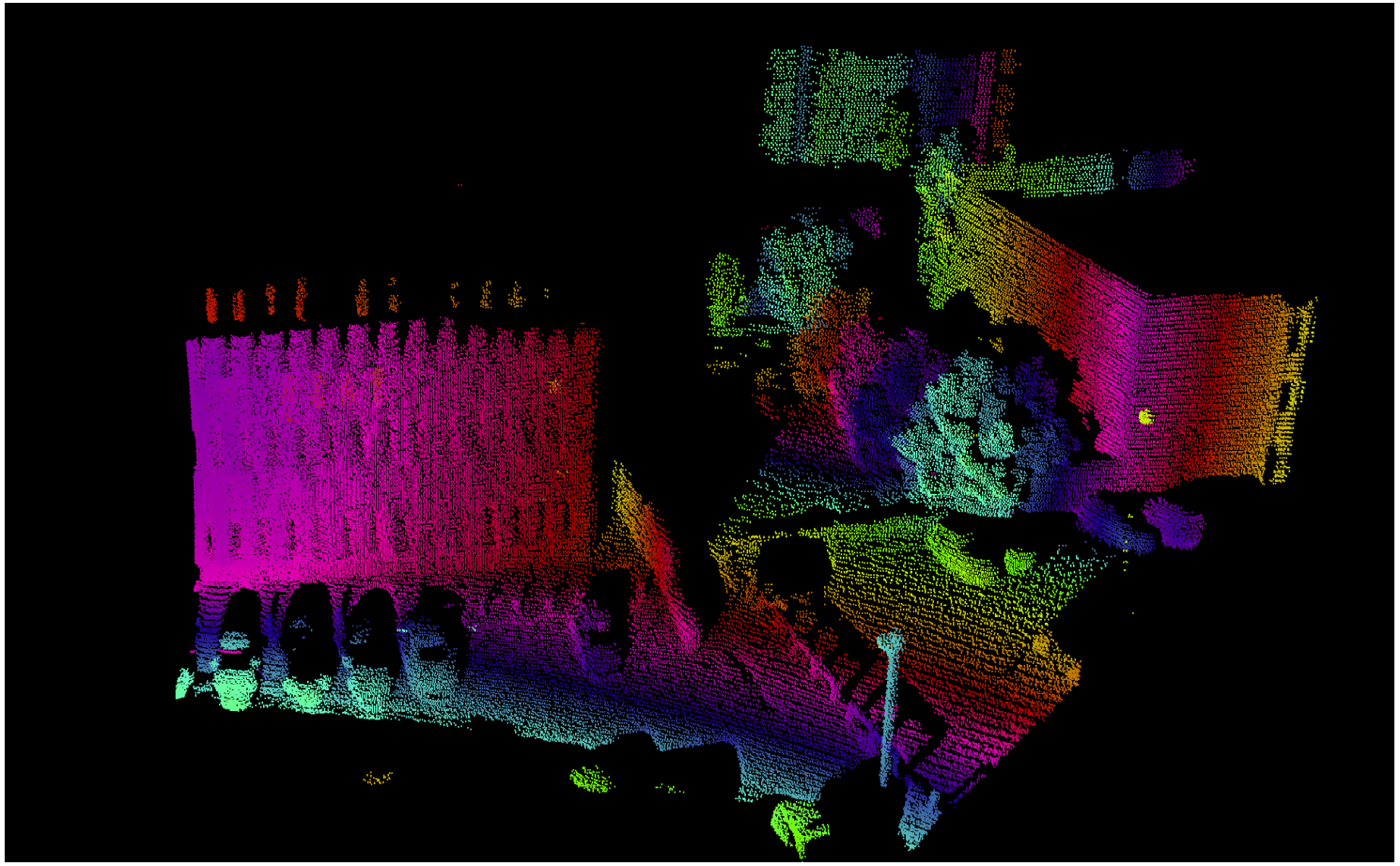
L3CAM: Multimodal imaging system

Presentation outline

- **Company background**
- Product
- Customers
- Key elements of the technology

3D LIDAR imaging



Company Profile

BEAMAGINE

- **SME** focused on the design, manufacturing and commercialization **MEMS-based 3D imaging LIDAR sensors**
- Founded in **2016** and **self-financed**
- Core team of **12 people**
- Proprietary technology protected with **14 patents**
- **Sensor Fusion** and **Perception AI** exploiting both 3D and 2D
- **Application domains**: Autonomous navigation / Smart cities
- **Strategy:** Focusing into highly demanding markets like Defense, Railway and Space
- **Intensive in R+D:** 2 PhD thesis defended and 3 more in progress

Rambla Sant Nebridi, 10
08222 Terrassa (Barcelona)

