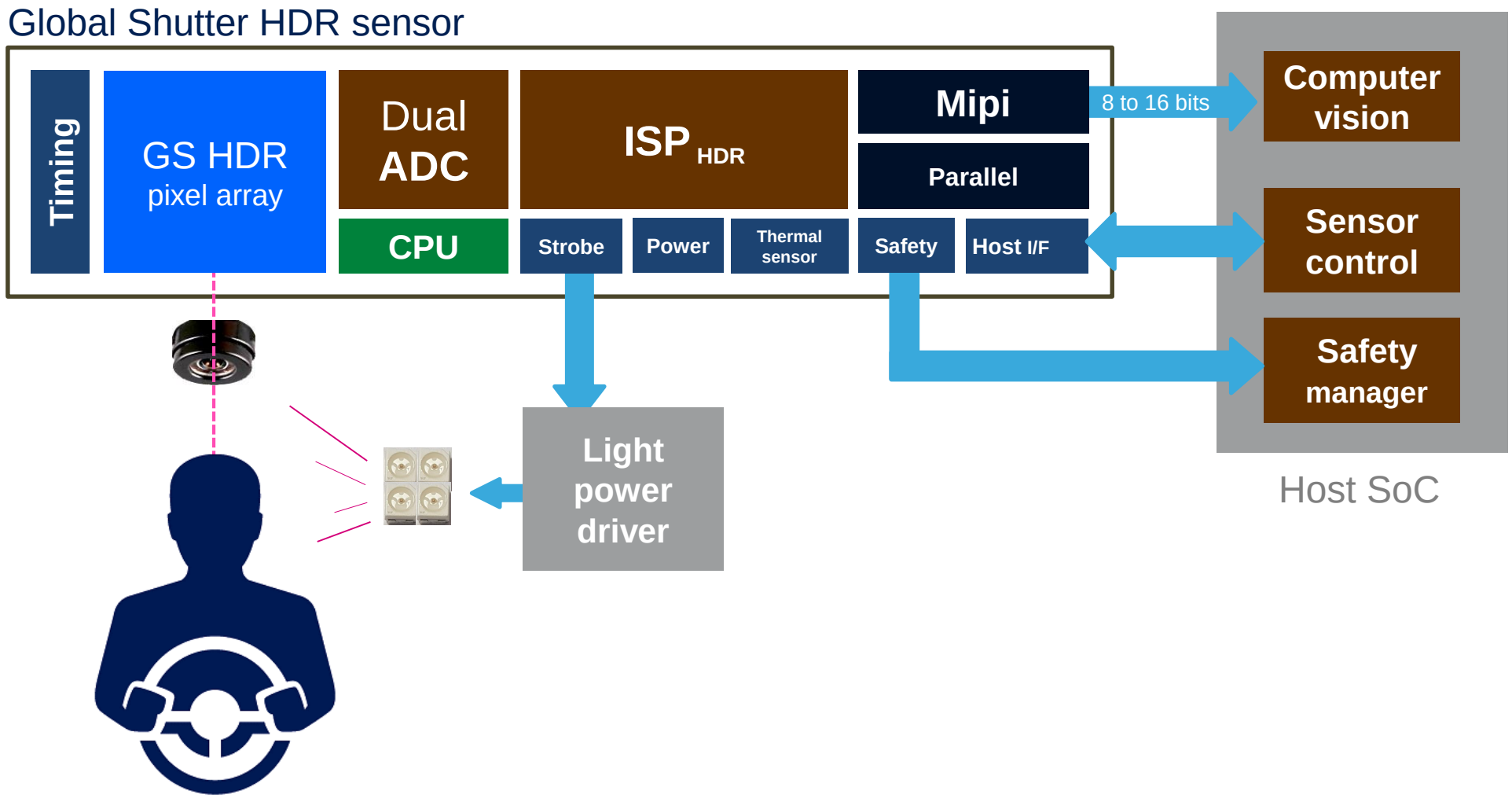
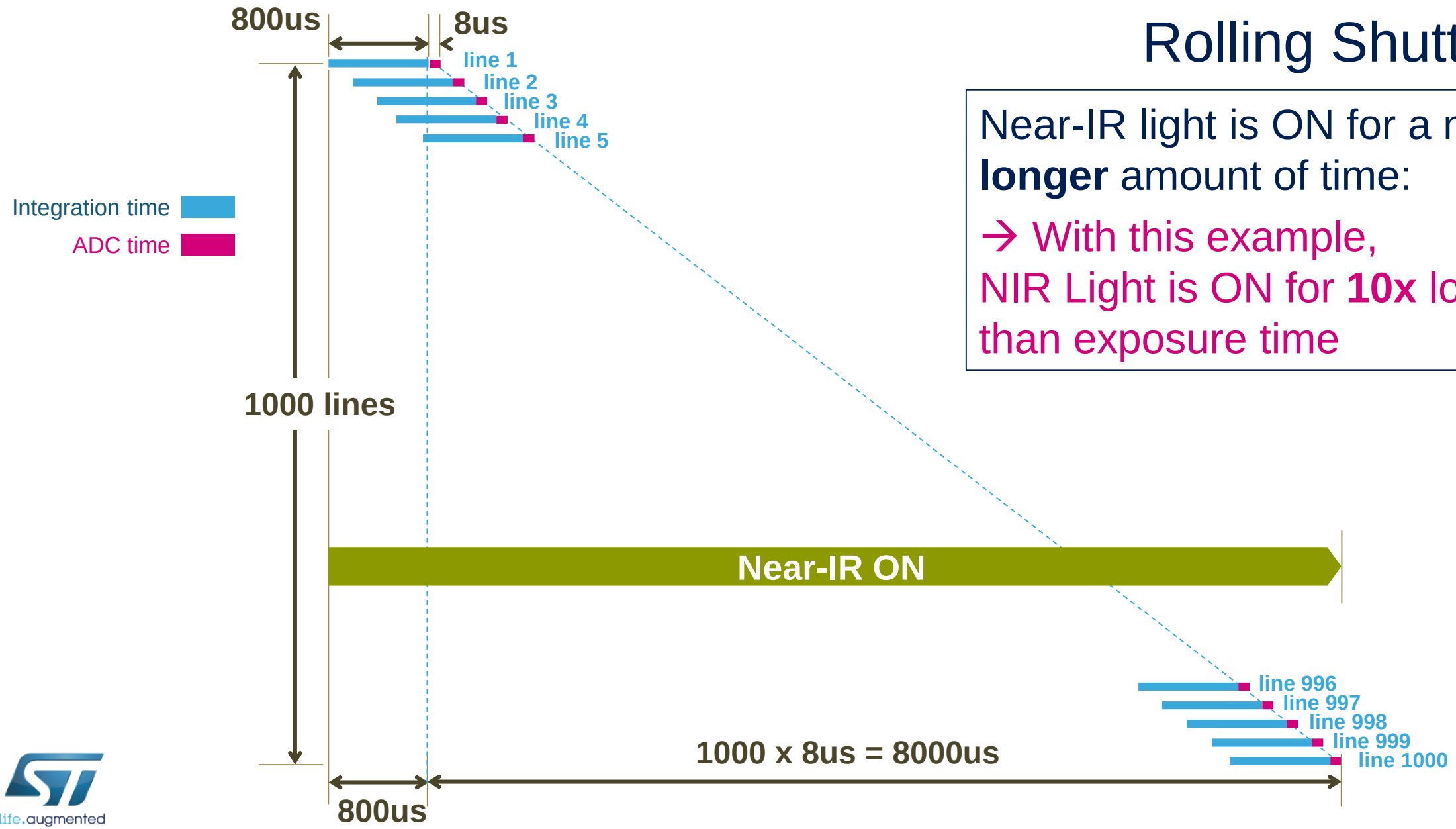
In-cabin Sensing

