



Ouster Introduction

We build the eyes of autonomy



OUSTER

Digital technology is the future of lidar

Digital lidar builds on the progress of analog products and solves for the barriers to improved performance and reduced cost.

- Fully integrated, **all-semiconductor** design
- **High-resolution** packed into the smallest form factor available today
- Simplified digital architecture results in highly **reliable and rugged** lidar sensor
- **Affordable**: lowest cost high-resolution lidar today, cost does not increase linearly with resolution



Ambient
(sunlight)



Signal



RAW OUTPUT

Ouster OS1-128



Diverse customer base across many markets



Products



Ouster's product portfolio



OS0

ULTRA-WIDE VIEW

32, 64, or 128 Channel

15 m range @ 10% reflectivity

45 m range @ 80% reflectivity

90° Vertical FoV

OS1

MID-RANGE

32, 64, or 128 Channel

45 m range @ 10% reflectivity

100 m range @ 80% reflectivity

45° Vertical FoV

OS2

LONG-RANGE

32, 64, or 128 Channel

80 m range @ 10% reflectivity

210 m range @ 80% reflectivity

22.5° Vertical FoV

Ultra-wide view OS0

Product Highlights

- 90° Vertical Field of View
- 32, 64, or 128 channels of resolution
- 0 m minimum range
- IP68, IP69K
- Modular cap for custom integrations
- Configurable horizontal FoV



“May Mobility wouldn’t be where we are today as a company delivering autonomous mobility as a service without incorporating ultra-wide view lidar sensors.”

Tom Voorheis
Director of Autonomy Engineering



Key Uses:

- Autonomous vehicles
- Commercial robotics
- Indoor mapping



Mid-range OS1 (Gen 2)

Product Highlights

- 45° Vertical Field of View
- 0 m minimum range
- 32, 64, or 128 channels of resolution
- Modular cap for seamless integration
- IP68, IP69K



“The OS1 lidar’s range, size, durability, and high-resolution are a perfect fit for [our autonomous delivery rover].”

Ali Kashani, VP of Special Projects



Key Uses:

- Autonomous driving
- Industrial automation
- Autonomous trucking
- Drone surveying navigation
- 3D mapping
- Security



Long-range OS2

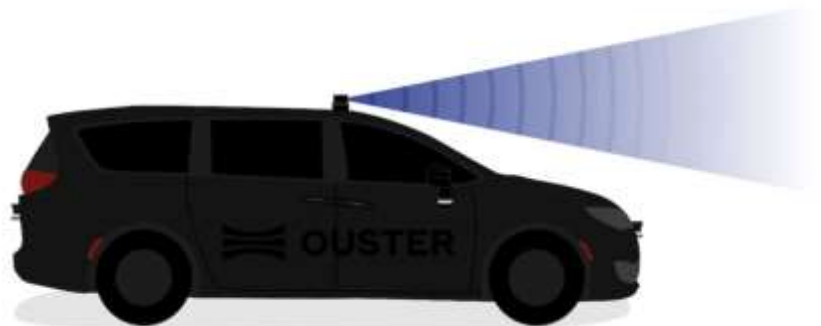
Product Highlights

- 22.5° Vertical Field of View
- 200+ m range
- 32, 64, or 128 channels of resolution
- 0.18° vertical angular resolution
- IP68, IP69K



“The Ouster OS2 is a solid solution that will augment [NVIDIA’s] long-range perception offerings thanks to its resolution and reliability.”

Gary Hicok
Senior Vice President of Automotive Hardware and
Systems



Key Uses:

- Autonomous vehicles
- Autonomous trucking
- Drone surveying and navigation

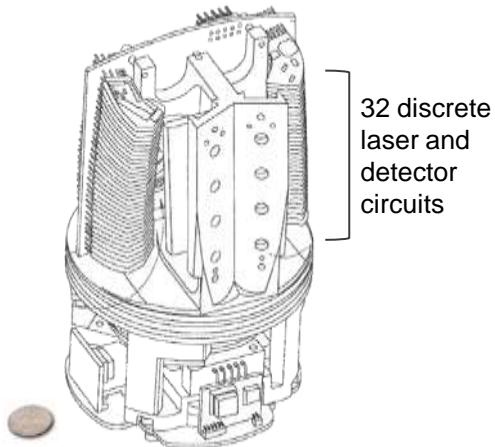


Technology

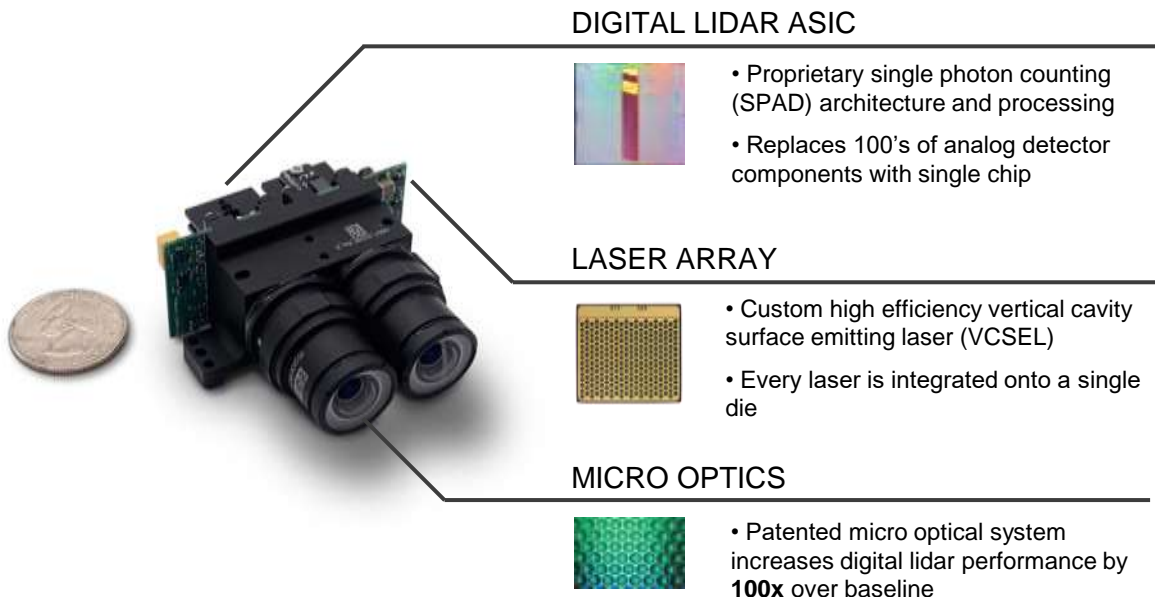


Ouster's digital lidar decouples cost from performance

Analog lidar (32 channel)

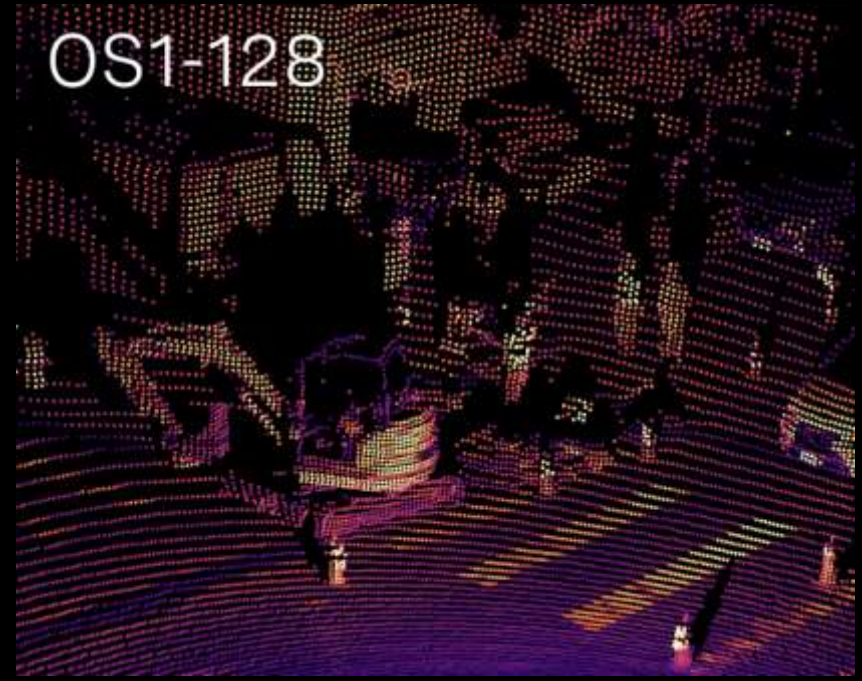


Digital lidar (128+ channel)



DIGITAL LIDAR

High-Resolution



DIGITAL LIDAR

Rugged & Reliable

Ouster sensors are designed and built to withstand the most challenging environmental conditions:

- Rated IP68 (immersion in > 1 m of water) and IP69K (withstands 2000 psi power washing)
- Passed many mechanical shock & vibration tests, including:
 - IEC 60068-2-27 (Amplitude: 100 g, Shape: 11 ms half-sine, 3 shocks x 6 directions)
 - IEC 60068-2-29 (Amplitude: 40 g, Shape: 6 ms half-sine, 1,500 shocks x 6 directions)
 - IEC 60068-2-64 (Amplitude: 3 G-rms, Shape: 10 - 1000 Hz, Mounting: sprung masses, 3 axes w/ 8 hr duration each)
- Temperature rated from -40° C to +60° C for OS0 and OS1; rated from -20 °C to +64 °C for OS2
- Currently undergoing full automotive-grade qualification and on track for ASIL B (D) and SIL-2 certification in 2022



Automotive-grade vibration testing



IP69K testing



Trip to the local car wash



Affordable

Ouster sensors are the most affordable high-resolution lidar sensors available today:

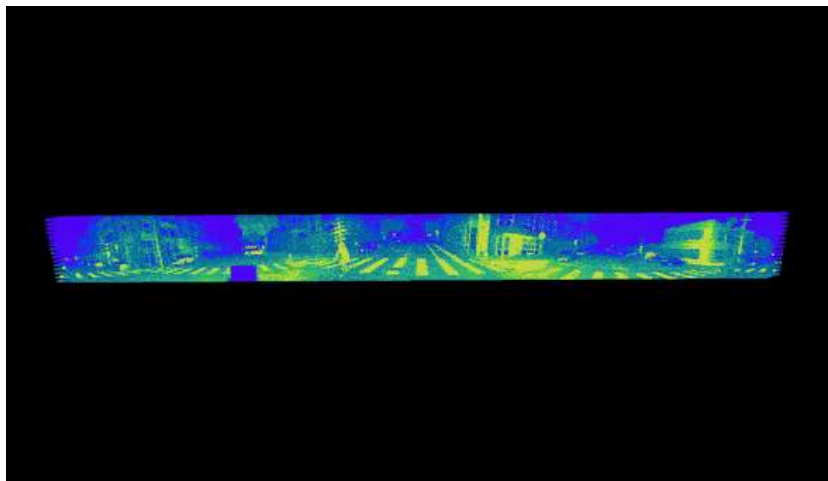
- Lowest price at all levels of resolution
- Internal IMU included
- Unique ambient data output enables lidar-only perception algorithms
- Standard two-year warranty included
- Price falls with volume purchases
- Beam spacing options available to get improved perception out of fewer beams



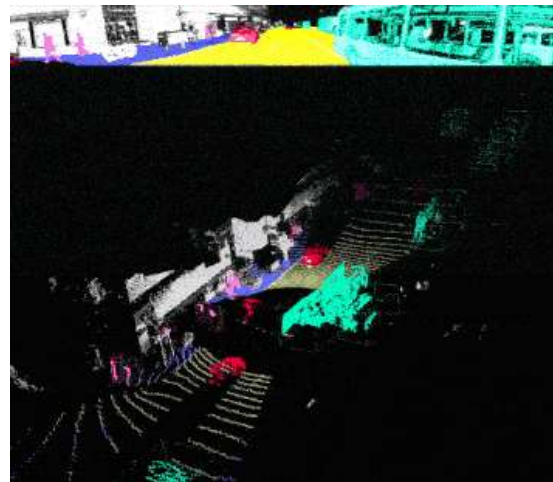
Perception and Localization



Perfect 2D:3D data spatial correspondence



Visualization of 2D to 3D data correspondence



Faster data labeling using 2D and 3D images simultaneously



DIGITAL LIDAR

More powerful machine learning

Computational efficiency

- Process data with **>10x greater computational efficiency**, leveraging compute designed for vectors (e.g., GPUs or specialized ASICs instead of CPUs¹)

Faster labelling

- **Reduce data labelling time by up to 50%** with unified 2D and 3D data

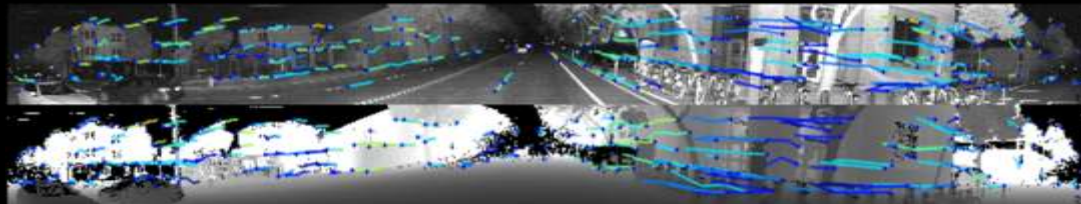
Algorithm compatibility

- **Apply existing 2D camera algorithms directly** to native ambient, signal, and range data

2D algorithms applied directly onto structured lidar data (no pre-processing)



CNN-based semantic segmentation on combined ambient, signal, and depth images



Superpoint²: CNN-based key point extraction run on signal and depth images

¹ <https://medium.com/@andriylazorenko/tensorflow-performance-test-cpu-vs-gpu-79f0d39170c>

² DeTone, Daniel, et al. "SuperPoint: Self-Supervised Interest Point Detection and Description." CV, April 2018.



Ouster sensors are higher resolution, smaller, more reliable, and more affordable

High Resolution

- Up to 128 vertical lines of resolution improves object detection

Rugged & Reliable

- IP69K and IP68 rated; lower total cost of ownership (TCO)

