

- **Ouster Technology Overview**

ASCA TECH



# INTRODUCTION TO OUSTER INC.

- 누구나 쉽게 사용 가능한 차대세 LiDAR
- 단순한 구조로 디자인된 새로운 개념의 LiDAR

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4

years of development

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#1

new lidar company\*

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\$90

million invested

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6,900

m<sup>2</sup> R&D and  
production facility

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150+

employees and  
growing

---

450+

customers in

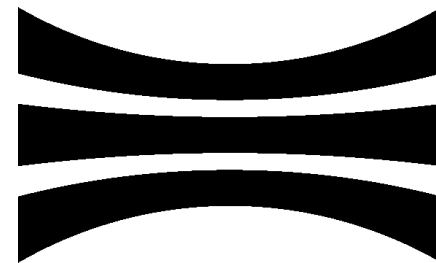
50+

countries

---

200+

units produced per  
month





# THE LIDAR MARKET TODAY

## Three generations of analog technology

GEN 1 (1990S)

### 2D Analog



**SICK**  
Sensor Intelligence.

- Inexpensive
- Reliable
- Indoor only
- Low resolution
- Limited FoV

GEN 2 (2005)

### 3D Analog scanning



Velodyne  
LiDAR.



LUMINAR

- High resolution
- 360° FoV
- Expensive
- Fragile & unreliable
- Analog signal

GEN 3 (2015-2020)

### 3D Analog solid-state\*



AEYE

INNOVIZ  
TECHNOLOGIES

- More reliable
- Programmable scanning
- Manufacturing complexity
- Lower resolution
- Limited FoV
- Limited to long range applications

\*Categorizes MEMS as solid state though it is not technically solid state



## A NEW GENERATION

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



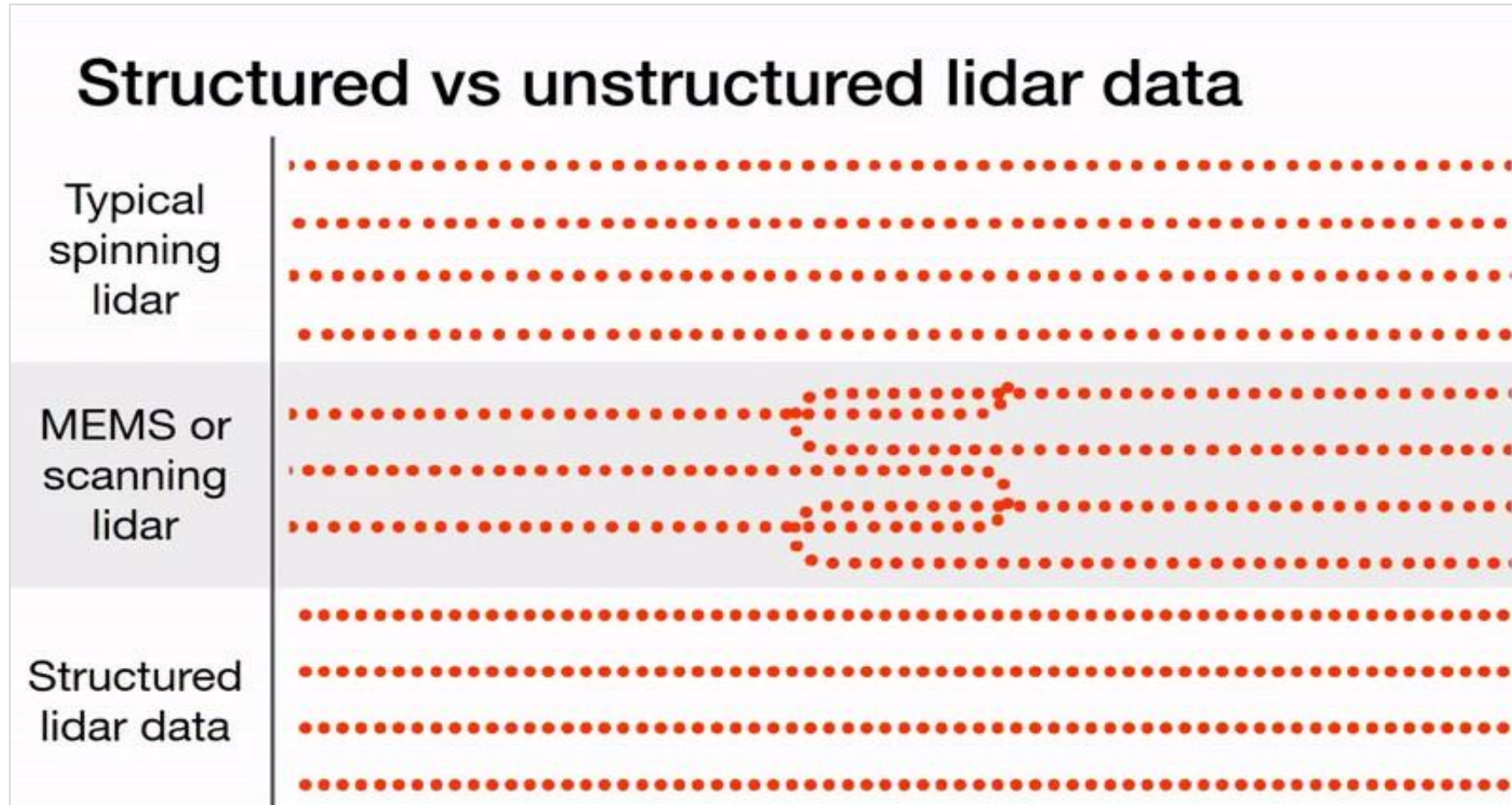
GEN 4 (2018+)