Near-IR Camera System



Near-IR Illumination

Rolling Shutter

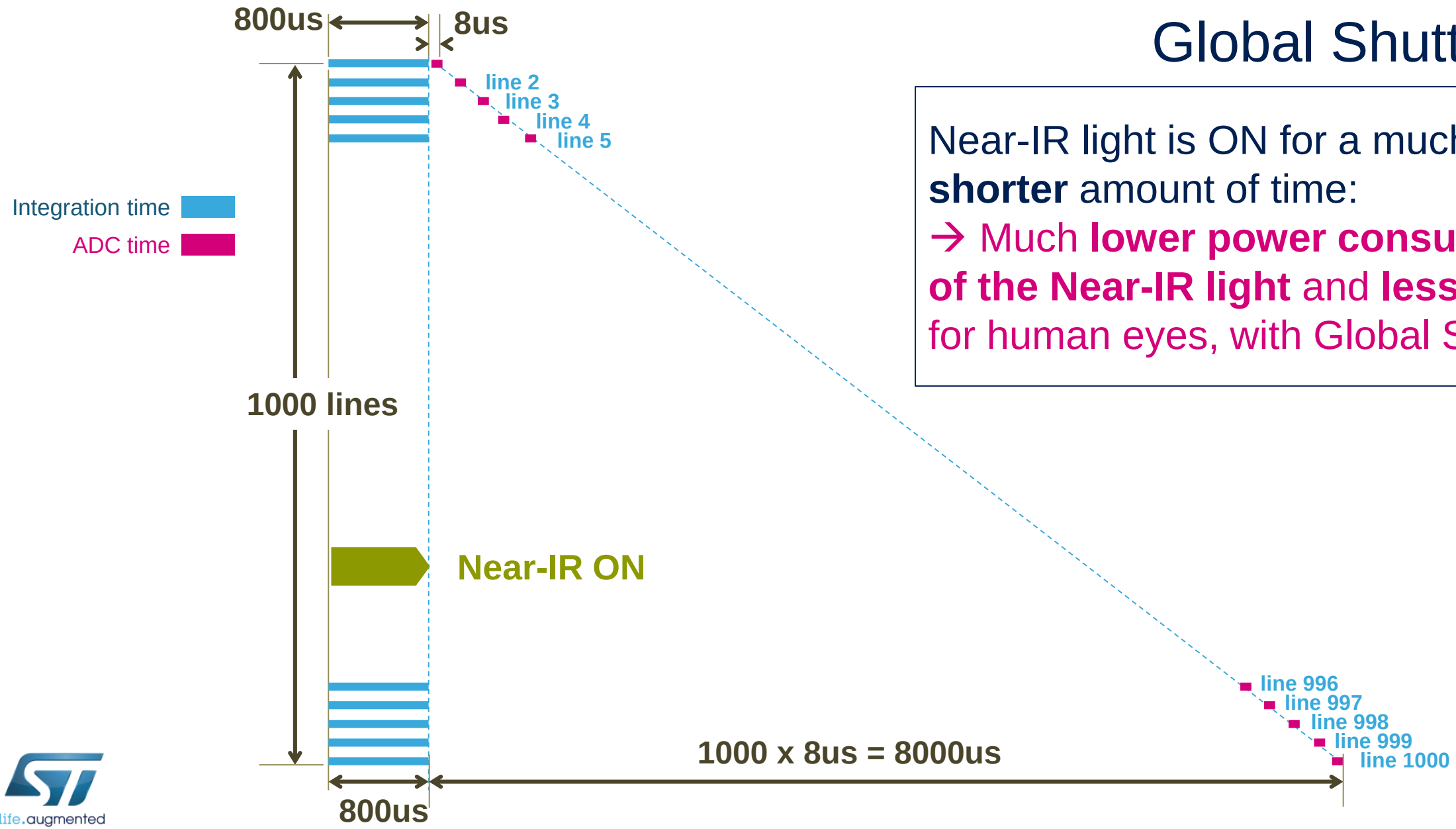


Near-IR light is ON for a much **longer** amount of time:

→ With this example,
NIR Light is ON for **10x** longer than exposure time

Near-IR Illumination

Global Shutter



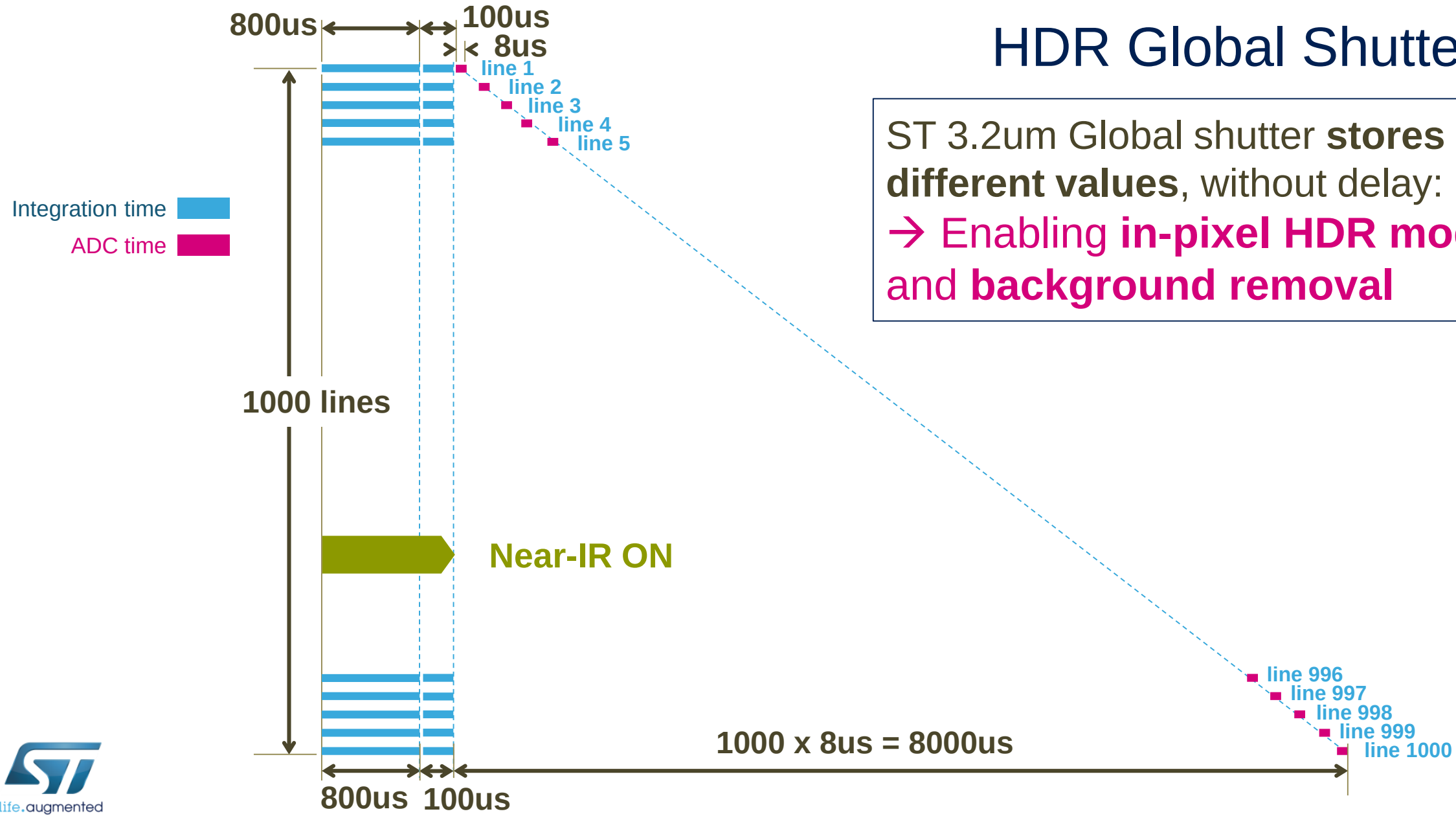
Near-IR light is ON for a much **shorter** amount of time:

→ Much **lower power consumption of the Near-IR light** and **less tiring** for human eyes, with Global Shutter

Near-IR Illumination

HDR Global Shutter

ST 3.2um Global shutter **stores two different values**, without delay:
→ Enabling **in-pixel HDR mode** and **background removal**



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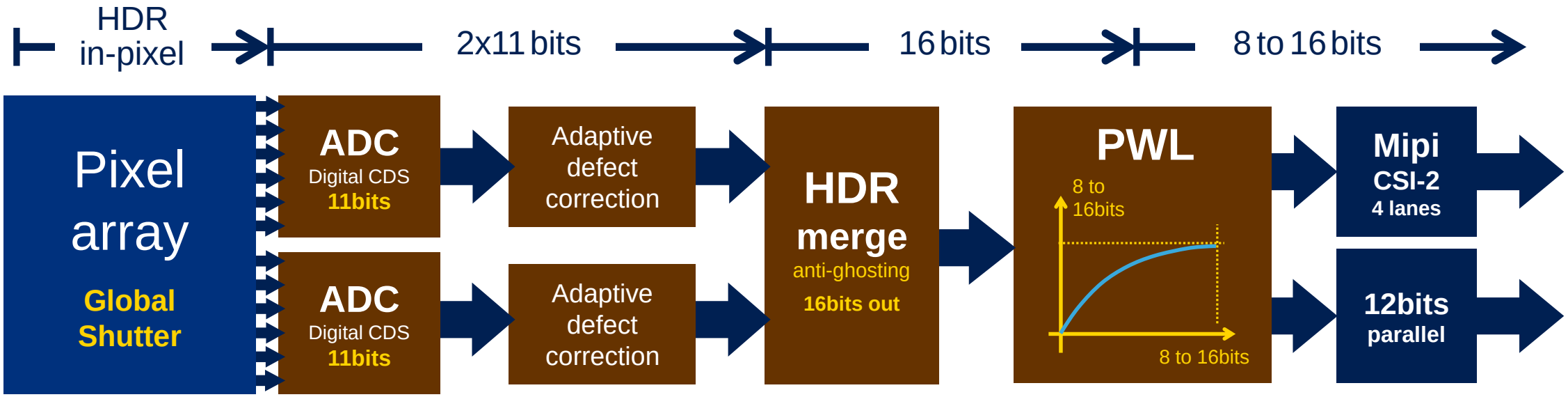
Disruptive Global Shutter

