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Lighting Up the Dark

Next-Gen Thermal Imaging Optics for Affordable Pedestrian Detection at Night

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Current Pedestrian AEB systems are ineffective at night

1.4M

people killed in road accidents every year

75%

Of VRU fatalities occur in degraded visibility conditions


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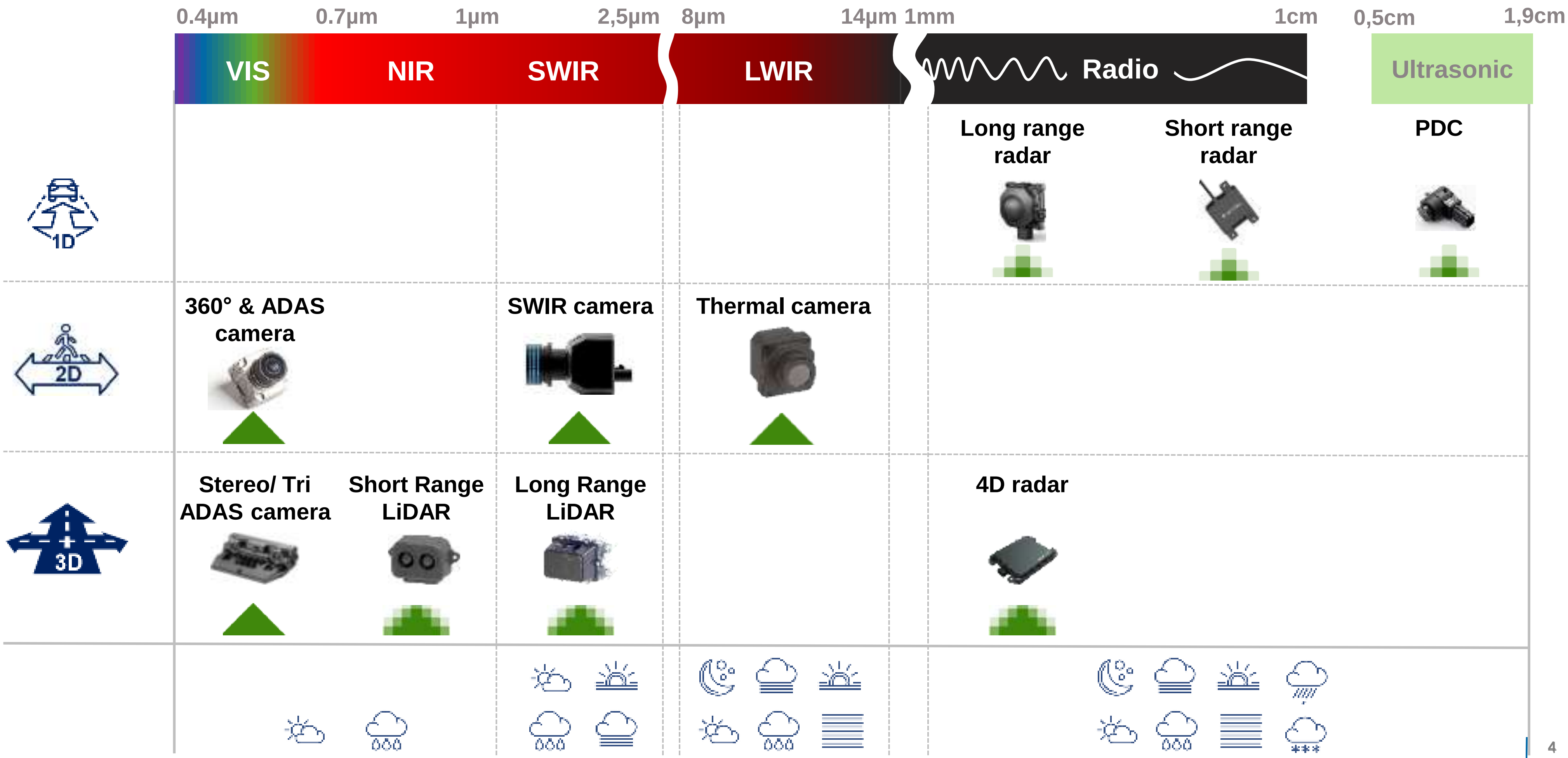
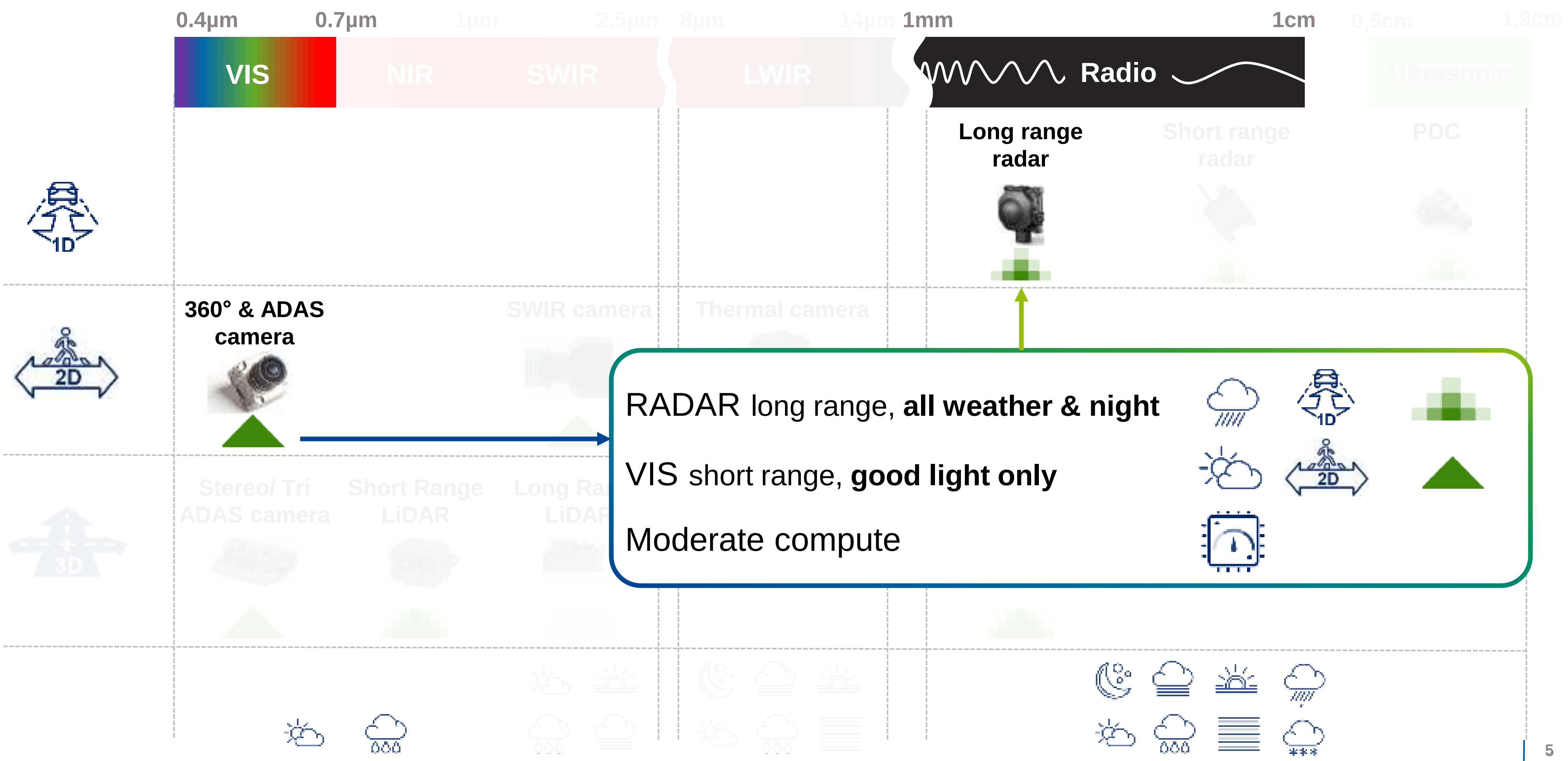
Avoiding the loss of lives comes first,
convenience of self driving is next
Imagine being involved
or one of your loved ones ...