## 3D digital lidar

- Very high resolution
- Inexpensive
- High reliability
- 360° FoV
- Digital signal output
- Rapid range improvement



# STRUCTURED LIDAR DATA



- Ouster LiDAR는 카메라처럼 수평 ,수직 각도가 일정한 데이터를 출력합니다. 고 해상도(pixel 수:2048 X 64)의 scanning이 가능한 고정형 디지털 LiDAR 입니다. 또한, 모든 프레임의 반사강도 및 주변 광 영상을 출력할 수 있으며, CNN(Convolutional Neural Network) 작업 뿐만 아니라, 영상 저장 및 레이블링 작업효율을 극대화 할 수 있습니다.



Signal image

Range image

Combined point cloud



RAW OUTPUT

Ouster  
OS1-64

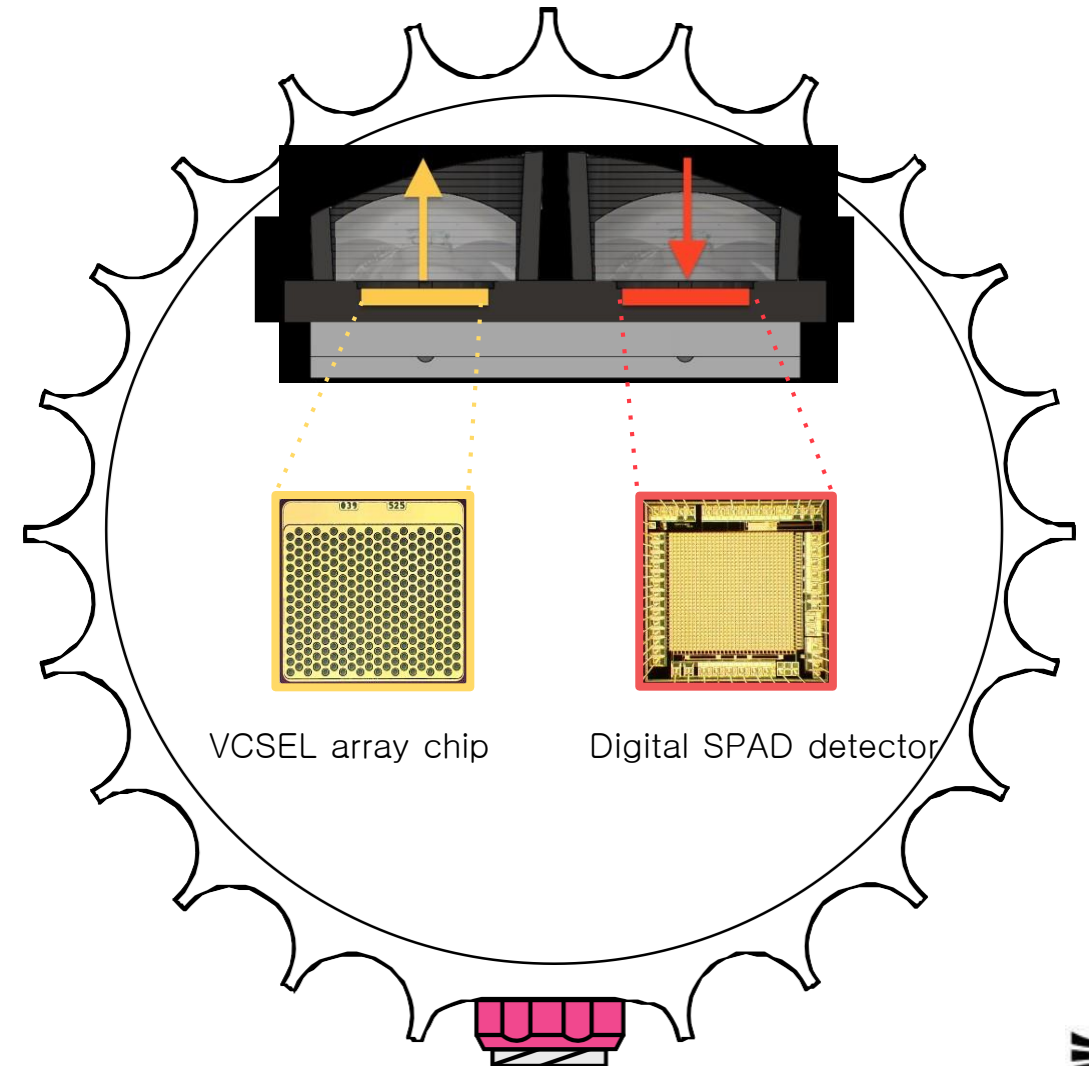




## Simplified architecture

- High-resolution flash lidar components (“Multi-beam Flash Lidar”) mounted on a robust spinning turntable
- 2 custom chips, 2 lenses, and one turntable 100–1000x reduction in component count
- Multi-beam flash lidar technology supports both spinning and fully solid-state LiDAR sensors