Native Linear HDR Sensor



- Disruptive dual memory 3.2um Global Shutter
- HDR or background removal computed internally
- No trade-off on the frame-rate, thanks to the dual pipe
- From 8 to 16-bit output to match with various Host SoC

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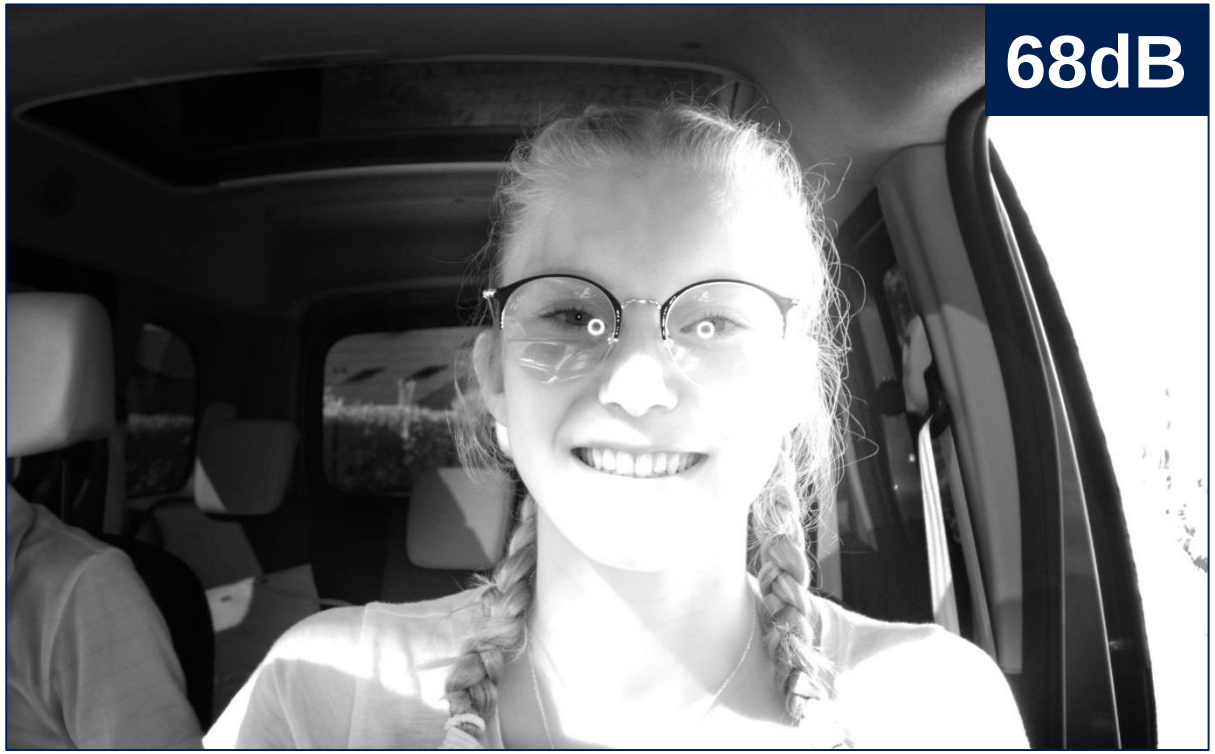
98dB in-pixel

Driver Monitoring

the Need for HDR Sensor, Even at 940nm Pass Only



Even with 940nm only, Sun energy is very high: in-cabin is a strong HDR case

- Images acquired with a 940nm narrow pass light filter
- Same tone mapping applied to both image only for human to see the 15-bits data
- No tone mapping required for Computer Vision, linear data preferred

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ST Automotive 3.2um Global Shutter