Facilities

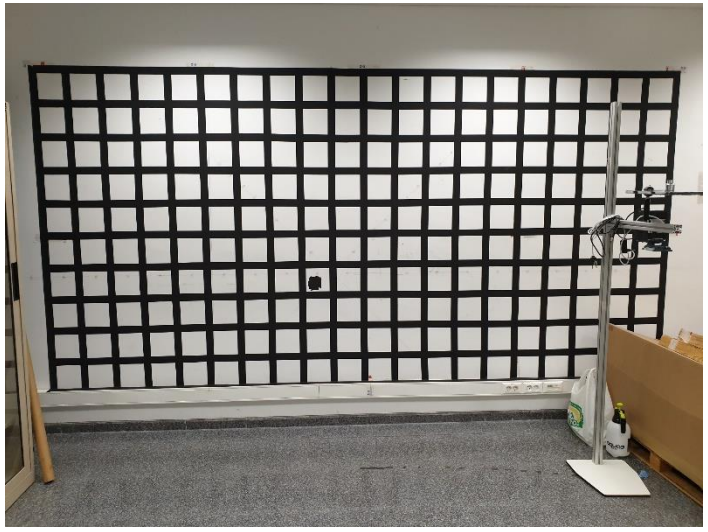
Optical lab

Electronics Workshop

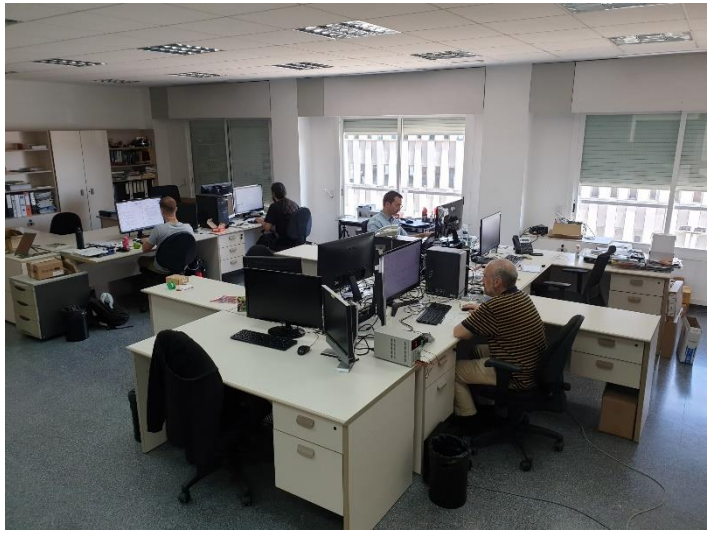
Mechanical Workshop

Optical assembly chamber

Calibration room



Technical office



List of IP

Id	Reference	Priority date	Authors	Property	Title
1	PCT/IB2012/000501 USA: US2014/0049783 A1 EUROPA: EP2686701 CHINA: CN103502839 JAPON: JP2014512525 ISRAEL: IL228505	18.02.2011	S.Royo, J.Riu	Beamagine	“System, method and computer program for receiving a light beam”
2	EU: EP2686701), CANADA: CA2901100 USA: US20150378023	13.02.2013	S.Royo, J.Riu	Beamagine	“Sistema y método para escanear una superficie y programa de ordenador que implementa el método”.
3	EP13005853.0	25.12.2013	S.Royo, F.Azcona, A.Jha	Beamagine	“A method of measuring a change in an optical path using differential laser self-mixing interferometry and a differential laser self-mixing interferometry measuring system”,
4	EP17181446	14.07.2017	S.Royo, J.Riu, N.Rodrigo, F.Sanabria, J.E.Kallhammer	Beamagine / Autoliv AB	“A vision system and vision method for a vehicle”
5	EP17181435	14.07.2017	S.Royo, J.Riu, N.Rodrigo, F.Sanabria, J.E.Kallhammer	Beamagine / Autoliv AB	“A vision system and vision method for a vehicle”
6	EP17181441	14.07.2017	S.Royo, J.Riu, N.Rodrigo, F.Sanabria, J.E.Kallhammer	Beamagine / Autoliv AB	“A vision system and method for a vehicle”

List of IP

Id	Reference	Priority date	Authors	Property	Title
7	EP17181436	14.07.2017	S.Royo, J.Riu, N.Rodrigo, F.Sanabria, J.E.Kallhammer	Beamagine / Autoliv AB	“A vision system and method for a vehicle”
8	EP18180420	28.06.2018	S.Royo, J.Riu, N.Rodrigo, F.Sanabria, J.E.Kallhammer	Beamagine / Veoneer AB	“A vision system and vision method for a vehicle”
9	EP18181448	03.07.2018	S.Royo, J.Riu, N.Rodrigo, F.Sanabria, J.E.Kallhammer	Beamagine / Veoneer AB	“A vision system and method for a vehicle”
10	EP19161075	06.03.2019	S.Royo, J.Riu, N.Rodrigo, S.Peña , J.E.Kallhammer	Beamagine / Veoneer AB	“Concentration imaging”
11	EP19170221	18.04.2019	S.Royo, J.Riu, N.Rodrigo, P.Garcia-Gómez, J.E.Kallhammer	Beamagine / Veoneer AB	“Lidar imaging apparatus for a motor vehicle”
12	EP19180843	18.06.2019	S.Royo, J.Riu, M.Ballesta, J.E.Kallhammer	Beamagine / Veoneer AB	“Lidar imaging apparatus for a motor vehicle”
13	P202030518	02.06.2020	S.Royo, J.L.Larriba, A.Prat	Beamagine / Sparsity Technologies LS	“Sistema y método para el rastreo de objetos en movimiento en vehículos”

List of PhD tesis in LIDAR Technology

Title	Author	Director	Year
“Cámara LIDAR de escaneo MEMS para imagen 3D de resolución especial variable”	Riu, J.	Royo, S.	2018
“Development of a multimodal imaging system based on LIDAR”	García-Gómez, P	Royo, S. Casas, J. R.	2021
“Multimodal data fusion and perception for autonomous driving”	De Mas, G.	Royo, S. Casas, J. R.	2023 (ongoing)

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L3CAM: Multimodal perception system

AT A GLANCE:

- System composed by three complementary imaging modes:
  - High resolution solid-state 3D LIDAR (12 patents)
  - RGB camera
  - Optional: Polarimetric and/or Thermal camera
- Embedded data fusion in-house calibrated
- Embedded AI perception software for automatic object detection
- Perception SW can be trained on demand for any kind of object
- Minimum false alarms due to the triple imaging analysis approach
- Performance guaranteed in all environmental conditions: day/night or bad weather (rain, snow, dust or wind)
- Small size: 10x18x20 cm

Multimodal perception for improved reliability

The combination of imaging technologies, taking the advantages of each one, is what make the system reliable in all operational scenarios, regardless of object type, material or weather conditions.

False alarms can be reduced exploiting and combining the information from the three sources.

3D LIDAR

Pros:

- 3D information
- Small cross-section object detection
- Bad weather and day&night OK

Cons:

- Sensitive to fog
- Short-medium range
- Power consumption

RGB

Pros:

- High-definition
- Color information
- Mature AI

Cons:

- Sensitive to fog
- Unstable at night
- No depth info

THERMAL

Pros:

- Stable in day and night conditions
- Fog penetration
- High contrast in human detection

Cons:

- Low resolution
- No depth info
- Less mature AI algorithms

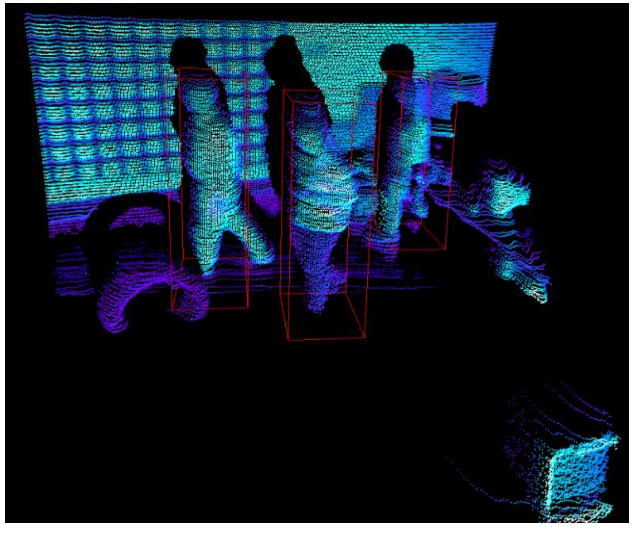
POLARIMETRIC

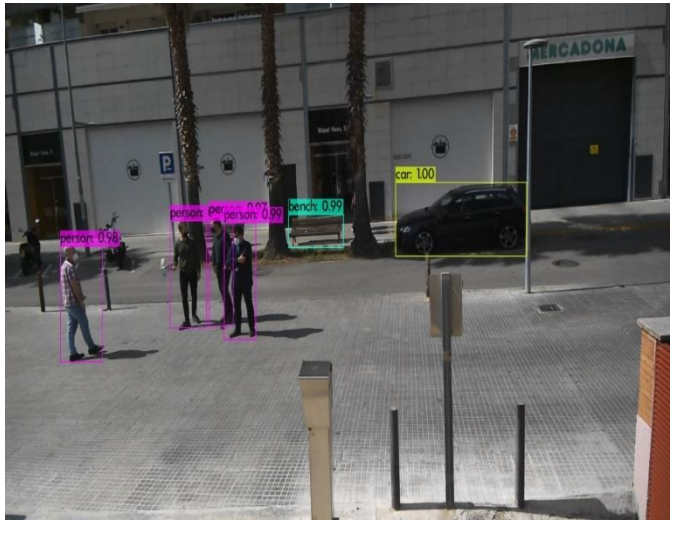
Pros:

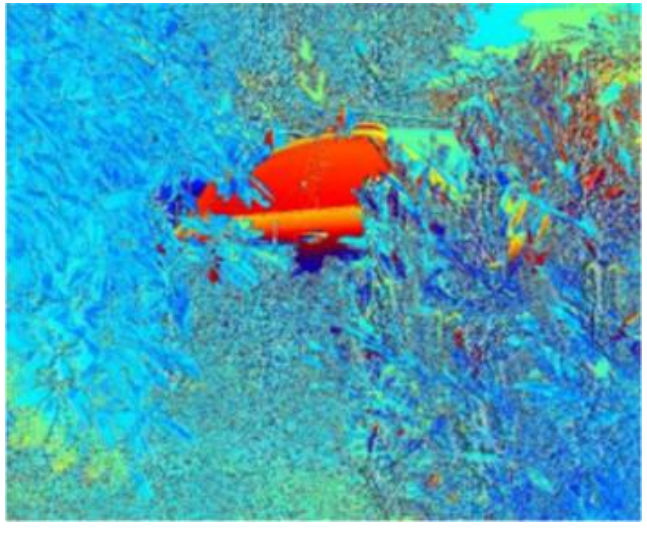
- Discrimination by material
- High contrast in maritime
- High resolution

Cons:

- Less mature AI algorithms
- No depth info
- Unstable at night



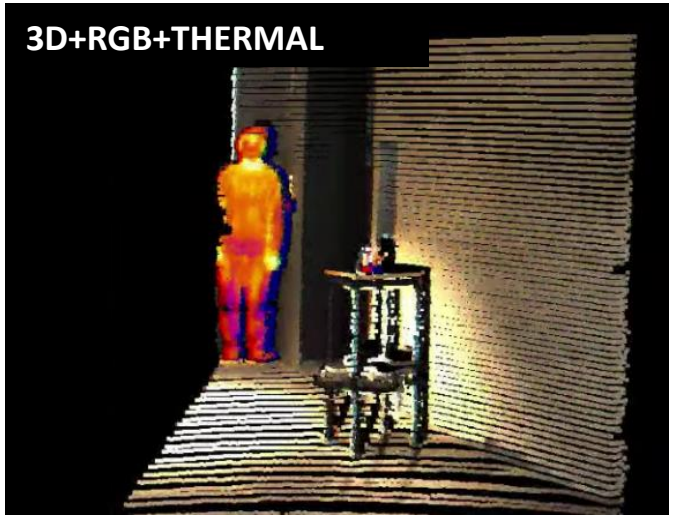


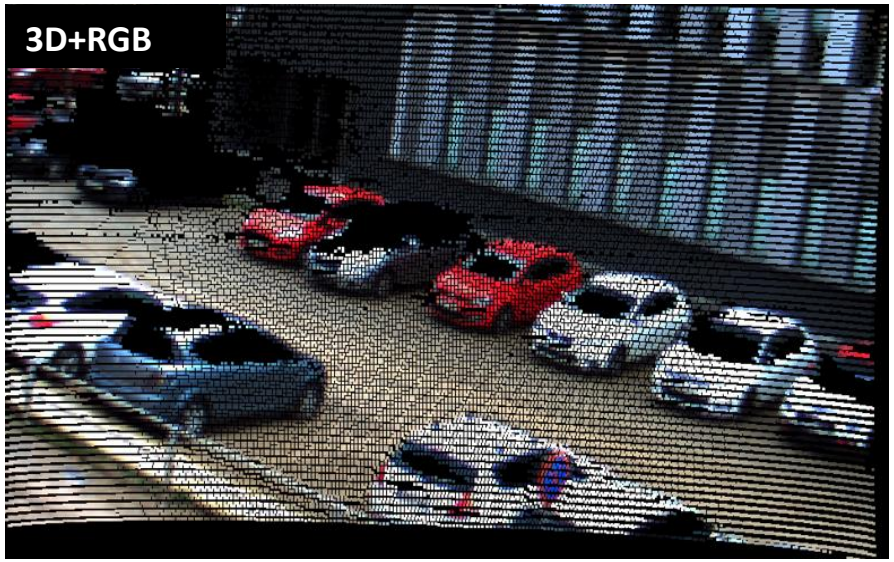


Integration aspects

	DETACHED	INTEGRATED
	The cameras are placed in different locations 	**Cameras are integrated into the same housing** 
Mechanical alignment	Performed by the user	Set in factory
Software integration	Performed by the user	Set in factory
Frame synchronization	Performed by the user	Set in factory
Optical calibration	Complex, completed by the user	Set in factory
Data fusion	Complex, completed by the user	Set in factory
Misalignments	Very likely	No
Parallax error	Very likely	No
Recalibrations	Very likely	No
Installation cost	High	Minimal