## Example: Lidar top view





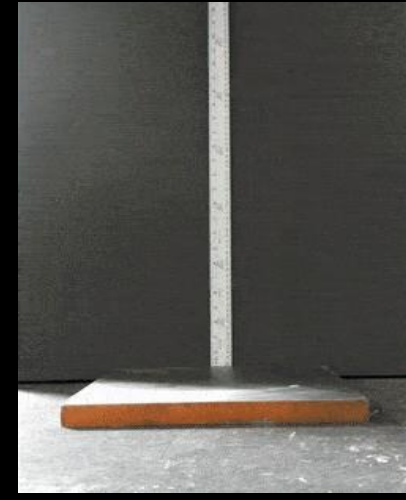
Ouster sensors are designed and built to withstand the most challenging environmental conditions:

- Rated IP68 (immersion in > 1 m of water) and IP69K (withstands 2000 psi power washing)
- **25 g (Pothole simulation)**
- **40 g (Closure slam simulation)**
- **100 g (Collision simulation)**
- Temperature rated to  $-20^{\circ}\text{C}$  and  $+50^{\circ}\text{C}$
- Currently undergoing full automotive-grade qualification and on track for ASIL B (D) certification by 2021

Passed many mechanical shock tests, including:  
→ **>5 g RMS** Vibration (Full sine and half sine)



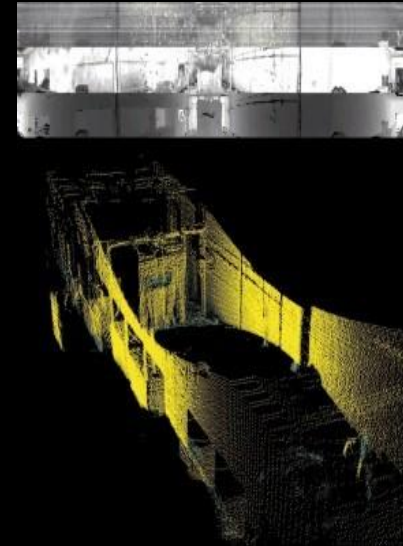
*Automotive-grade vibration testing*



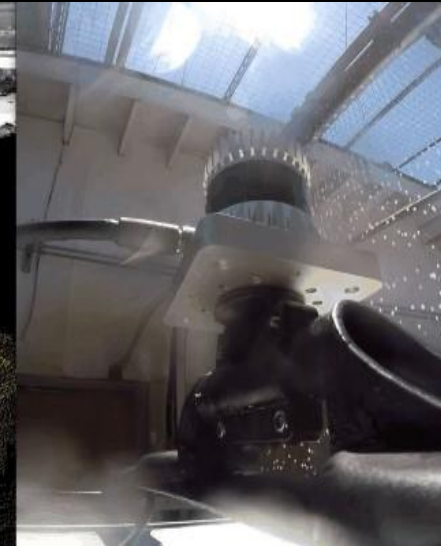
*1 m drop test*



*IP69K testing*



*Trip to the local car wash*





# RELIABILITY: NEW CONNECTOR & CABLE



(Rugged and secure bayonet connector)

- Spinning lidar doesn't need to be unreliable
- 자동차등급의 품질요건 충족
  - ▶ 윈도우 방수보강, 커넥터 및 케이블 업그레이드
  - ▶ IP68에서 IP69K로 등급 상향



# OS0 - ULTRA-WIDE VIEW LIDAR SENSOR

	OS0- 32	OS0- 64	OS0- 128
Vertical Resolution	32 channels	64 channels	128 channels
Horizontal Resolution	512, 1024, or 2048		
Range	55m		
Vertical Field of View		95° ( $\pm 47.5^\circ$ )	
Vertical Angular Resolution	0.7° - 5.5°(optional)		0.7°
Precision	$\pm 1.5 - 5\text{cm}$		
Points Per Second	655,360	1,310,720	2,621,440
Rotation Rate	10 or 20Hz		
Power Draw	14 - 20W		
Weight	445g		
Ingress Protection Rating	IP68, IP69K		

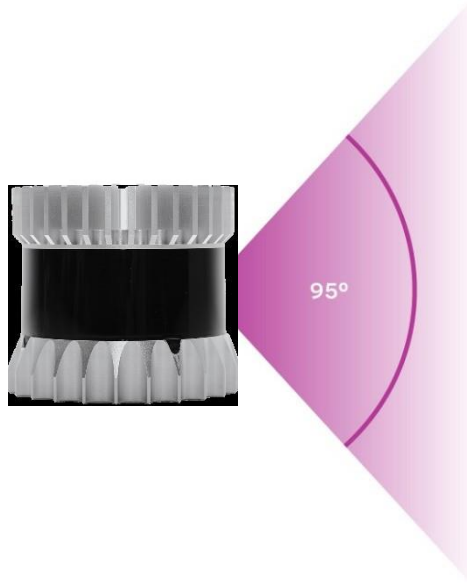


- PTP and NMEA/PPS time synchronization options
- On-the-fly programming of frame rate and horizontal resolution
- Fixed angle data measurement
- Multi-sensor crosstalk resistance
- Pluggable space-style bayonet connector
- Over-the-network firmware updates
- Class 1 eye-safe
- Output: range, intensity, reflectivity, ambient NIR, azimuth angle, timestamp