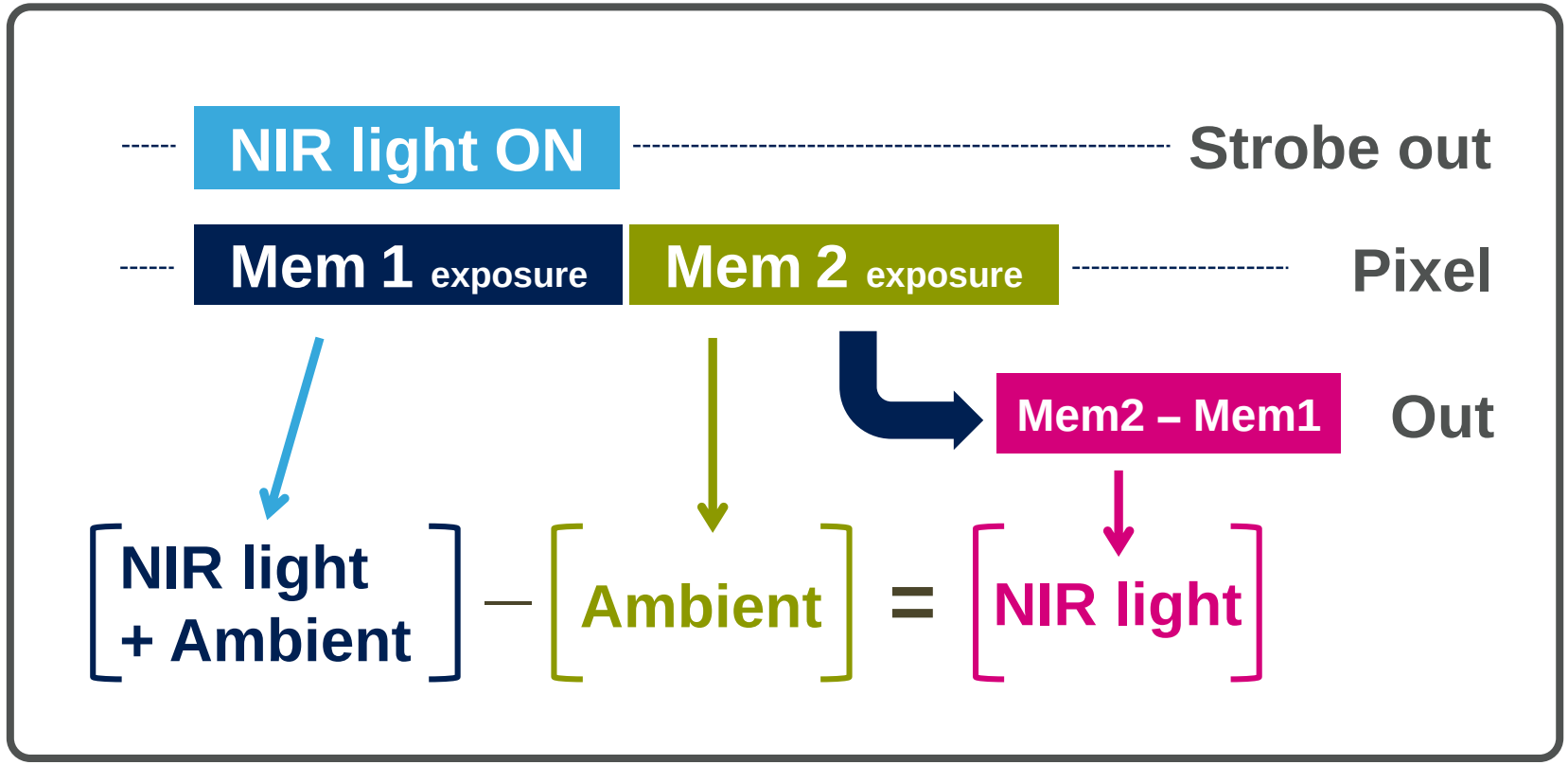
Background Removal

Sensor outputs only information from the local zone lightning

ST Automotive 3.2um Global Shutter

Background Removal

Only the light from the illumination is kept in the sensor output image



This feature enables **Background Subtraction**

- Only the local zone illuminated by the NIR light is sent to the host SoC
- Avoiding the Host SoC to analyze irrelevant part of the scene

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ST In-pixel
Background Removal

No impact on the frame-rate, and no need for external processing

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ST 3.2um Automotive Global Shutter

a Unique Disruptive Technology

Dynamic Range @ **60°C**		
ST high density storage in-pixel	**Total Full Well**	2x **8.3ke-**
	Usable Full Well	2x **7.1ke-**
Low total noise at high temperature	**Total Noise** Temporal noise + FPN	**2.75e-** 2.35e- @ 25°C
Very good intrinsic Dynamic range	**Dynamic Range @ 60°C**	**68.2dB**
Linear HDR mode	**Dynamic range** Ratio long/short @ **60°C**	4: 80dB **8: 86dB** 16: 92dB **32: 98dB**

Above ratios are examples, any long/short integration times can be used within their ranges

Dark current	@ **60°C**
Memory zone	**5 e-/s**
Photodiode zone	**22 e-/s**
PRNU	0.4%
PLS 550nm f/2	-64dB
PLS 850nm f/2	-57dB
PLS 940nm f/2	-54dB

- ✓ Very low noise
- ✓ Very low dark current **robust to high temperature**
- ✓ High intrinsic dynamic range
- ✓ In-pixel linear HDR mode **or Background removal mode**