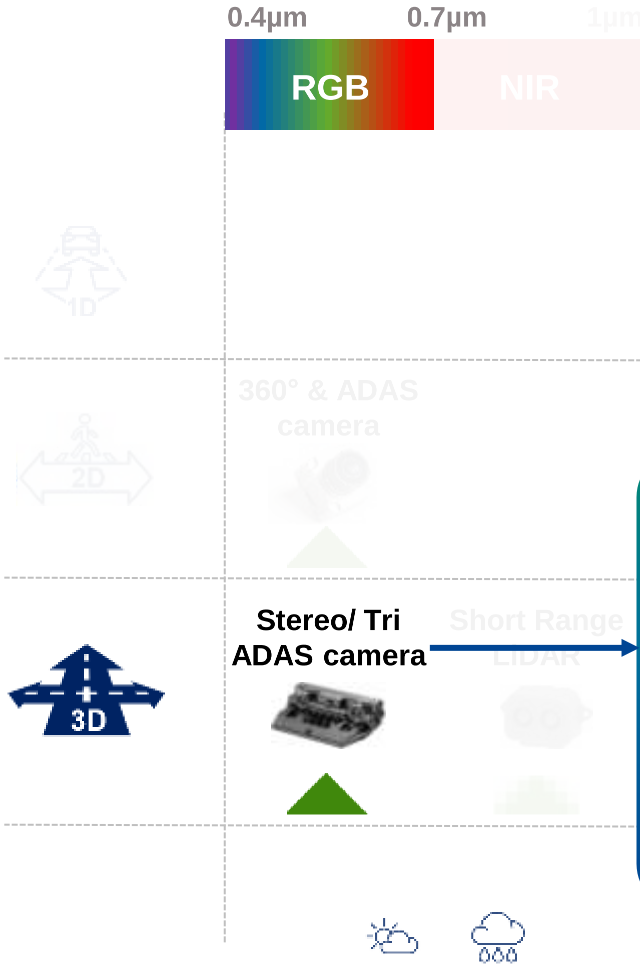
It starts with the sensors we have

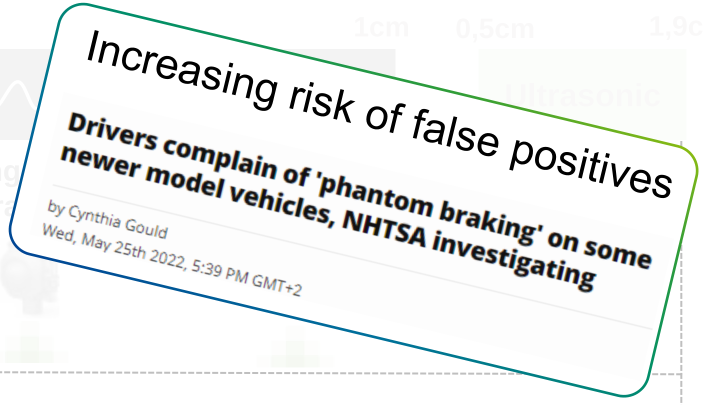


Common sensor scenario today for PAEB



Tesla Vision HW3.0 for PAEB, no more RADAR





Tricam RGB* 1,3Mp, FOV 35°, 50°, 120°

- 3D, short/medium range
- high resolution
- **good light only**
- extensive compute

*Source: Automotive Teardown Track, System Plus Consulting, 2020)

Thermal imaging improves detection significantly

0.4µm | 0.7µm | 1µm | 2,5µm | 8µm | 14µm | 1mm | 1cm | 0,5cm | 1,9cm

RGB | NIR | SWIR | **LWIR** | Radio | Ultrasonic

Long range radar | Short range radar | PDC

1D | 2D | 3D

Thermal emittance of a pedestrian (50W/m2)

≈

Visible emittance of pedestrian @ 15m from high beam

Thermal camera

Thermal

- 2D, long range
- medium/high resolution
- most weather conditions
- **no light source needed**
- Machine learning: easy