# OS0 - 32, 64, 128 : LIDAR BEAM CONFIGURATIONS

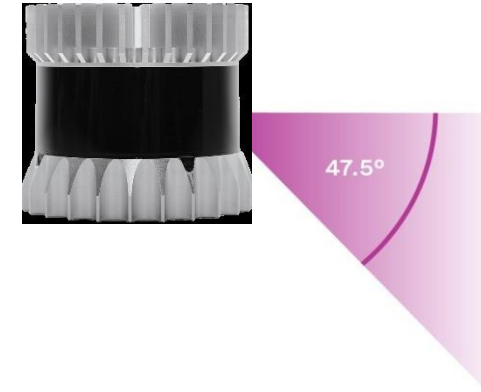
Uniform



Gradient



Below-horizon



OS0-128은 Uniform만 제공하며, OS0 - 32, 64는 3가지 모두 가능함



# OS1 - MID-RANGE LIDAR SENSOR

	OS1 - 32	OS1 - 64	OS1 - 128
Vertical Resolution	32 channels	64 channels	128 channels
Horizontal Resolution	512, 1024, or 2048		
Range	120m		
Vertical Field of View		45° ( $\pm 22.5^\circ$ )	
Vertical Angular Resolution	0.35° - 2.8°(optional)		0.35°
Precision	$\pm 1.5$ - 5cm		
Points Per Second	655,360	1,310,720	2,621,440
Rotation Rate	10 or 20Hz		
Power Draw	14 - 20W		
Weight	445g		
Ingress Protection Rating	IP68, IP69K		

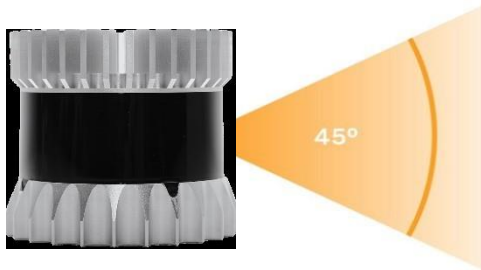


- PTP and NMEA/PPS time synchronization options
- On-the-fly programming of frame rate and horizontal resolution
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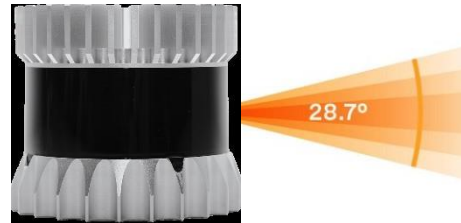


# OS1 - 32, 64, 128 Lidar beam configurations

Uniform



Gradient



Below-horizon



OS1-128은 Uniform만 제공하며, OS1 - 32, 64는 3가지 모두 가능함



# OS1(GEN1) - MID-RANGE LIDAR SENSOR

	OS1 - 16	OS1 - 32	OS1 - 64
Vertical Resolution	16 channels	32 channels	64 channels
Horizontal Resolution	512, 1024, or 2048		
Range	120m		
Vertical Field of View		33.2° ( $\pm 16.6^\circ$ )	
Vertical Angular Resolution	0.53° - 2.2°	0.53° - 1°	0.53°
Precision	$\pm 1.5 - 10\text{cm}$		
Points Per Second	327,680	655,360	1,310,720
Rotation Rate	10 or 20Hz		
Power Draw	14 - 20W		
Weight	425g		
Ingress Protection Rating	IP68, IP69K		



- PTP and NMEA/PPS time synchronization options
- On-the-fly programming of frame rate and horizontal resolution
- Fixed angle data measurement
- Multi-sensor crosstalk resistance
- Pluggable space-style bayonet connector
- Over-the-network firmware updates
- Class 1 eye-safe
- Output: range, intensity, reflectivity, ambient NIR, azimuth angle, timestamp



# OS2 - LONG-RANGE LIDAR SENSOR

	OS2- 32	OS2- 64	OS2- 128
Vertical Resolution	32 channels	64 channels	128 channels
Horizontal Resolution	512, 1024, or 2048		
Range	240m		
Vertical Field of View		22.5° ( $\pm 11.25^\circ$ )	
Vertical Angular Resolution	0.18° - 0.73°(optional)		0.18°
Precision	$\pm 1.5$ - 5cm		
Points Per Second	655,360	1,310,720	2,621,440
Rotation Rate	10 or 20Hz		
Power Draw	14 - 20W		
Weight	930g		
Ingress Protection Rating	IP68, IP69K		



- PTP and NMEA/PPS time synchronization options
- On-the-fly programming of frame rate and horizontal resolution
- Fixed angle data measurement
- Multi-sensor crosstalk resistance
- Pluggable space-style bayonet connector
- Over-the-network firmware updates
- Class 1 eye-safe
- Output: range, intensity, reflectivity, ambient NIR, azimuth angle, timestamp