Affordable

- Ouster sensors offer the best value for performance available today

Small & Lightweight

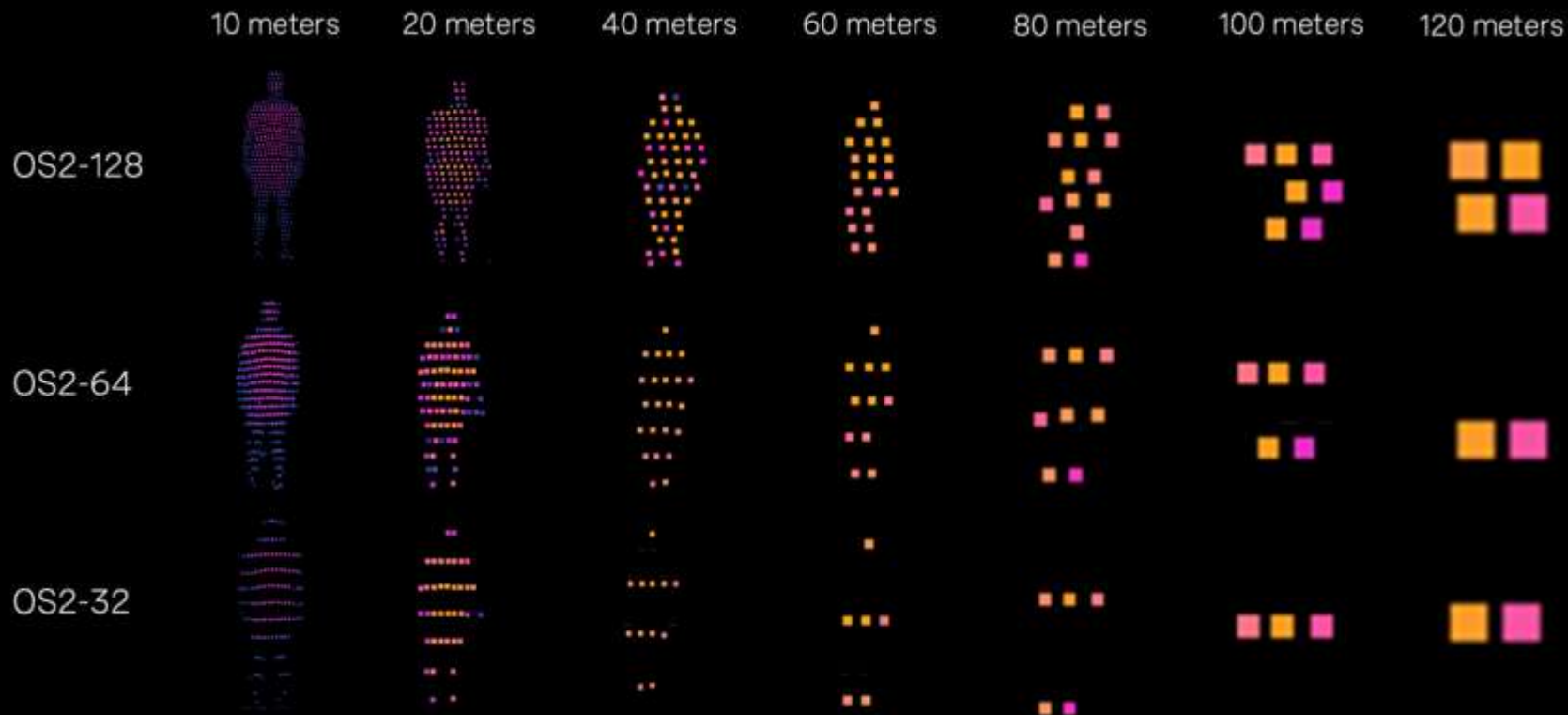
- Smallest and lightest sensor available on the market