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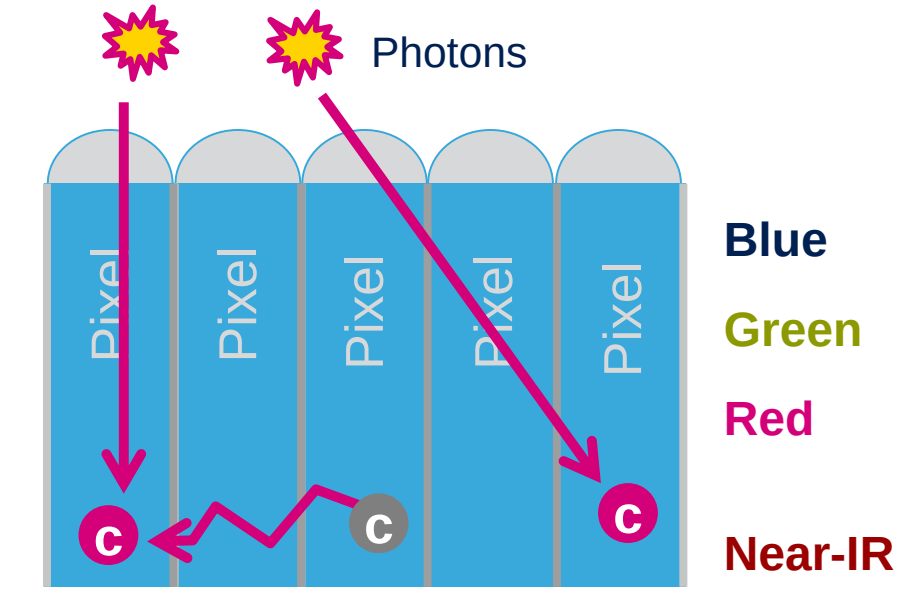
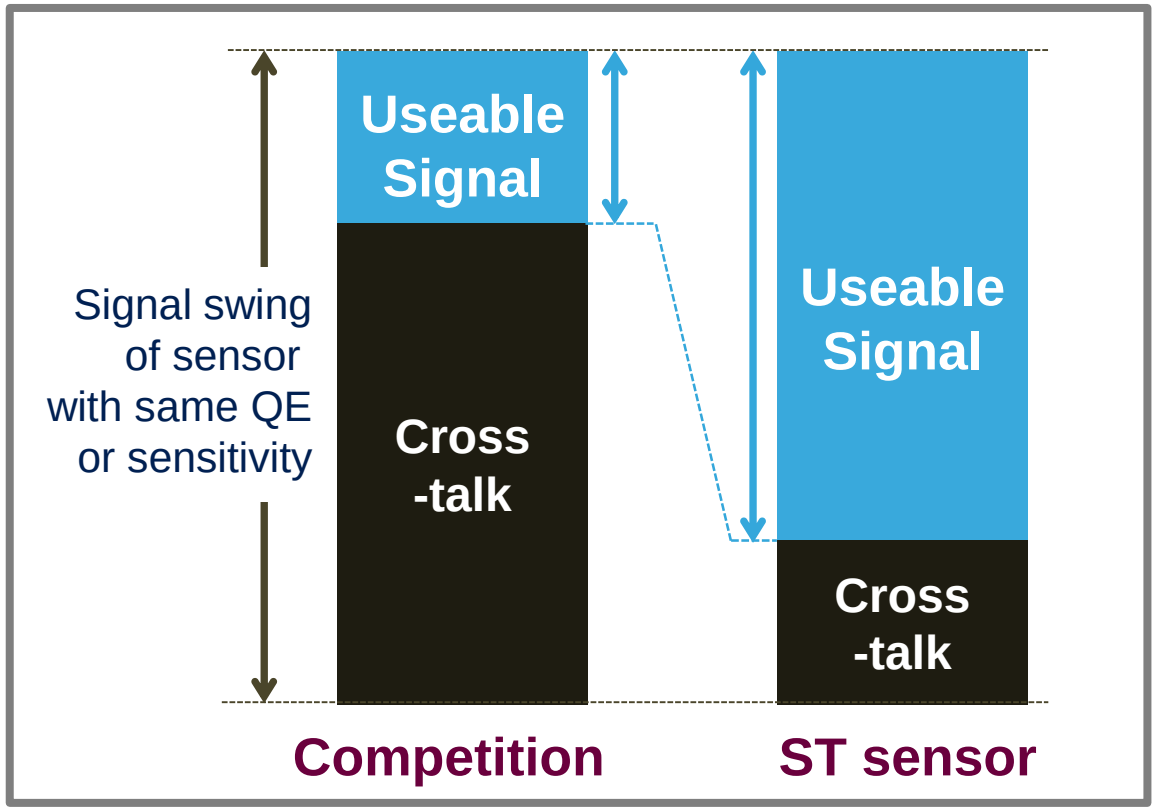
Pixel to Pixel Crosstalk

Crosstalk is worst in Near-IR



Charge creation from photon happens deeper in the photodiode

…Limiting the crosstalk is much more difficult with Near-IR wavelengths than with visible light



- Low crosstalk is key for computer vision
- Crosstalk can be considered as a ‘noise’

➡ Increasing the QE is not good if it increases the crosstalk significantly

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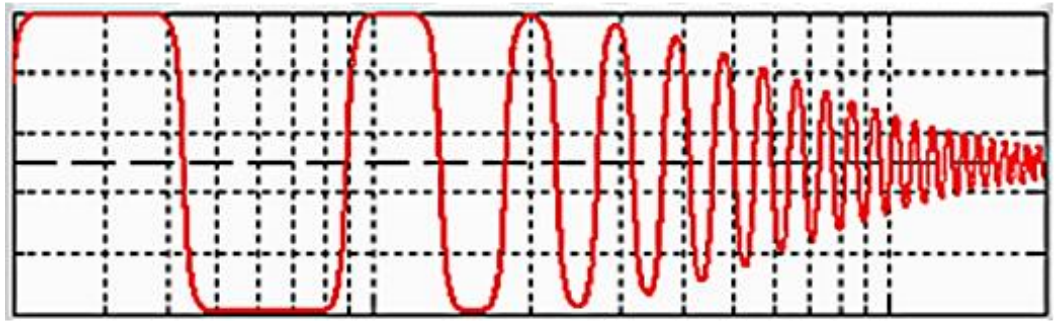
Lower Sensor Crosstalk → Higher MTF

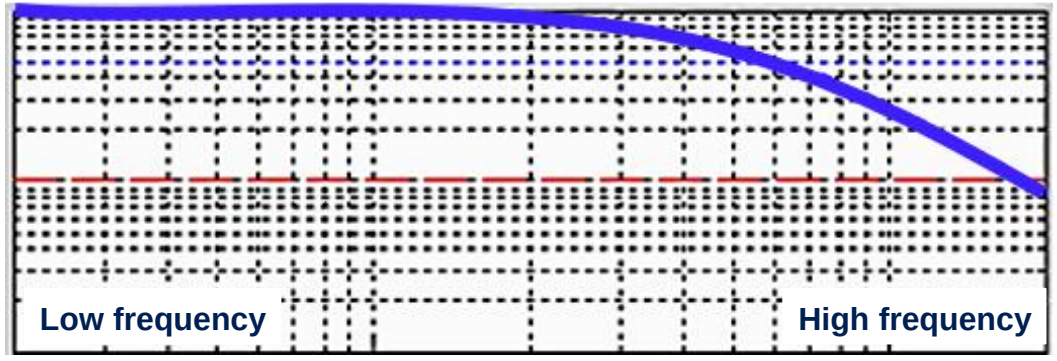
Courtesy of
Imatest LLC
www.imatest.com

Input scene
From left to right, low to high spatial frequency

Image sampled by the sensor



Data of one line
With spatial frequency increasing, the details of the image are attenuated. The low number of details is lowering the easiness for computer
vision to detect and understand the scene.