# OS2 - 32, 64, 128 : LIDAR BEAM CONFIGURATIONS

Uniform



Gradient




Below-horizon



OS2-128은 Uniform만 제공하며, OS2 - 32, 64는 3가지 모두 가능함



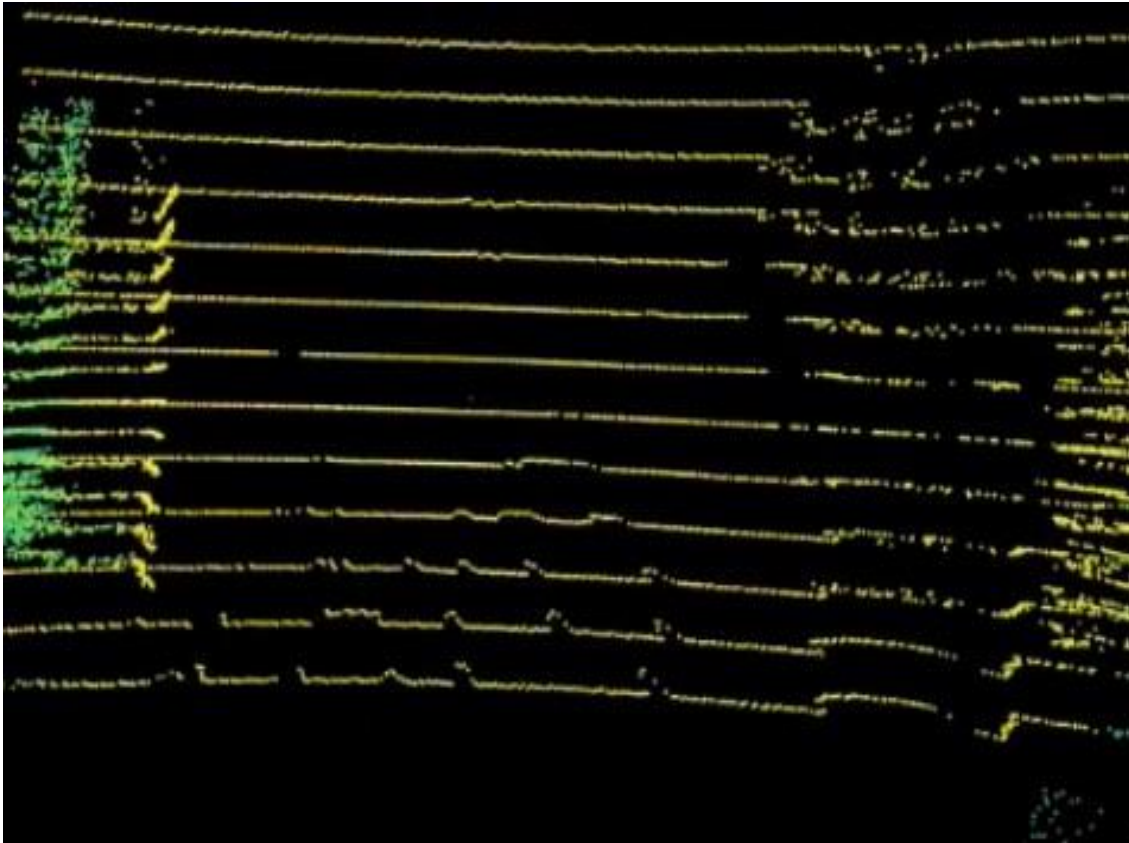
# OUSTER LIDAR RESOLUTION

Cat.	Beam Spacing (Angle)	OS0-32 / 128, OS1-16 / 64 / 128					OS-2-64,128		
		10.0	30.0	50.0	70.0	100.0	150.0	200.0	250.0
OS0-32,128	0.7	0.12	0.37	0.61					
OS1-16A	2	0.35	1.05	1.75	2.45	3.50			
OS1-16B/D	1	0.17	0.52	0.87	1.22	1.75			
OS1-64	0.5	0.09	0.26	0.44	0.61	0.87			
Pixel Size(10Hz): 0.35°x0.5°		0.06x0.09	0.23x0.18	0.44x0.31	0.61x0.43	0.87x0.61			
OS1-128	0.35	0.06	0.18	0.31	0.43	0.61			
Pixel Size(10Hz): 0.35°x0.35°		0.06x0.06	0.18x0.18	0.31x0.31	0.43x0.43	0.61x0.61			
OS2-64	0.35	0.06	0.18	0.31	0.43	0.61			
Pixel Size(10Hz): 0.35°x0.35°		0.06x0.06	0.18x0.18	0.31x0.31	0.43x0.43	0.61x0.61			
OS2-128	0.18	0.03	0.09	0.16	0.22	0.31			
Pixel Size(10Hz): 0.18°x0.18°		0.03x0.03	0.9x0.9	0.16x0.16	0.22x0.22	0.31x0.31			
									