Hardware pain out of the software team
Reliable data in, good perception out





L3CAM specifications

SYSTEM Specs	
Connection	1000Mbit Ethernet – UDP packets
Drivers	Windows, Linux and ROS. ONVIF possible
Operating voltage	12V-36V (regulated)
Power consumption	35W
Size (HxWxD)	10x18x20 cm
Weight	4Kg
Mounting	4 M4 screws at the bottom
Case ingress protection	IP67
Temperature range	-30ºC to +60ºC
Certification	CE, RoHS
Eye-safety	Class 1 eye-safe per IEC 60825-1:2014 *(Class 3E available under demand)*

LIDAR Specs	
Laser wavelength	1064nm
Range @ Class 1 *Solar background 250W/m²*	90m @ 10% reflectance 200m @ 50% reflectance
Range @ Class 3R *Solar background 250W/m²*	150m @ 10% reflectance 330m @ 50% reflectance
Resolution (HxV)	460 x 150 px
Angular resolution (HxV)	0.13º x 0.13º
FOV (HxV)	60x20º
Frame rate	8 fps
Point rate	700 Kpx/s

The system can be tailored according to the customer specifications. Parameters like range, FOV, resolution and frame rate are interrelated and can be adjusted within certain limits fixed by the trade-offs.

UAS detection LIDAR

Parameter	Value	Options
Range	500m for 0,35cm drone	>1Km for extended targets
H-FOV	360º	Can focus forward instead of 360º More narrow OFV –> higher point density
V-FOV	20º	Up tp 40º
Frame rate	2 Hz	Up to 8Hz
Resolution X	1000 px	Can be tailored
Resolution Y	300 px	Can be tailored
Angular resolution X	0,36 deg (fully covered by diverging beam in X)	Can be tailored
Angular resolution Y	0,067 deg	Can be tailored
Points per second	300K px/s	Depending on the arquitecture, up tp 2.4Mpx/s
Size estiamation	Diameter: 20cm, Hight: 30cm	
Power consumption	30W	
Weight	2Kg	
Communication	Gigabit Ethernet (UDP for data, TCP/IP for commands)	
Ingress	IP67	

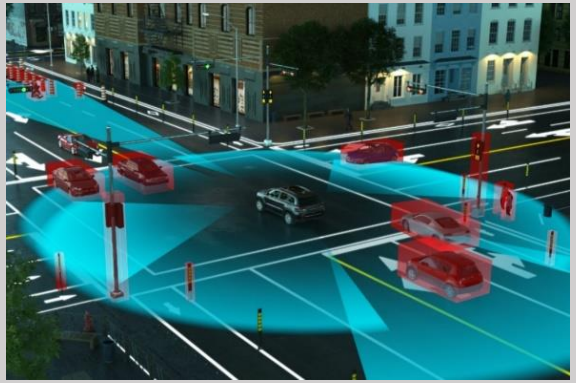
Presentation outline

- Company background
- Product
- **Customers**
- Key elements of the technology

Application domains

AUTONOMOUS VEHICLES AND NAVIGATION

SECURITY AND SURVEILLANCE



Customers

Development program for a high-resolution and solid-state LIDAR sensor for autonomous cars.

Through this collaboration, we generated 12 active patents around the L3CAM concept. Exploitation rights corresponds to Beamagine.

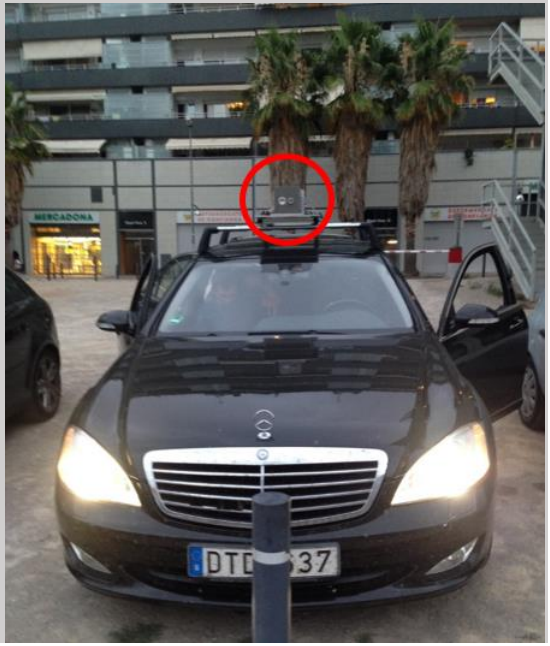
Country: Sweden

Market: Automotive

Customers:

Autoliv

veoneer



Development of a data collection LIDAR unit with sensor fusion for drivable space detection tasks.

Special focus on small object detection on the road. A custom LIDAR with high resolution on the vertical axis was developed.