Thermal imaging is now affordable for PAEB

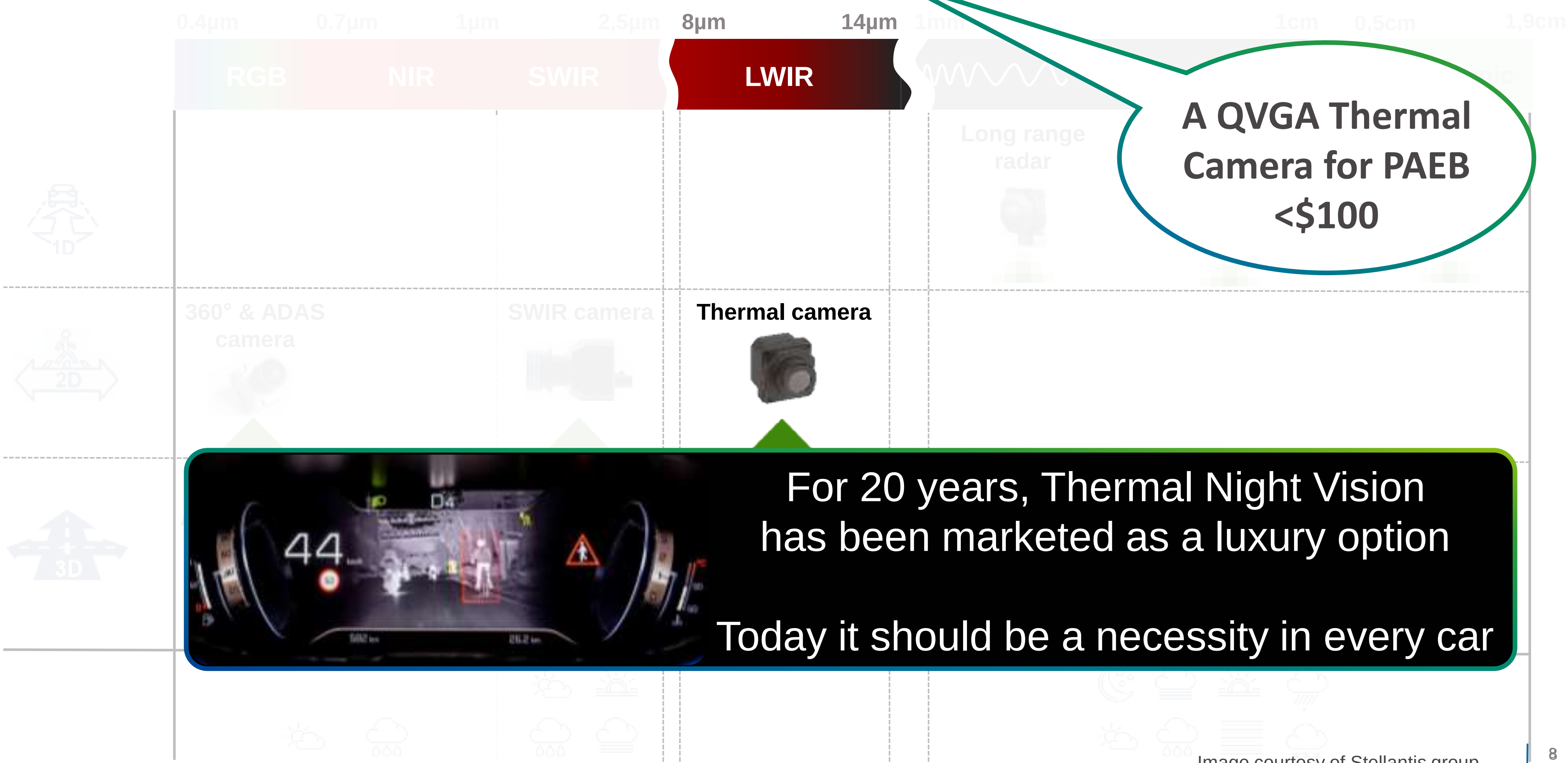
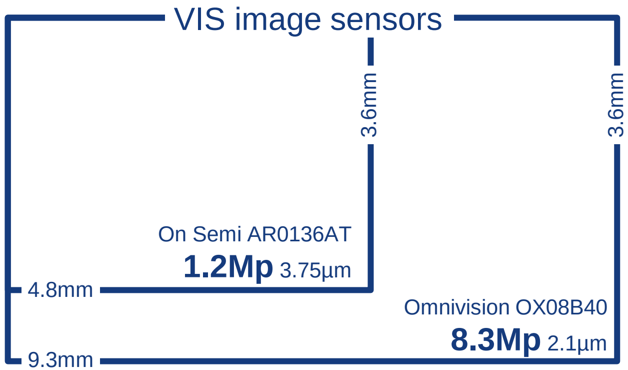
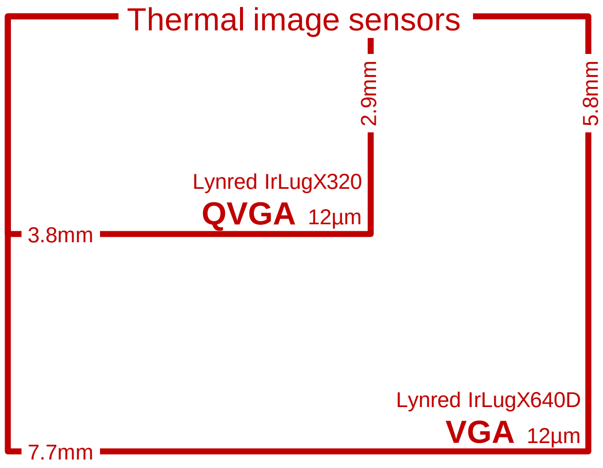