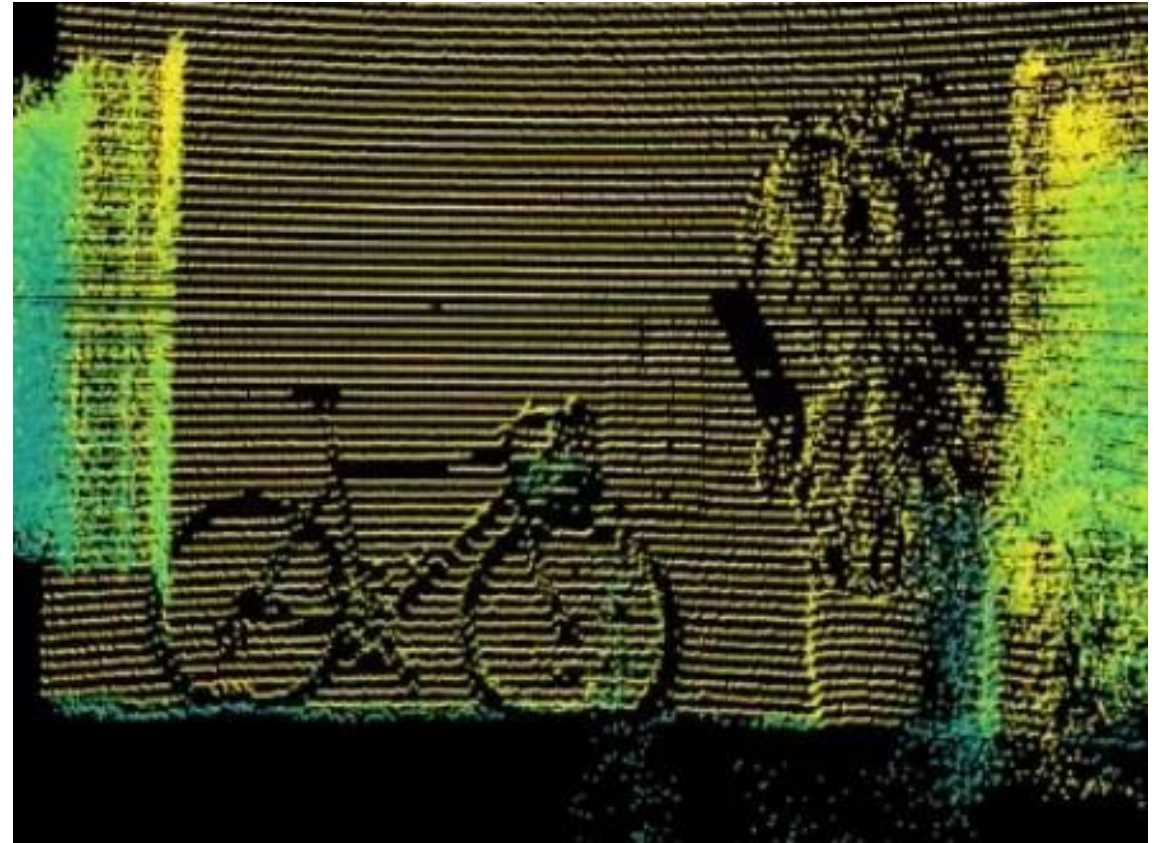
# RESOLUTION MATTERS

- Why resolution is important?



OS-1-16

vs



OS-1-64



# NEW OPPORTUNITY FOR CAMERA/LIDAR PROCESSING

## More efficient machine learning

### Computational efficiency

→ Process data with **>10x greater computational efficiency**, leveraging compute designed for vectors (e.g., GPUs or specialized ASICs instead of CPUs<sup>1</sup>)

### Faster labelling

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

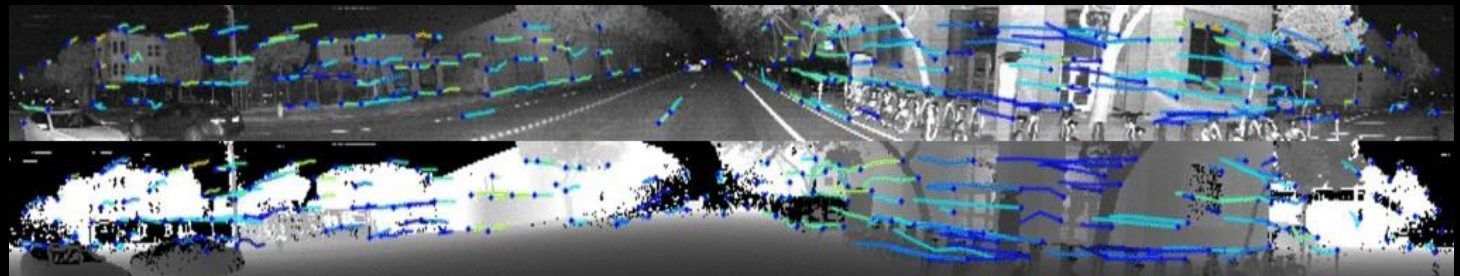
### Algorithm compatibility

→ 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



Superpoint<sup>2</sup>: CNN-based key point extraction run on signal and depth images

<sup>1</sup> <https://medium.com/@andriylazorenko/tensorflow-performance-test-cpu-vs-gpu-79fcd39170c>