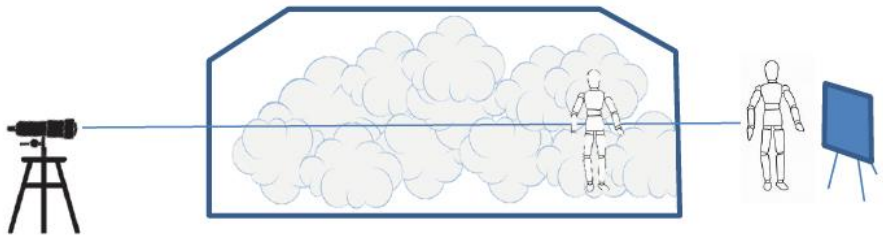
Country: Germany

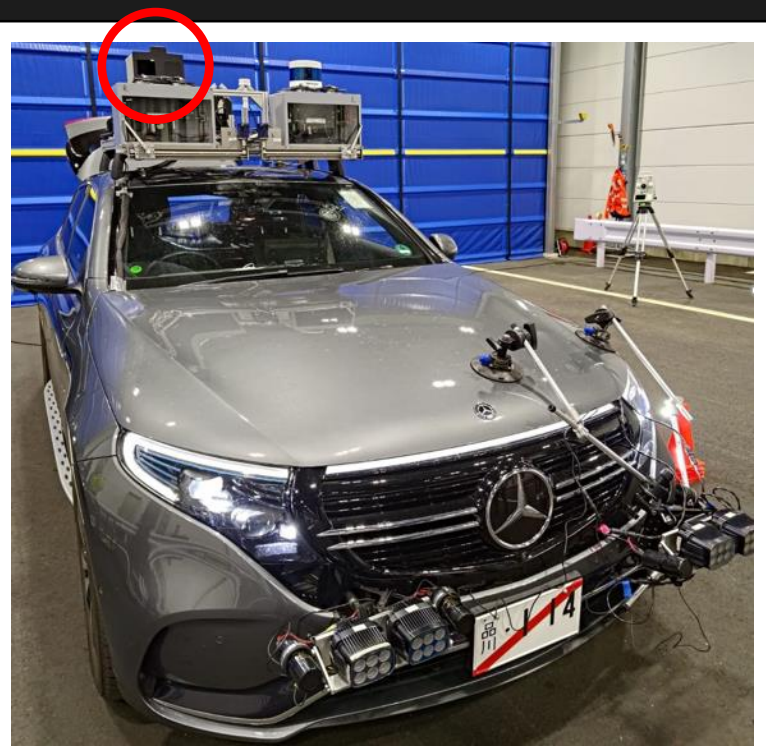
Market: Automotive

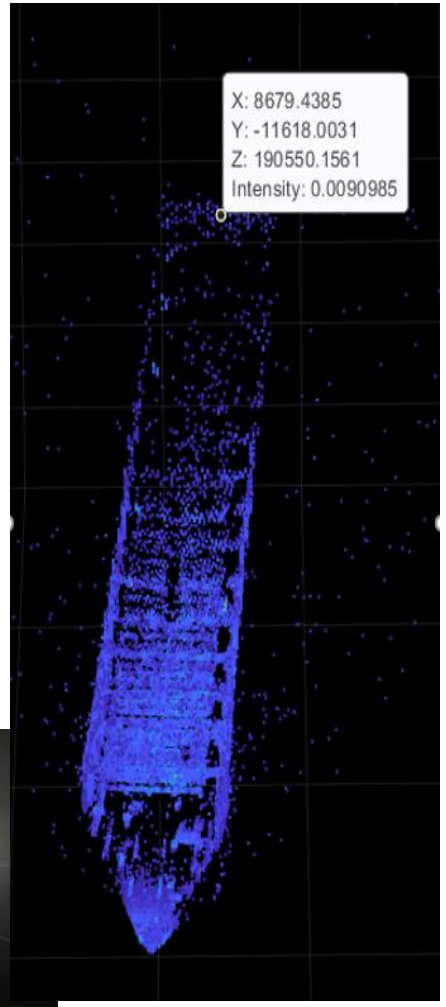
Customer:

Mercedes-Benz

Customers







Customers

Development of a space qualified solid-state LIDAR for orbital servicing.

Design based on the L3CAM technology. Redesign for fail-safe operation. Complete environmental testing included.