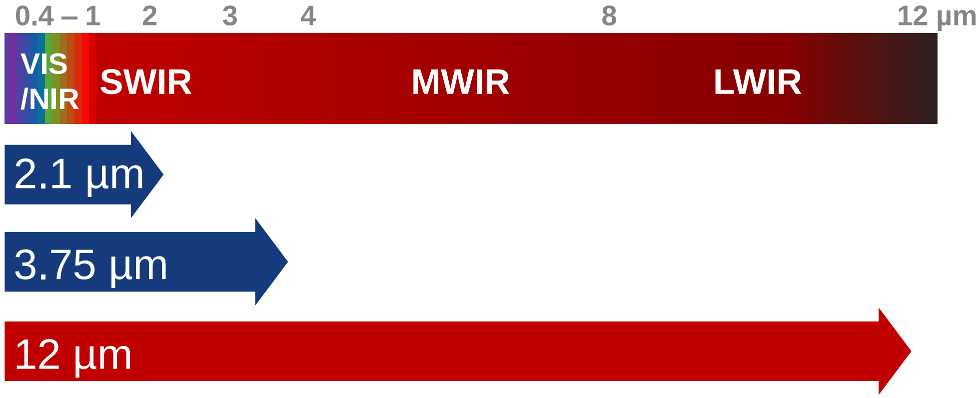
Image courtesy of Stellantis group

Make it affordable: choose the right sensor size

Sensor size is similar to visible, pixel pitch is quite different







Pixel size ≥ Wavelength

Thermal imager resolution is **significantly lower** for same die size

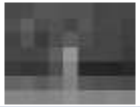
How much resolution is needed?

DRI versus DORI standards compared

Thermal camera
Detection of a VRU with high confidence
Identification difficult

Visible camera
Detection of a VRU difficult
Identification with high confidence

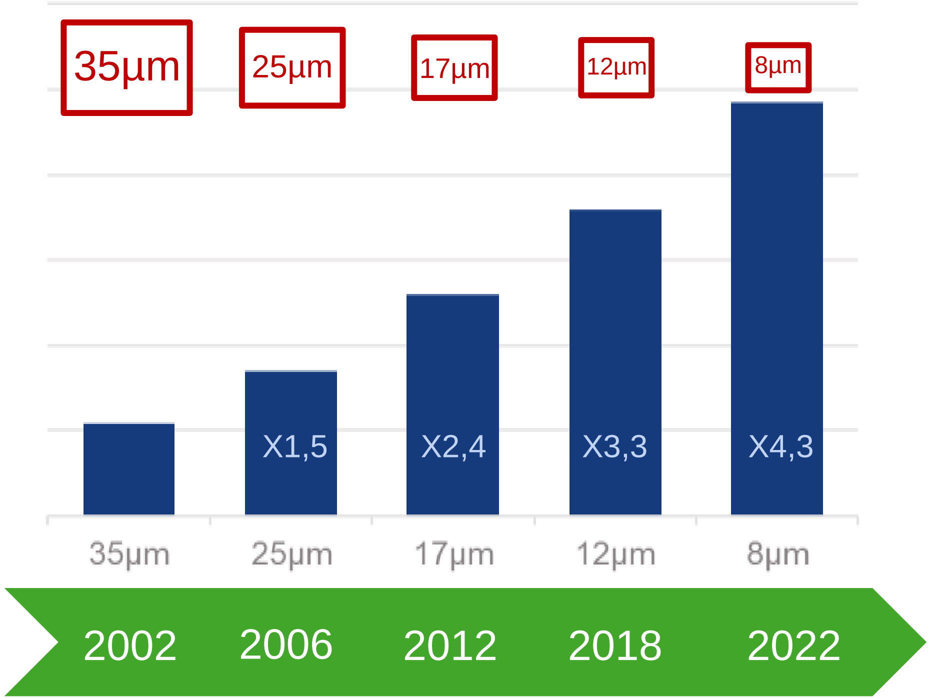
A thermal camera requires x10 less pixels to detect a human