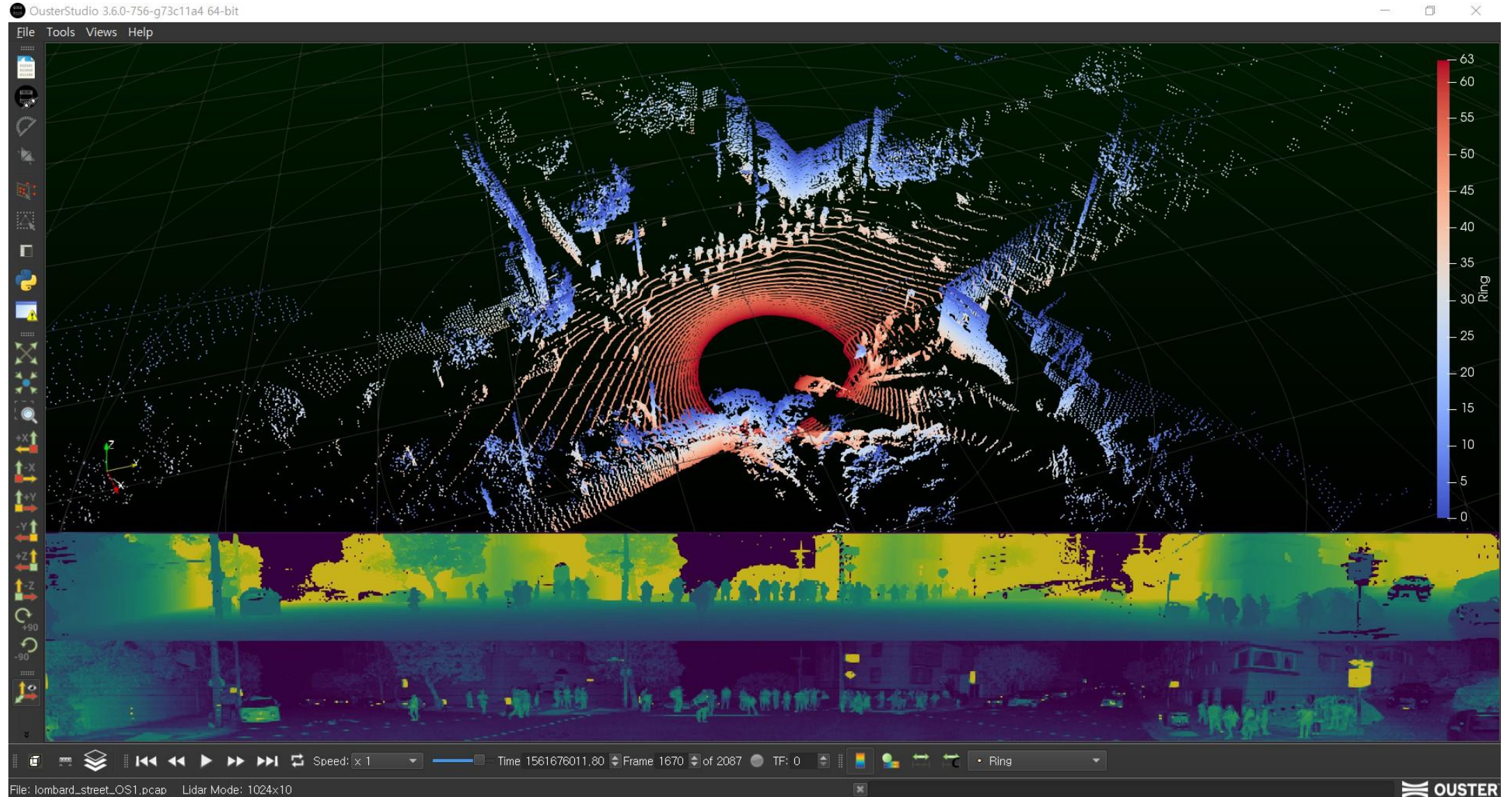
<sup>2</sup> DeTone, Daniel, et al. "SuperPoint: Self-Supervised Interest Point Detection and Description." CV, April 2018.