100%

MTF is a measure of contrast lose
100% => no contrast attenuation;
0% => not any contrast/details remaining

0%

What is MTF ?

- **M**odulation
- **T**ransfer
- **F**unction

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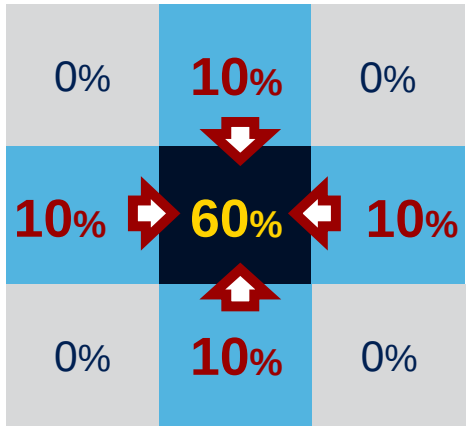
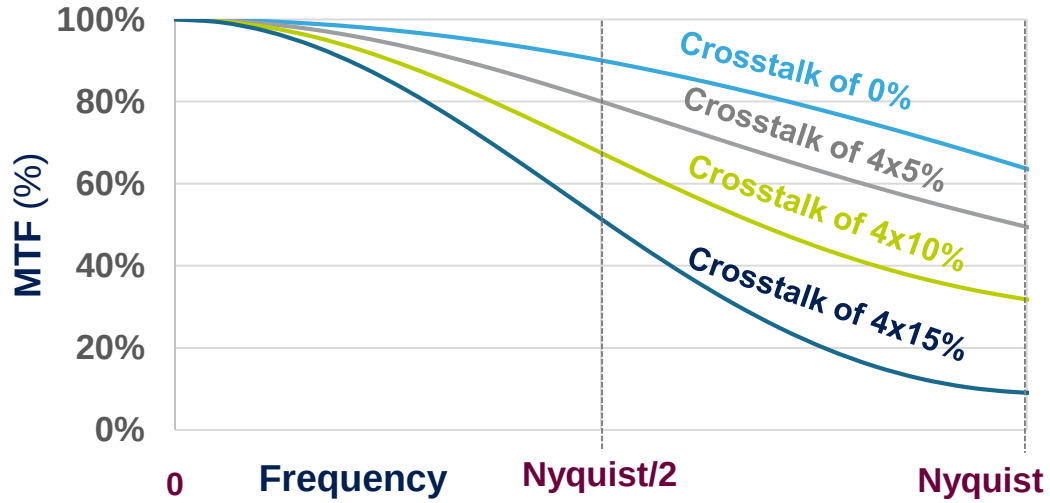
ST Auto Global Shutter Very High MTF