Fin



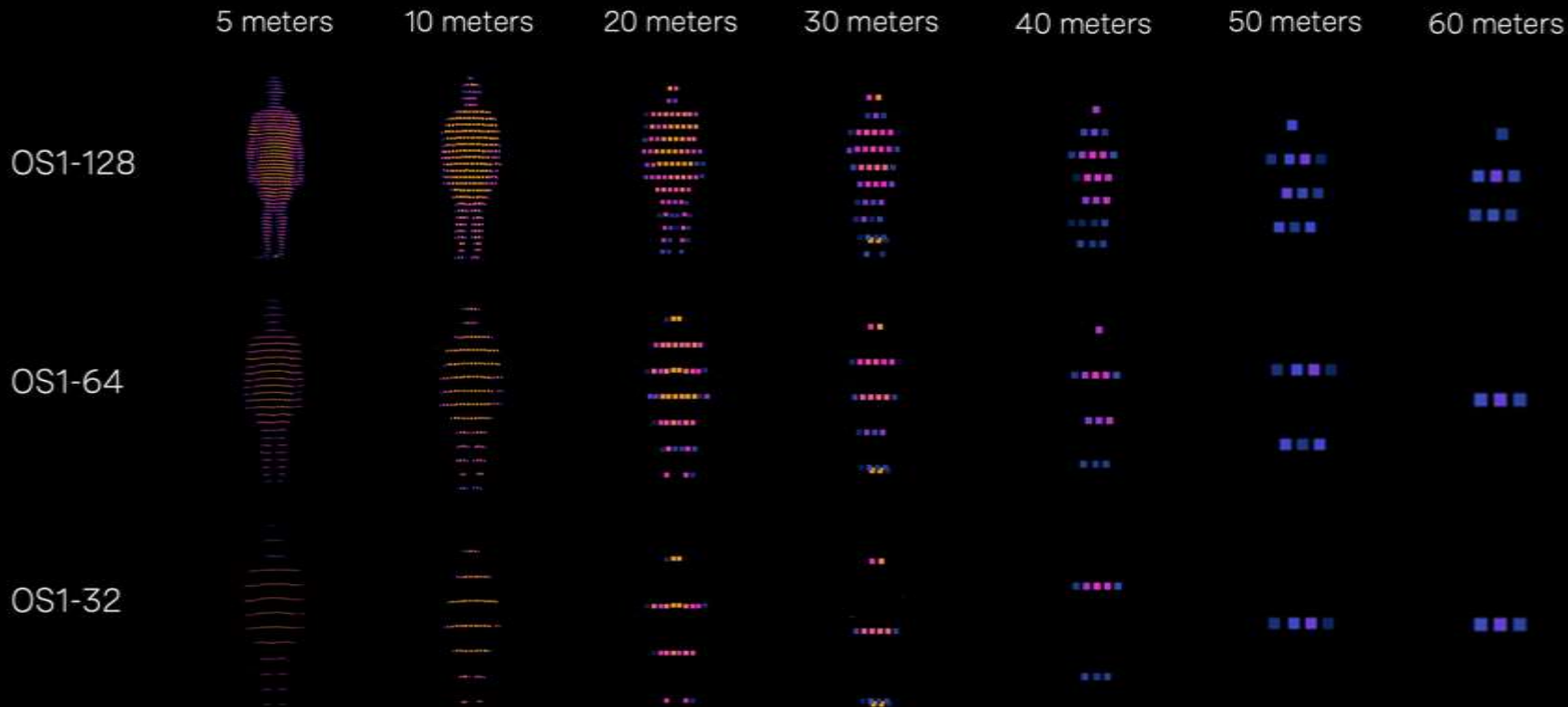
OS2 Resolution Comparison



*Person is 1.8 m (6 ft) tall



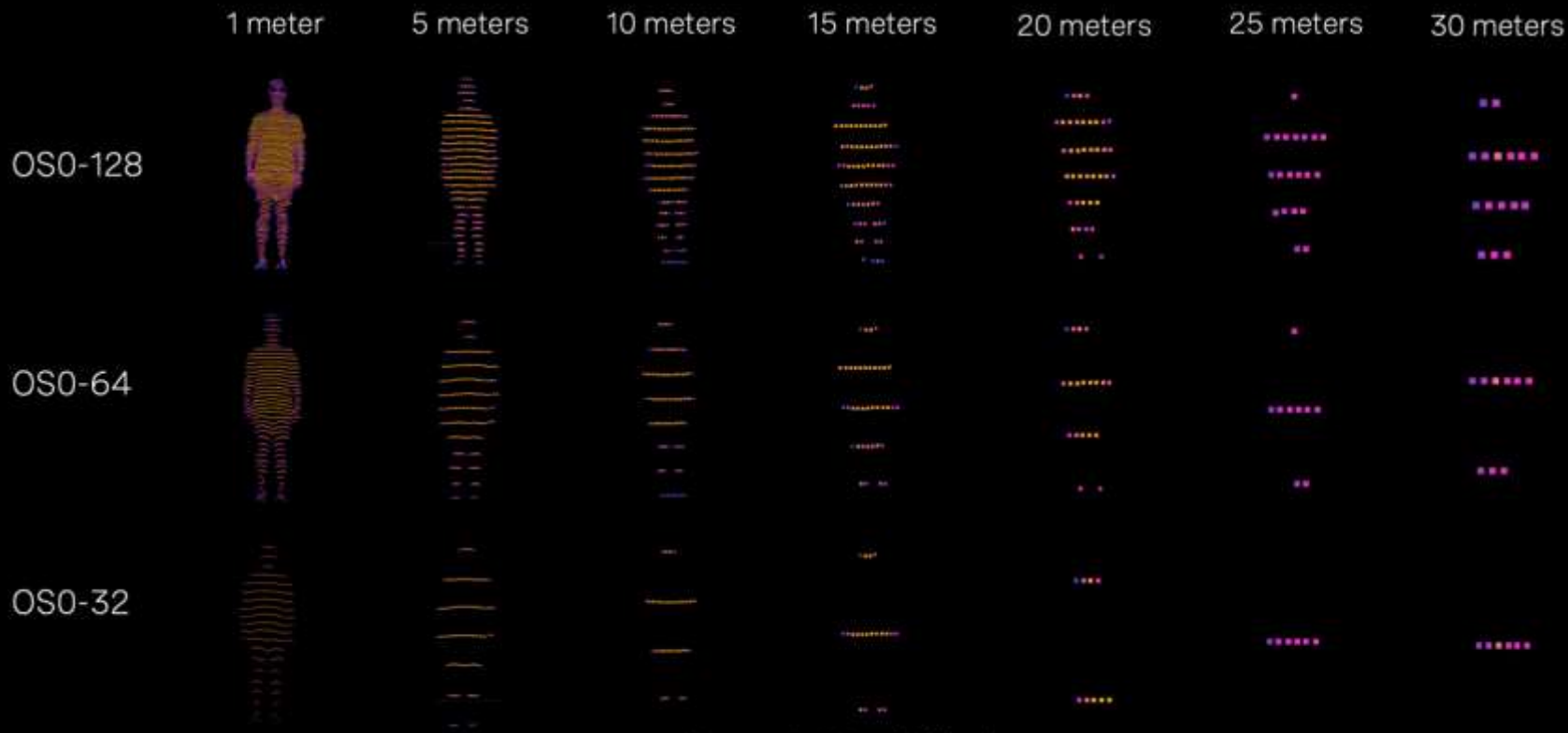
OS1 Resolution Comparison



*Person is 1.8 m (6 ft) tall



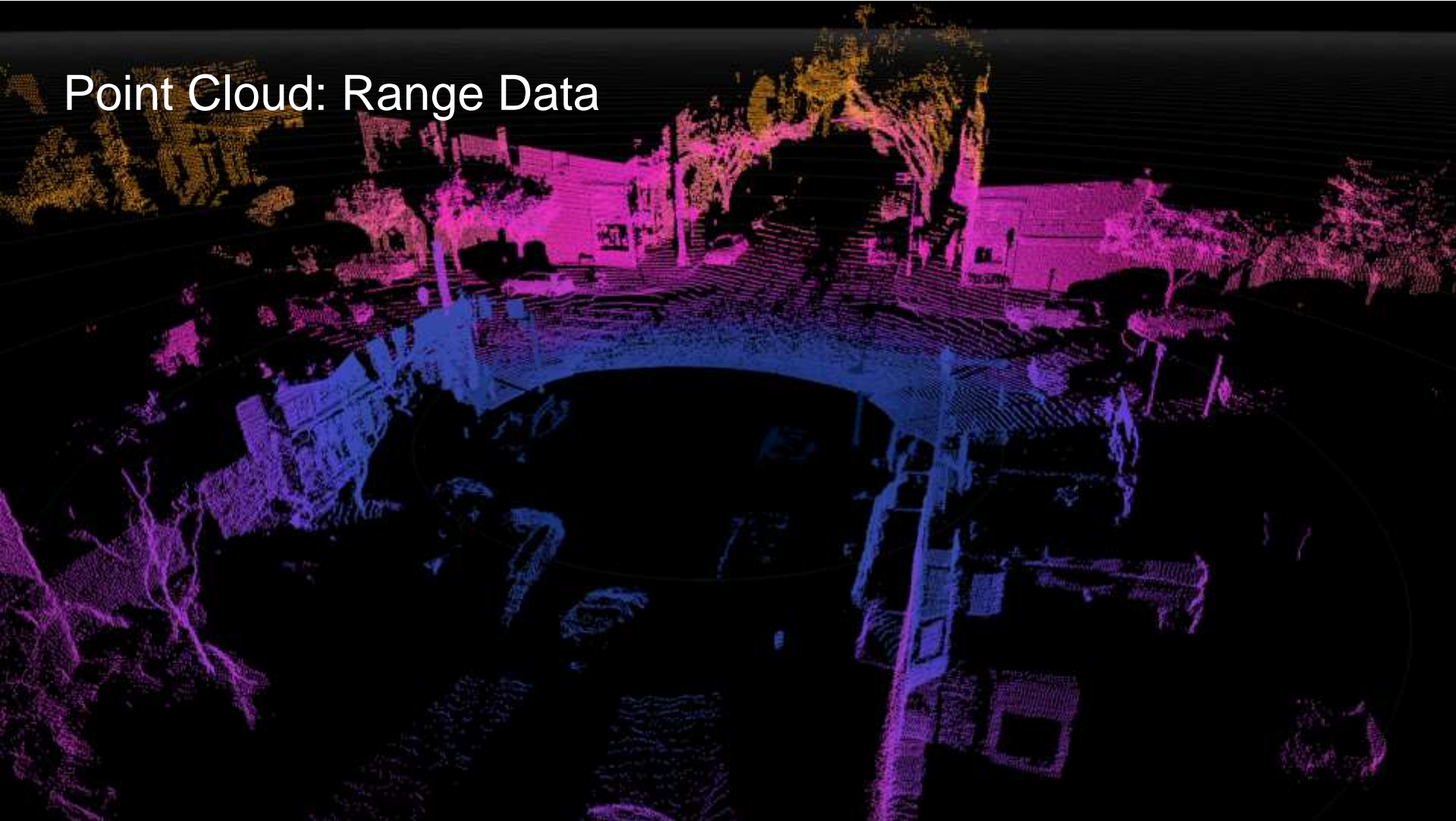
OS0 Resolution Comparison



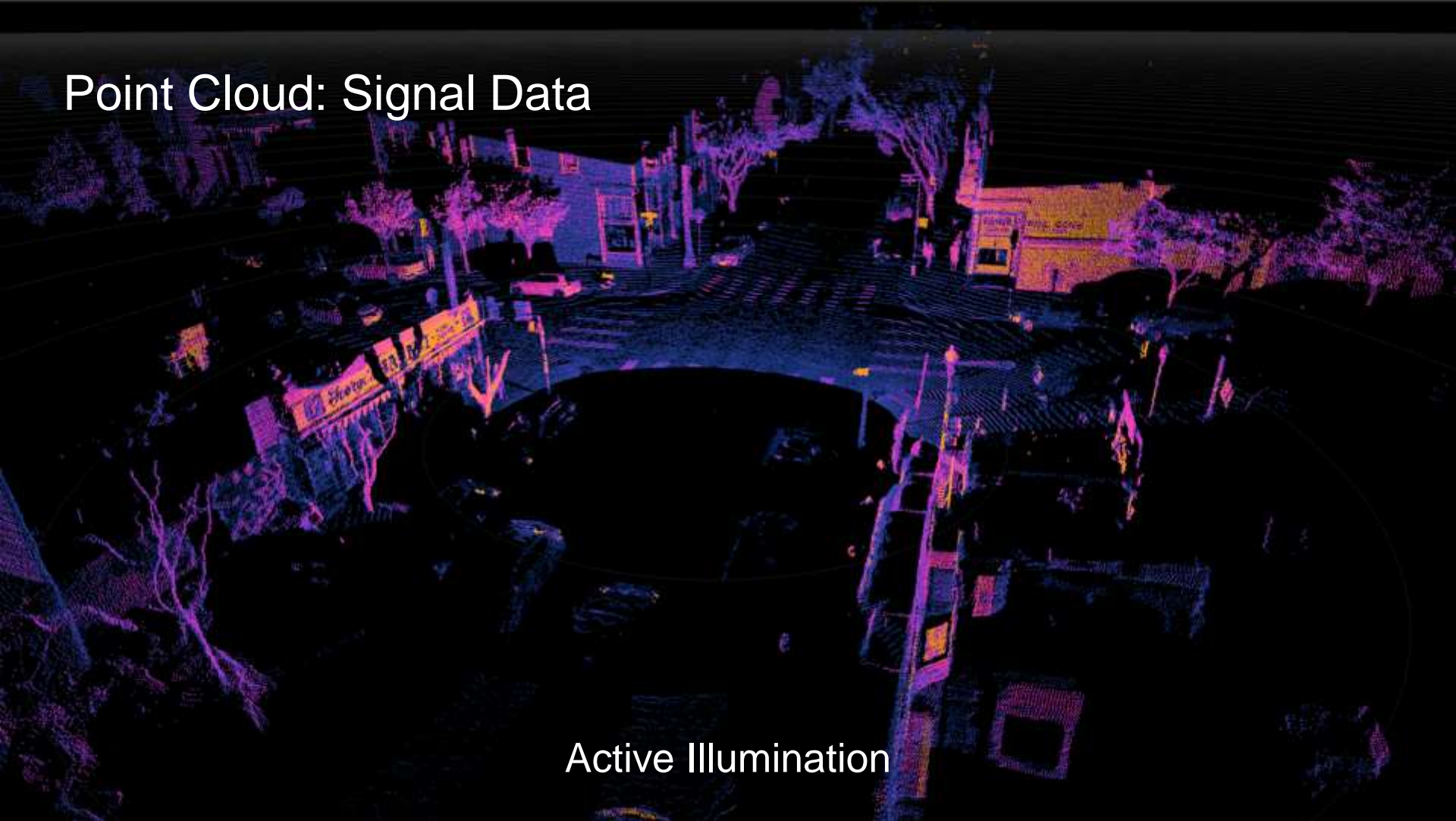
*Person is 1.8 m (6 ft) tall



Point Cloud: Range Data



Point Cloud: Signal Data

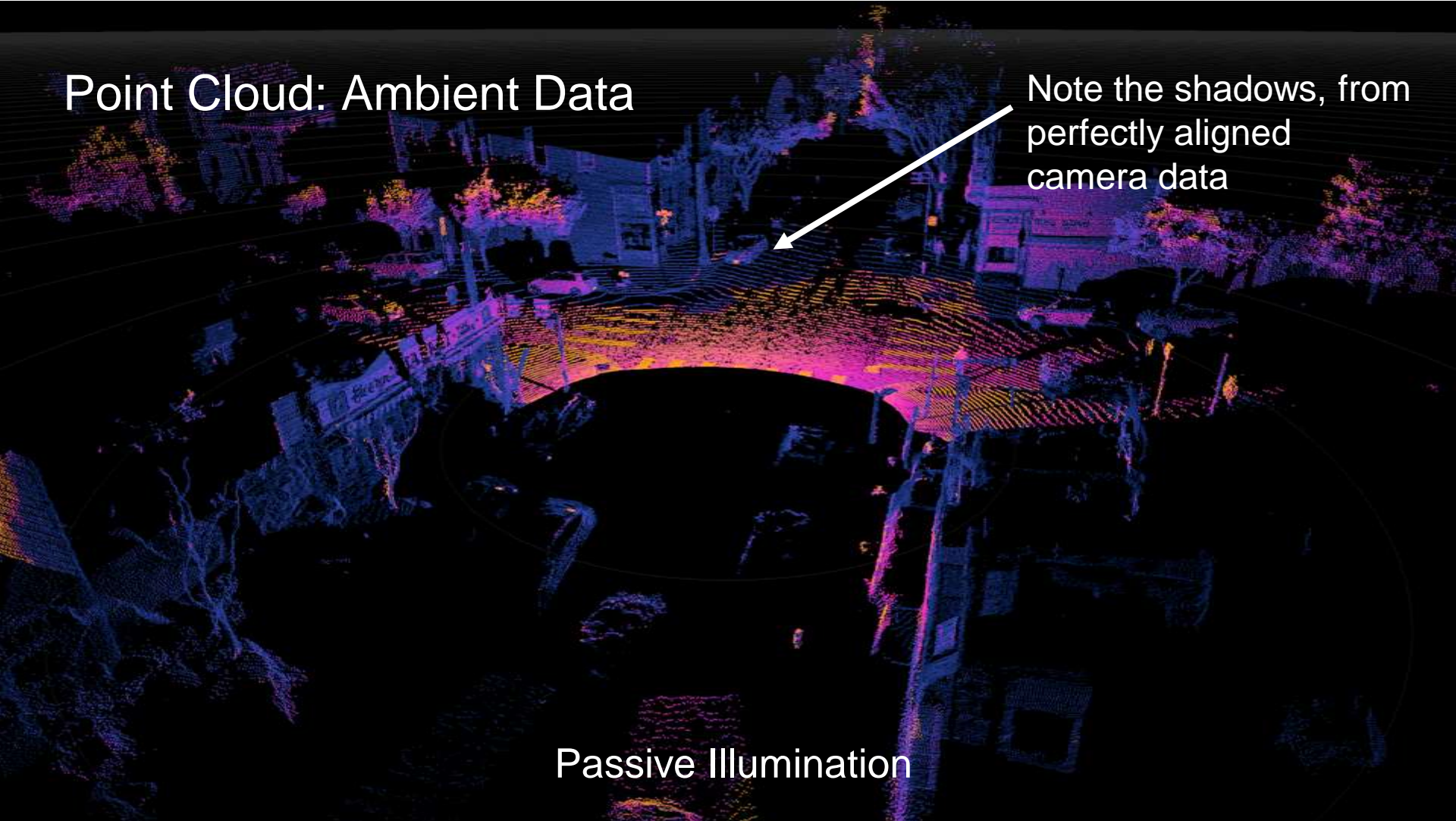


Active Illumination

Point Cloud: Ambient Data