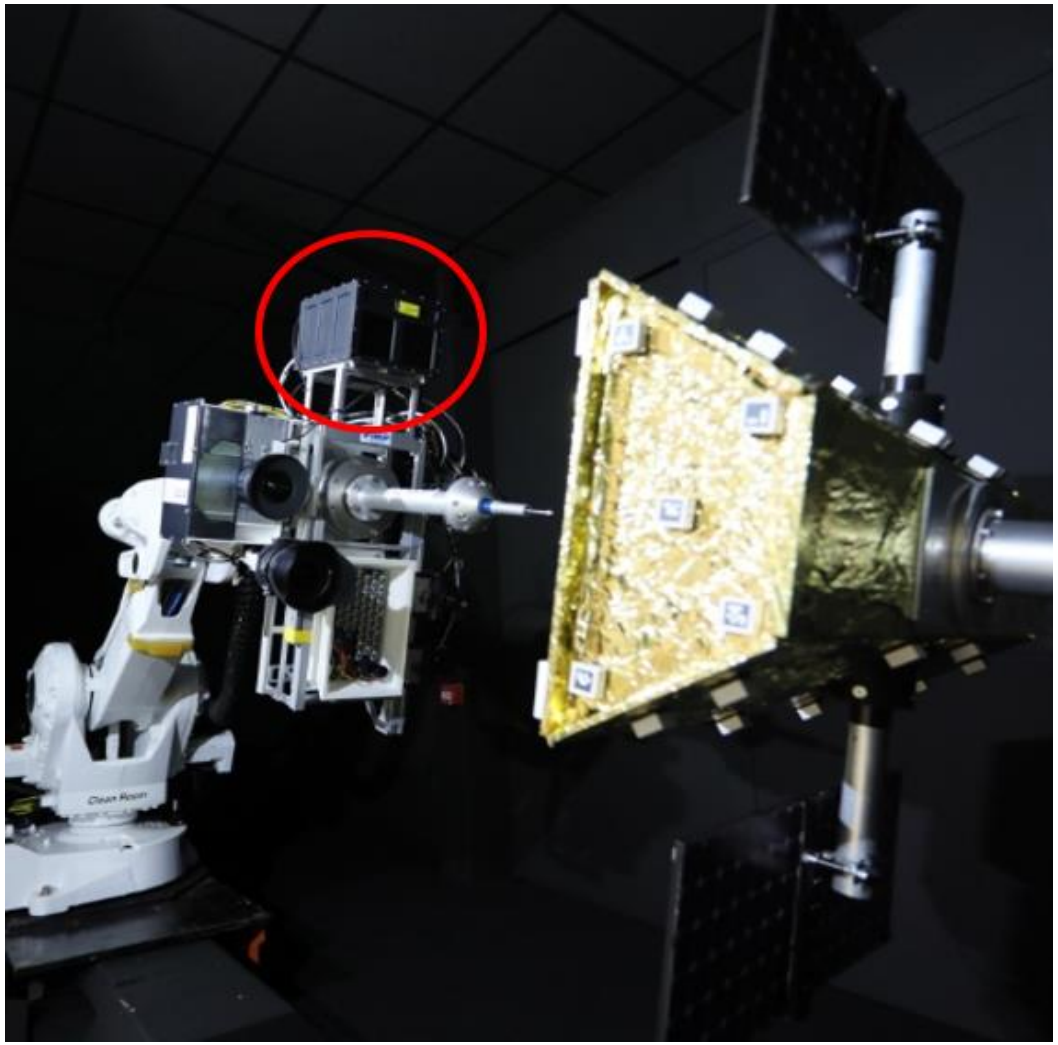
Country: France

Market: Space

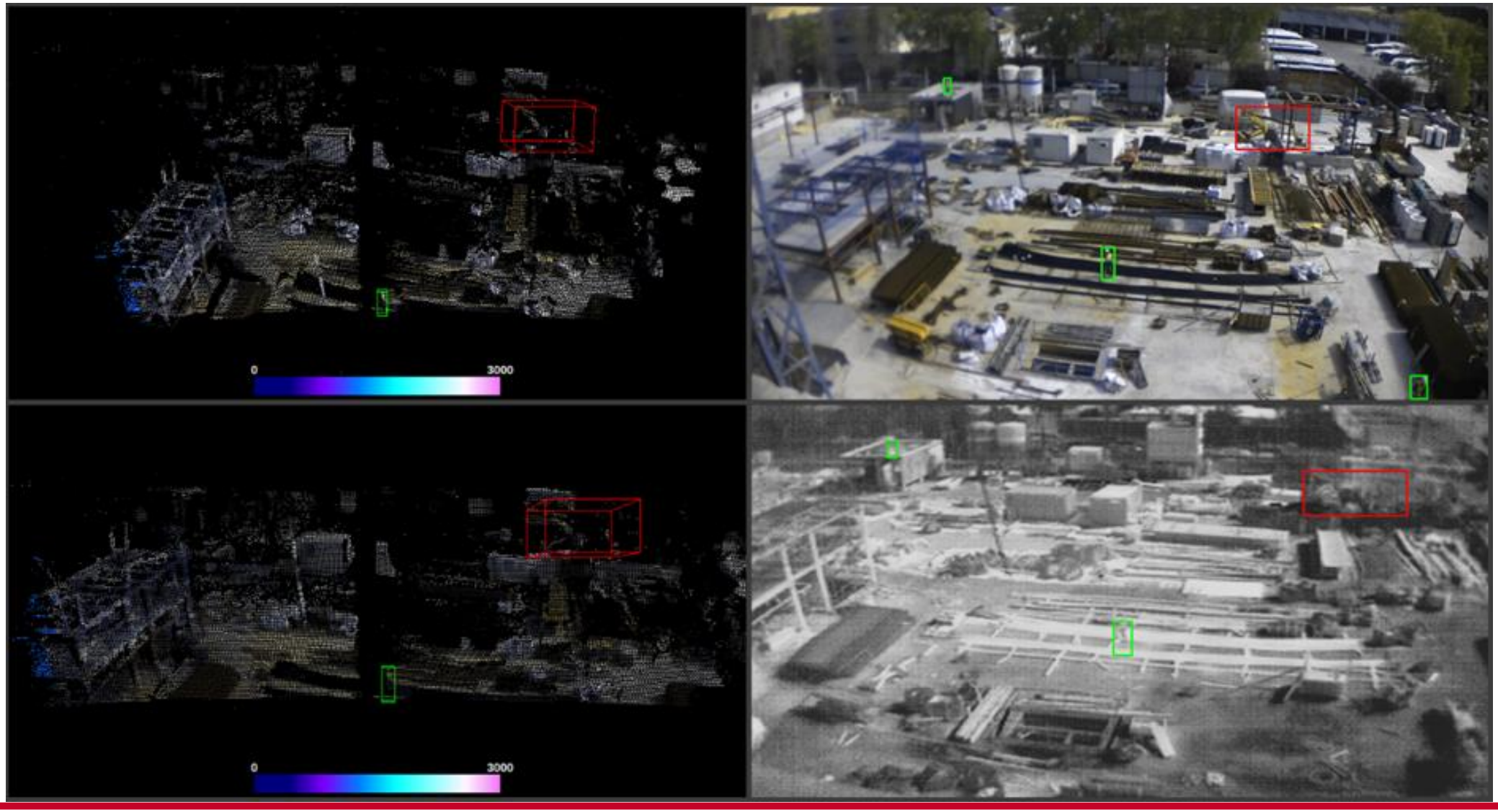
Customers:

ThalesAlenia Space
A Thales / Finmeccanica Company

esa
European Space Agency



Customers



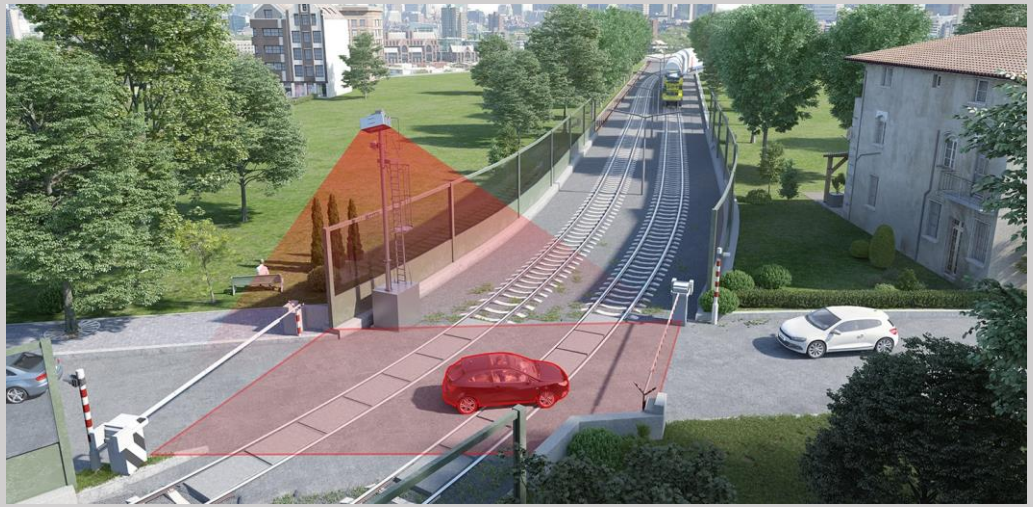
Customers

Development of a custom L3CAM under customer requirements for area monitoring

Modification of the standard L3CAM to cover FOV. The customer develops AI by using the L3CAM multimodal sensor

In parallel, Beamagine is developing a cost-efficient unit for volume production in line with Siemens requirements.

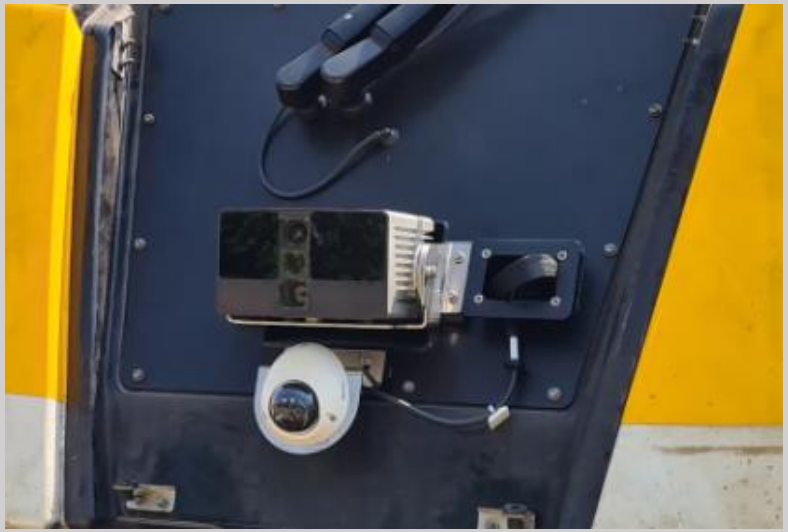
SIEMENS



Development of a multisensory platform for Railway Autonomous Shunting and obstacle detection applications