	Thermal: DRI of human (Johnson criteria for thermal cameras)			**Visible: DORI of human** (IEC EN62676-4: 2015 for VIS/NIR security cameras)
Detection	**2 PPM** → Something is there			**25 PPM** → human presence
Recognition	**6 PPM** → A person is there			**125 PPM** → Who is the human
Identification	**12 PPM** → The person is a civilian			**250 PPM** → Identification beyond doubt

Make it affordable: Choose the right pixel pitch

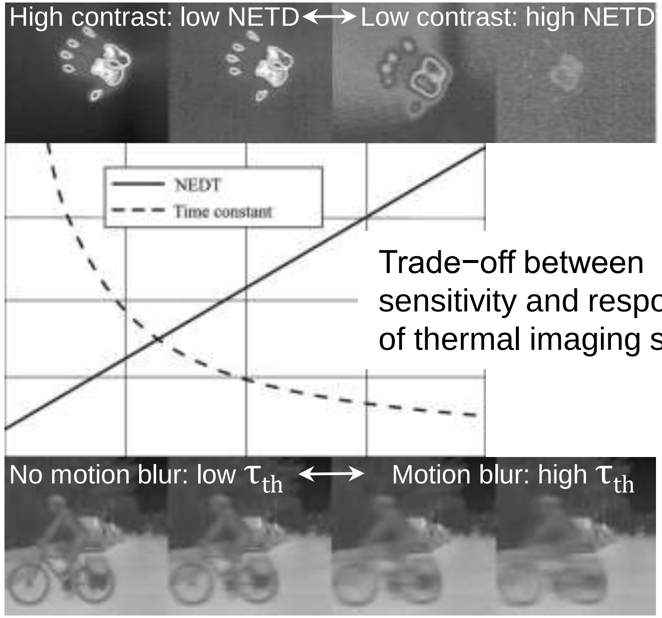
Smaller pixel pitch is lower cost, but could impact optics design

Nr of QVGA detector dies in an 8" wafer (estimate)



Impact on sensitivity? : *NETD*

(40 < NETD < 50 mK)



Trade−off between sensitivity and response time of thermal imaging systems

Impact on response time?: τ_{th}

→ not a critical factor for this application

(10 < τ_{th} < 16 ms)

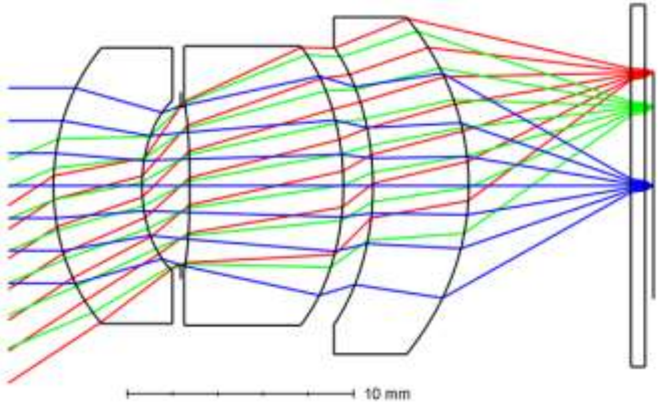
*NETD: Noise Equivalent Temperature Difference, image courtesy of Teledyne Flir

Optimizing lens design to balance performance and cost

Impact of smaller sensor size

As the focal length is proportional to the sensor size, a smaller sensor implies a shorter focal length → **smaller optics**