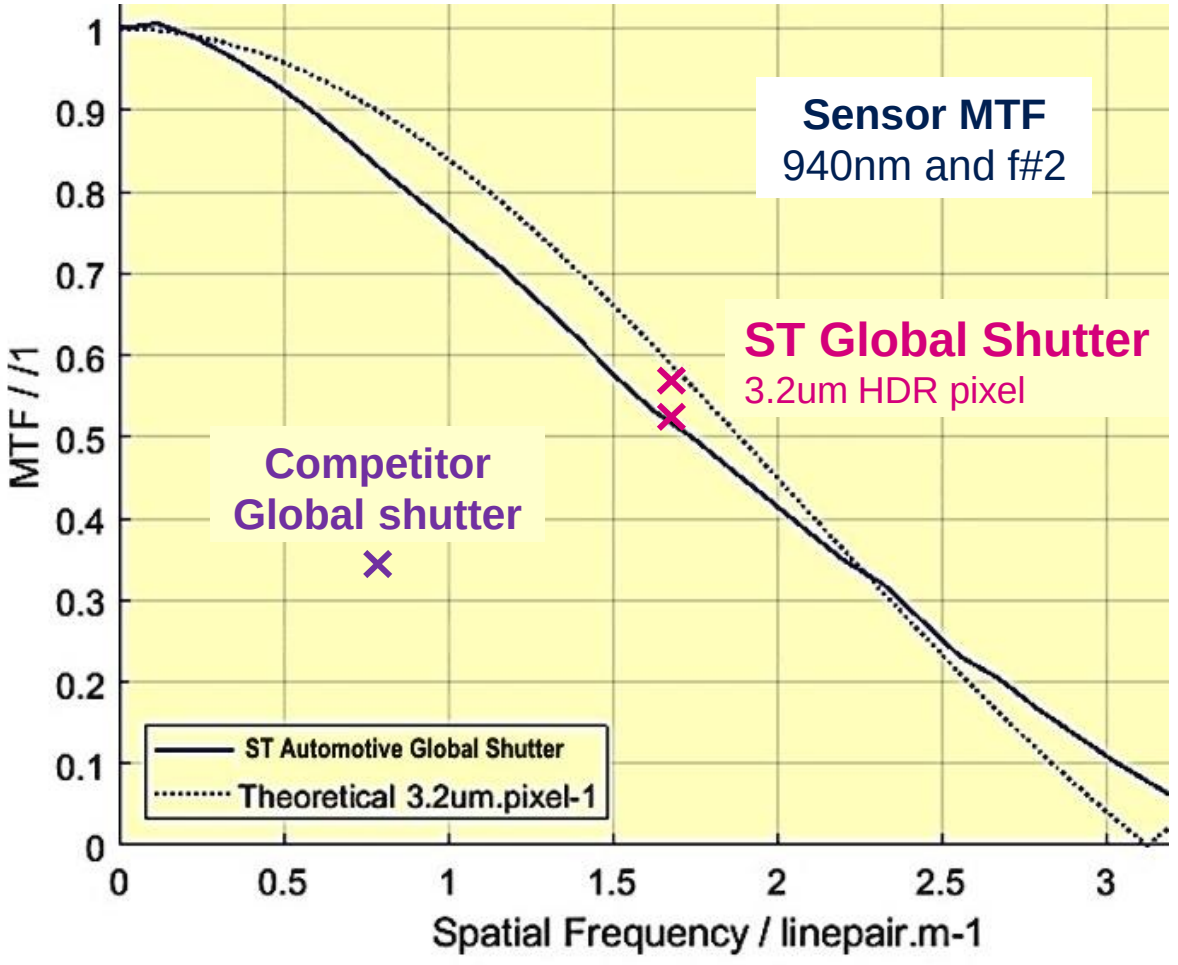
Pixel array



Pixel crosstalk
increased

Sensor MTF
strongly decreased





ST Global Shutter pixel **approaches the max theoretical limit with outstanding MTF**, up to 940nm

Quantum Efficiency: QE_{505nm}= 73%, QE_{850nm}= 20%, QE_{940nm}= 9.3% @ 60°C

ST Close to Max MTF

Outstanding 940nm Sensor Sharpness

Very high sensor sharpness and contrast, even at 940nm

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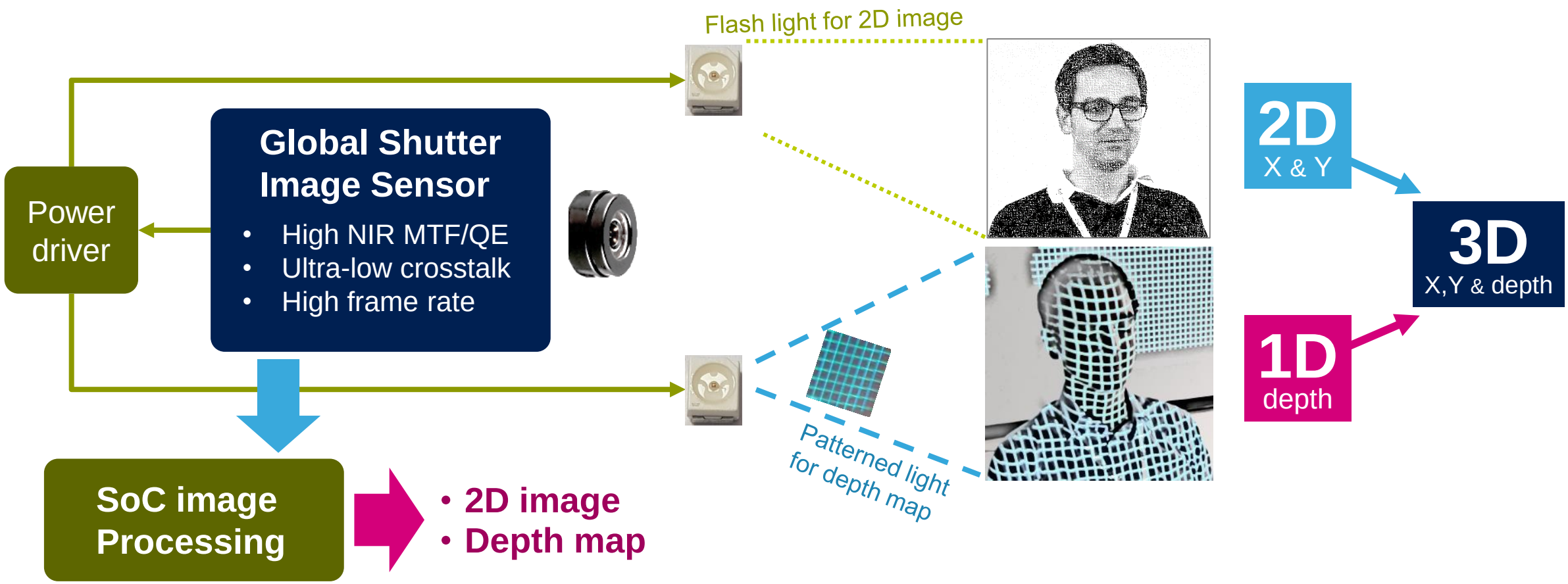
With PDF file, image quality is not representative

In-cabin 3D Sensing



Structured Light requires very high MTF at 940nm

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This enables both a **high resolution 2D** and an **accurate depth image**

98dB in-pixel

3.2µm HDR GS Automotive pixel

ST Automotive GS Sensor

Engineered for in-cabin Computer Vision

High resolution

Enabling better detections

Resolution	1.6Mp	2.3Mp
Ratio	4:3	16:9
Format	1/3”	1/2.5”
Array diagonal	5.9mm	7.3mm
Width	1464	1944
Height	1104	1204

High MTF ➡ effective resolution

High frame-rate

Enabling lower latencies

1.6Mp sensor	75 fps	1.6Mp	2x11 bits
	100 fps	1.4Mp	2x10 bits
	120 fps	1.0Mp	2x11 bits
	200 fps	0.6Mp	2x10 bit
	300 fps	0.1Mp	2x10 bit
2.3Mp sensor	60 fps	2.3Mp	2x11 bits
	75 fps	1.9Mp	2x11 bits
	100 fps	1.4Mp	2x11 bits

Features full

Enabling powerful system

- 2 programmable light strobes
- 4 light strobes output pins
- 4 frames contexts linkable
- Each frame context includes exposure, strobes, modes, ROI…
- 8 Regions Of Interest

- **AEC-Q100 grade 2**
- **ASIL B support**
  Some features seen with higher ASIL level, like dual lock steps CPU, full L/Mbist, ECC,…

Highly Automotive

Enabling high Safety grades

➡ 1.6Mp & 2.3Mp sensors sampling from Q1’2018

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Thank You

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