# LIDAR VIEWER

- **Download :** <https://www.paraview.org/ousterstudio/>





# A LEADING GLOBAL MARKET PLAYER

#1

in customers and  
shipments  
among new entrants

#2

in monthly  
shipments overall

450+

customers  
globally

1000+

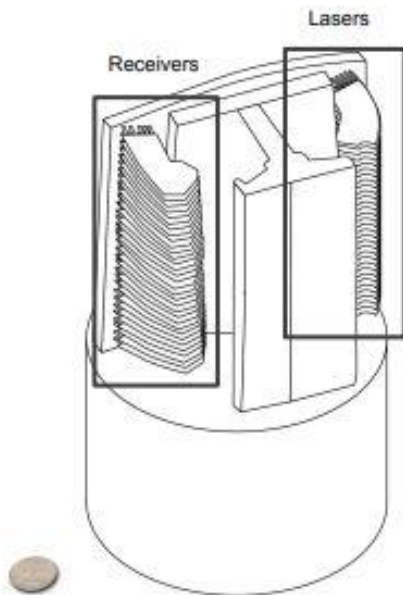
units shipped in first 9  
months





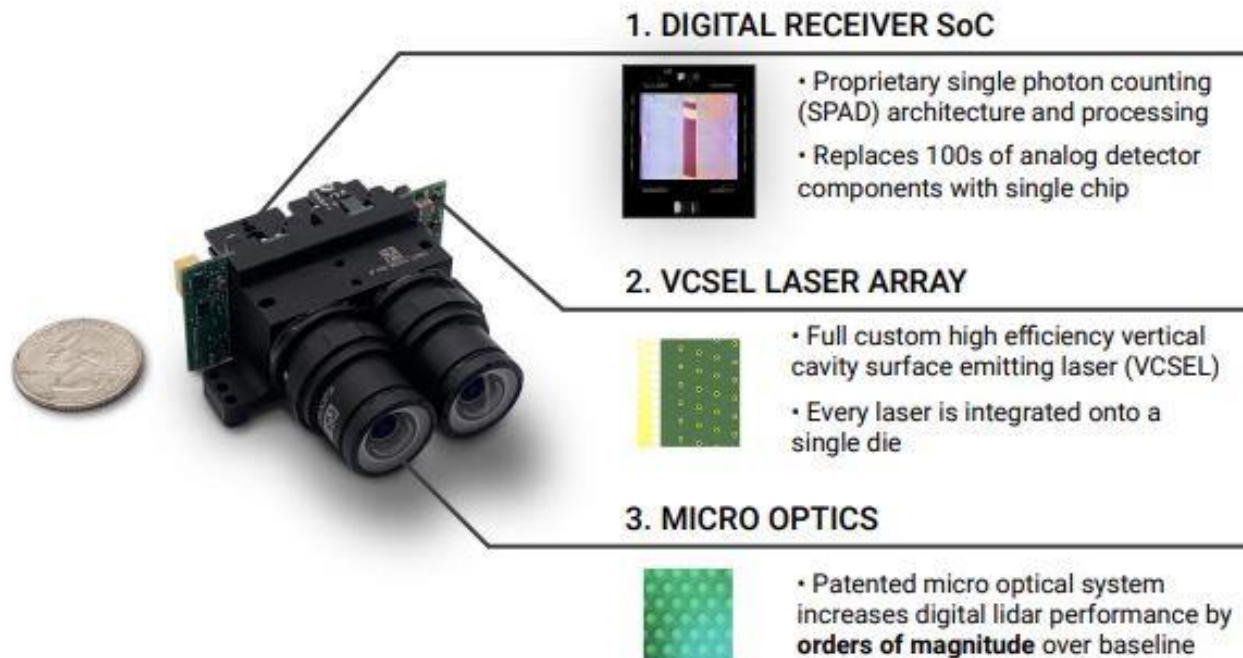
## ANALOG LIDAR

100s of duplicate parts



## DIGITAL LIDAR

3 integrated technologies

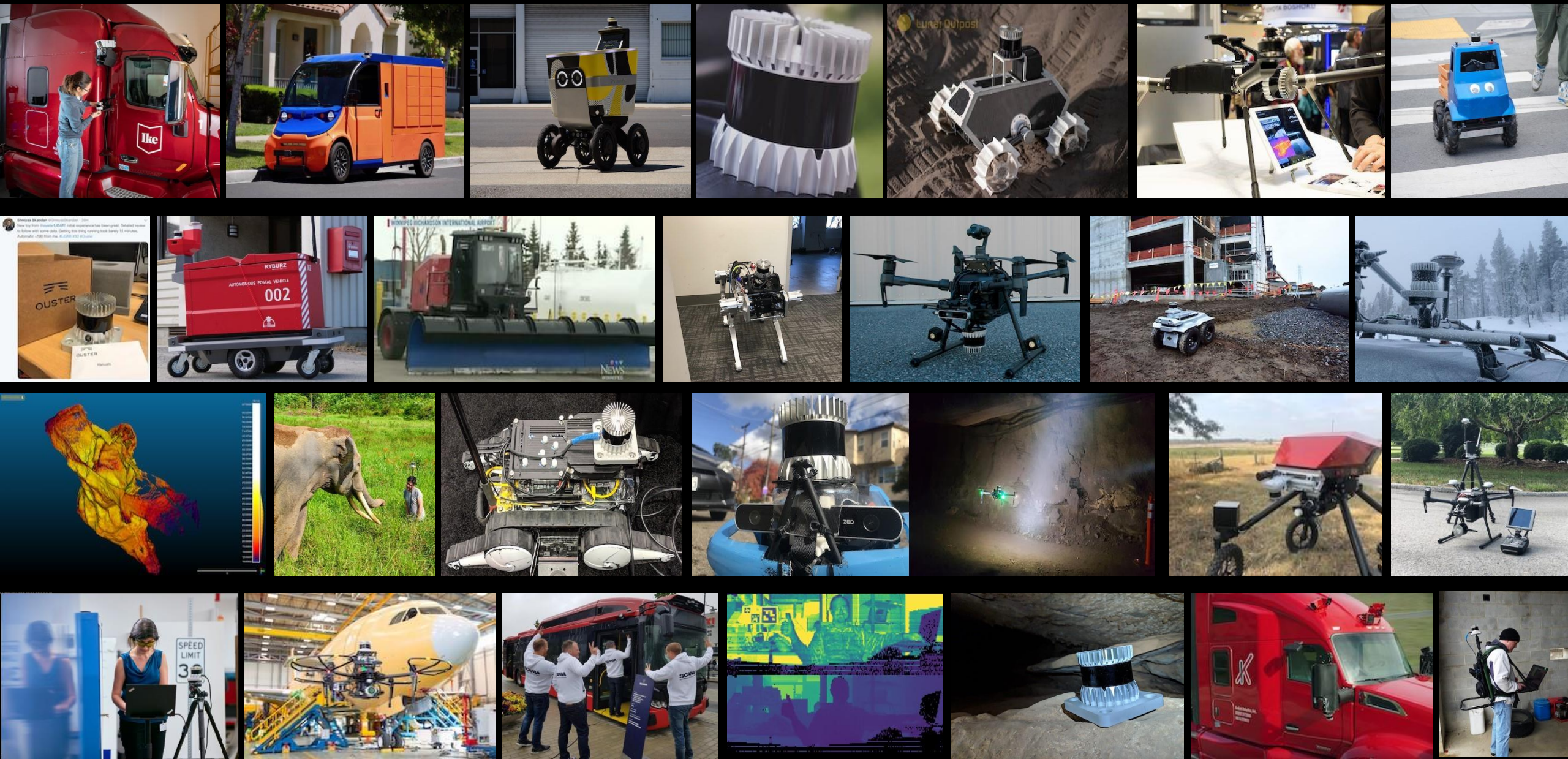


Analog lidar: 동일한 부품을 복제 및 적층하여 제조. -> 제품 경량화 불가.  
 Digital lidar: 발광부, 수광부에 자체 개발 VCSEL, SPAD 적용. 추가로, 인증된 micro optic 적용하여 간단한 구조로 제품 제조.





## DIVERSE CUSTOMER BASE, IN AND OUT OF AUTOMOTIVE





## High-Resolution

→ Up to 128 vertical lines of resolution improves object detection and speeds up mapping

## Reliable

→ IP69K and IP68 rated; automotive-grade tested

## Small & Lightweight

→ Smallest and lightest sensor available on the market

## Affordable

→ Ouster sensors offer the best value for performance available today

OS0 – 32, 64, 128



55m / 445g

OS1 – 16, 32, 64, 128



120m / 445g

OS2 – 32, 64, 128



240m / 930g





# 감사합니다!

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