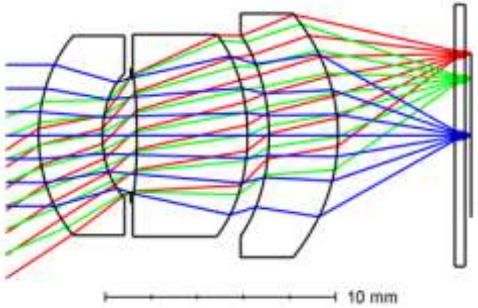
$$Field\ of\ View \approx \frac{Sensor\ width}{Focal\ length}$$



VGA 12µm → 8,5µm pixel pitch

Simple scale down of optics*

Focal length 8.8mm → 6.3mm



*Lens requirements for sub 10µm pixel pitch uncooled microbolometers for LWIR – Raphaël Proux DCS 2023

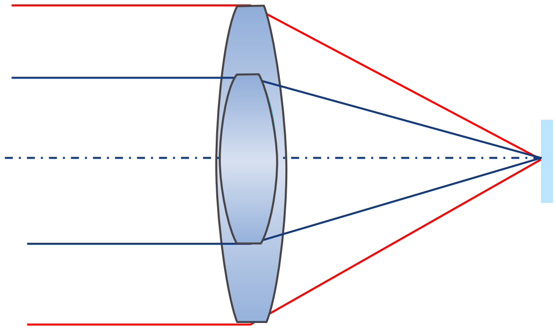
Optimizing lens design to balance performance and cost

Impact on Sensitivity? ½ pixel size → ¼ amount of light

4 x the light → ½ the f-number (N) → 2x size of the optics

$$\mathit{Collected\ light} \propto \text{pitch}^2$$
$$\propto 1/(f - number)^2$$

$$\mathit{Diameter\ of\ lens\ entrance\ pupil} = \frac{focal\ length}{f - number}$$

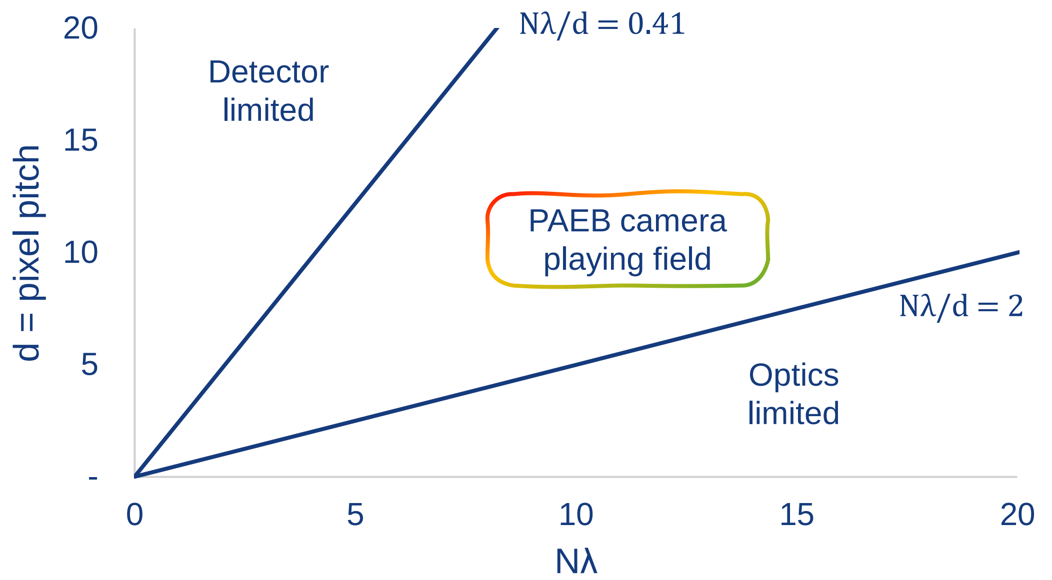


Luckily, the design of the pixel can be optimized to limit NETD impact

For the PAEB application, impact of smaller pixels on NETD is not causing a significant penalty on the cost of the optics.

Optimizing lens design to balance performance and cost

Resolution of thermal imaging system is diffraction limited



Rayleigh criterion for $\lambda = 10\mu m \;\; N = f/1.0$

$$R_{Airy\ Disk} \approx 1.22 \times \lambda \times N \approx 12\ \mu m$$

A balanced design of sensor and optics makes an affordable thermal camera possible as part of a PAEB sensor system.