Note the shadows, from perfectly aligned camera data

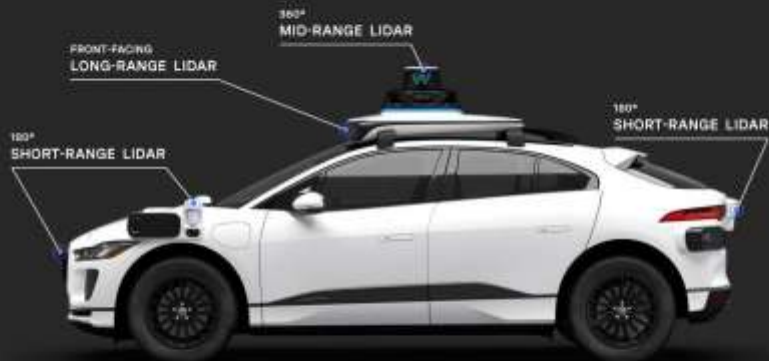
Passive Illumination



The Automotive opportunity for short and mid range is bigger than long range

Autonomous Car (Level 4-5)

Autonomous Truck (Level 4-5)



Lidar type	Quantity on-vehicle
Short-range	4
Mid-range	2
Long-range	1
Total Package	7

Lidar type	Quantity on-vehicle	Range	Field of View (H x V)
Mid-range	2	0 - 50 meters	180° x 45°
Long-range	1	5 - 200+ meters	100° x 20°



Industrial

Heavy Industry



Lidar type	Quantity on-vehicle	Range	Field of View (H x V)