The project focus on the design of a custom multisensory unit that joints high-resolution LIDAR with multiple cameras (RGB and LWIR)

CAF



Customers

Electrical

- Supply power:
  - Dynamic: from alternator
  - Static: from charger or supply

Mechanical

- Fix sensors outside
- Provide rig for placing additional sensors easily
- Fix equipment in the trunk with ease of disassembly
- Smart cabling
- Fix in-seat screen

Sensors

- Multimodal
- Fusion
- Enhanced vision under adverse conditions

Software

- ROS compatible
- NVIDIA based

ROS Robot Operating System

NVIDIA DRIVE

Presentation outline

- Company background
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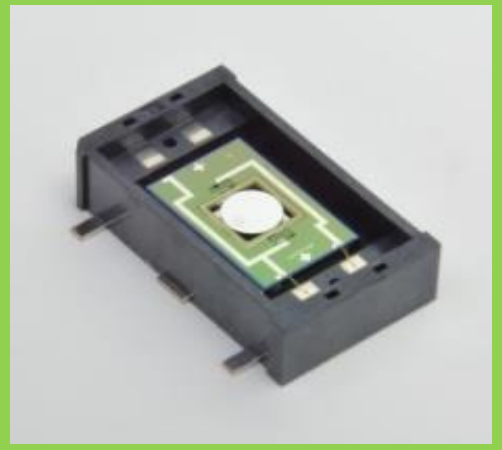
- **Key elements of the technology**

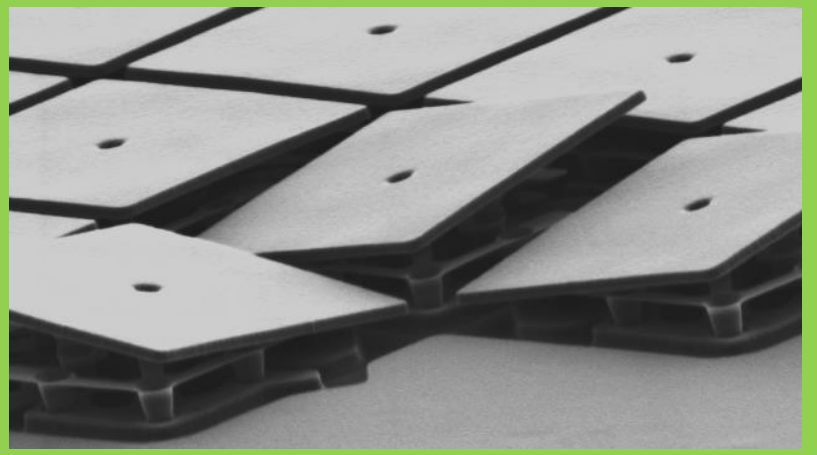
Key element 1: Long term robustness

- **PROBLEM: Sensors with moving parts**
  - Sensitive to vibration, shock and thermal variations
  - Sensitive to thermal changes and humidity
  - Robustness and reliability issues at medium and long term

BEAMAGINE SOLUTION: SOLID-STATE APPROACH WITH NO MOVING ELEMENTS

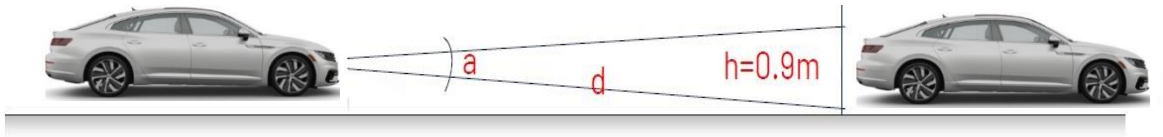
- Solid-state approach based on MEMS scanners (with automotive certification)
- Robust at long term operation
- Patented approach with 12 active patents
- Solar background suppression combined with large entrance pupil diameter -> Long range detection

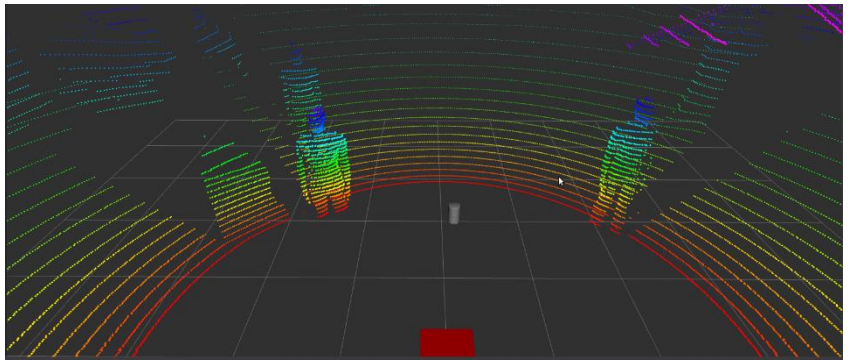




Key element 2: Image resolution

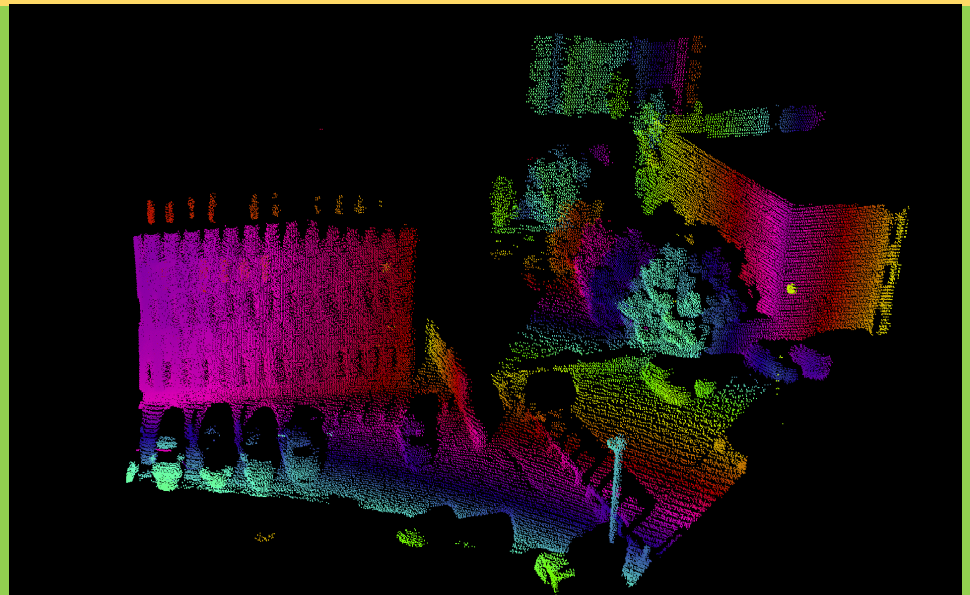
- **PROBLEM: Low resolution at the Y-axis**
  - Resolution is needed for small height object detection
  - LIDARS normally have good resolution at the X-axis but not in Y-axis. Example: with 64 layers, a car at 100m is max 2 pixels, so not enough for detection and classification.
  - Low reliability at mid/long range detection for small objects