Gerald C. Holst and Ronald G. Driggers, “Small detectors in infrared system design”, Optical Engineering 51(9), 096401

NHTSA new PAEB test parameters

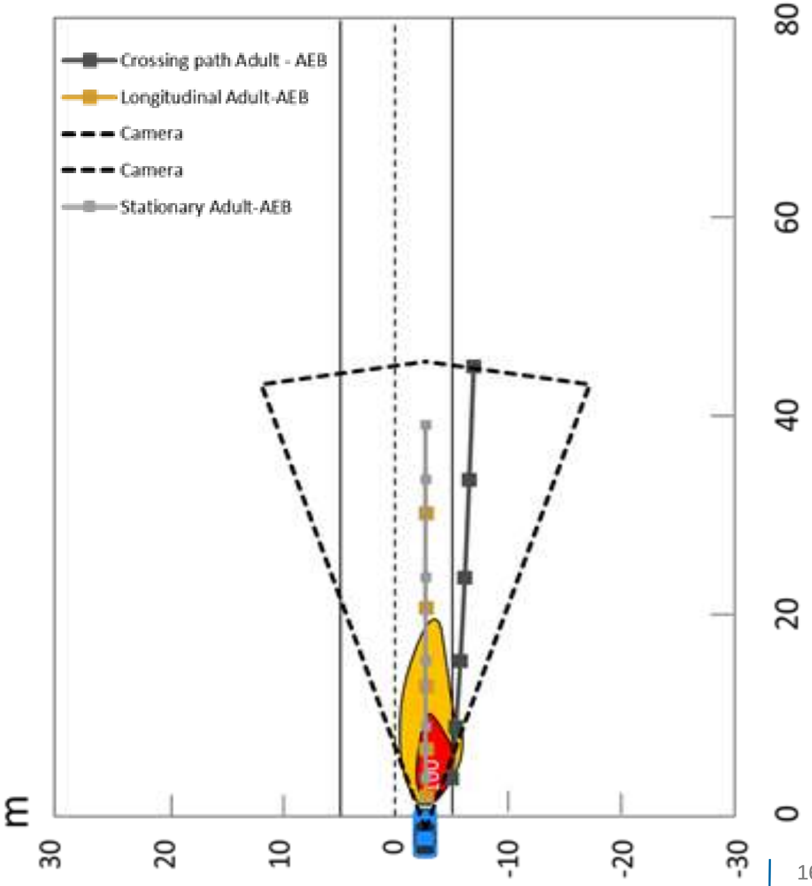
Affordable thermal camera meeting new NHTSA standard

Scenarios	Crossing from right	Stationary on road	Moving along road
Vehicle speed	10 – 60 km/h	10 – 60 km/h	10 – 65 km/h
Available light	≤ 0.2 lux		
VRU	Adult only		
Recommended Deceleration	0,5g (~4.9m/s^2)		

	Low speed - HFOV max		High speed - range max	
Test	HFOV	Range	HFOV	Range
Crossing path Adult – AEB	≤ 47.5°	5.6 m	≥ 10.4°	46.8 m
Stationary Adult-AEB		3.4 m		40.7 m
Longitudinal Adult-AEB		3.4 m		31.8 m

Conclusion: a <$100 thermal camera for PAEB is here!

Specification*		Value
Target	Surface (side view)	0,8m²
Atmospheric conditions		No attenuation
Detector	Horizontal resolution	320 – 400 pixels
	Pixel pitch	8,5µm
Optics	FOV	37°
	Focal length	4.1 mm
	F-number	1.0
Range with recognition 90%		>50m



*Simulation, feasibility and cost analysis
by Quentin Noir, Lynred and Raphaël Proux, Bendix De Meulemeester, Umicore

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Unique business model

INTERNAL DRIVER

Supportive megatrends

EXTERNAL DRIVER

Let's go for zero

Industry leader in sustainability

Employees	Production + R&D Sites	Revenues	Adjusted EBITA	R&D spend
11,565	44 + 15	€ 4.2 bn	€ 1.2 bn	€ 245 m

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Scan to register for the Umicore Lynred Sekurit Rooftop event @ the Sofitel tonight at 19u30

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