Short-range	3-4	0 - 50 meters	180° x 90°
Mid-range	1-2	0 - 100 meters	180° x 45°

Factory Automation



Lidar type	Quantity on-vehicle	Range	Field of View (H x V)
Short-range	3-4	0 - 50 meters	180° x 90°
Mid-range	1-2	0 - 100 meters	360° x 45°



Smart infrastructure

Intelligent Transportation Systems (ITS)



Lidar type	Quantity per intersection	Range	Field of View (H x V)
Short-range	2-4	0 - 50 meters	360° x 90°
Mid-range	2-3	0 - 100 meters	360° x 45°
Long-range	1-2	5 - 200+ meters	360° x 20°

Security (Building and Perimeter)



Lidar type	Quantity per 100 m ²	Range	Field of View (H x V)
Short-range	4-10	0 - 50 meters	360° x 90°
Mid-range	2-4	0 - 100 meters	360° x 45°
Long-range	1-2	5 - 200+ meters	360° x 20°



Robotics

Drones



Lidar type	Quantity on-vehicle	Range	Field of View (H x V)
Mid-range	1	0 - 100 meters	360° x 45°

Last-mile Delivery Vehicles



Lidar type	Quantity on-vehicle	Range	Field of View (H x V)
Short-range	3-4	0 - 50 meters	180° x 90°
Long-range	1	1 - 200 meters	360° x 20°