BEAMAGINE SOLUTION: HIGH RESOLUTION IN THE VERTICAL AXIS

- L3CAM has been specially designed for small height object detection
- The resolution in the vertical axis has been optimized in the past for automotive application.
- Resolution in the vertical, in the best case, can go down to 0.05º. Easy customization (firmware and calibration).



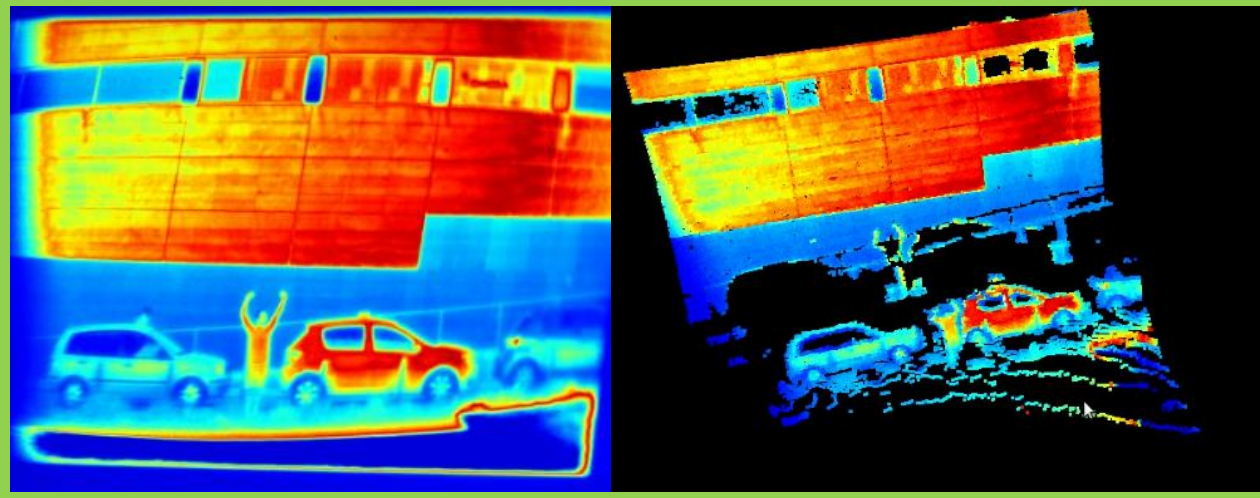
Demo video: Real time raw lidar data https://vimeo.com/325604480

Key element 3: Multi-sensor image fusion

- **PROBLEM: Parallax error in data fusion**
  - When fusing LIDAR + image (2D), parallax error appears. No match between the point cloud and image at all distances
  - Small cross-section objects do not match spatially, data is not congruent
  - False detections and low reliability

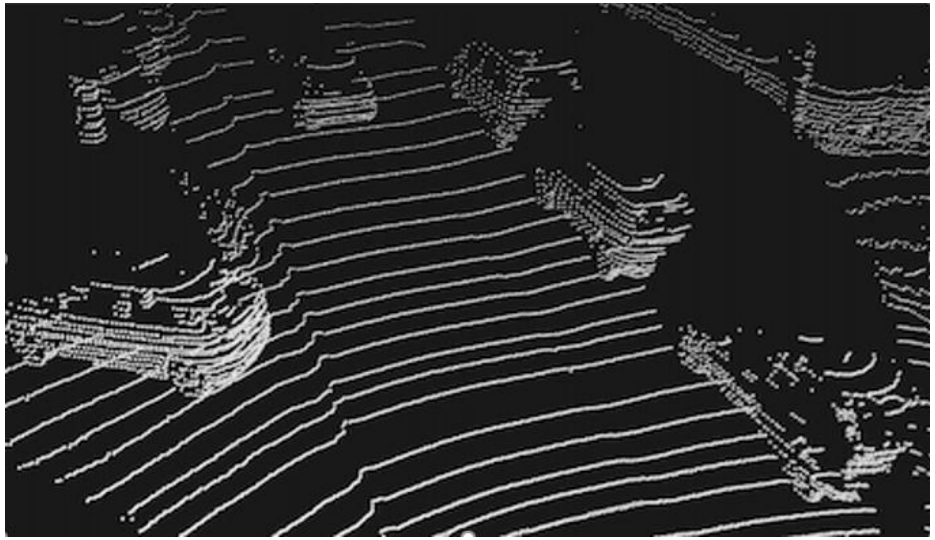
BEAMAGINE SOLUTION: CONGRUENT DATA FUSION

- Embedded parallax-free data fusion included
- Compatible with all camera types: RGB, Thermal, NIR, SWIR, polarimetric, etc.
- Specific mechanics to guarantee no miss-alignments and recalibration.
- “Plug&Play” multi-sensor system, straightforward integration (hardware pain out of the software team!)



Key element 4: Fine tuning of the perception AI

- **PROBLEM: Implementing Artificial Intelligence (AI)**
  - Most of the LIDAR sensors do not come with AI, so the end-user has to deal with the point cloud.
  - The little ones that include AI are very general use cases (detection of pedestrians, cars, traffic signs, etc.)
  - Point cloud processing is a complex topic, less mature than in the 2D case.



BEAMAGINE SOLUTION: EMBEDDED AND TRAINABLE AI

- Embedded high performance edge computing for AI
- AI based on neural networks with 3D and 2D perception
- Neural networks can be trained according with specific customer use cases
- Multi-imaging approach for increased robustness and minimum false alarms
- Output data: alarm events instead of non-processed raw images

THANKS FOR YOUR ATTENTION!

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