Imaging LIDARs for space industry

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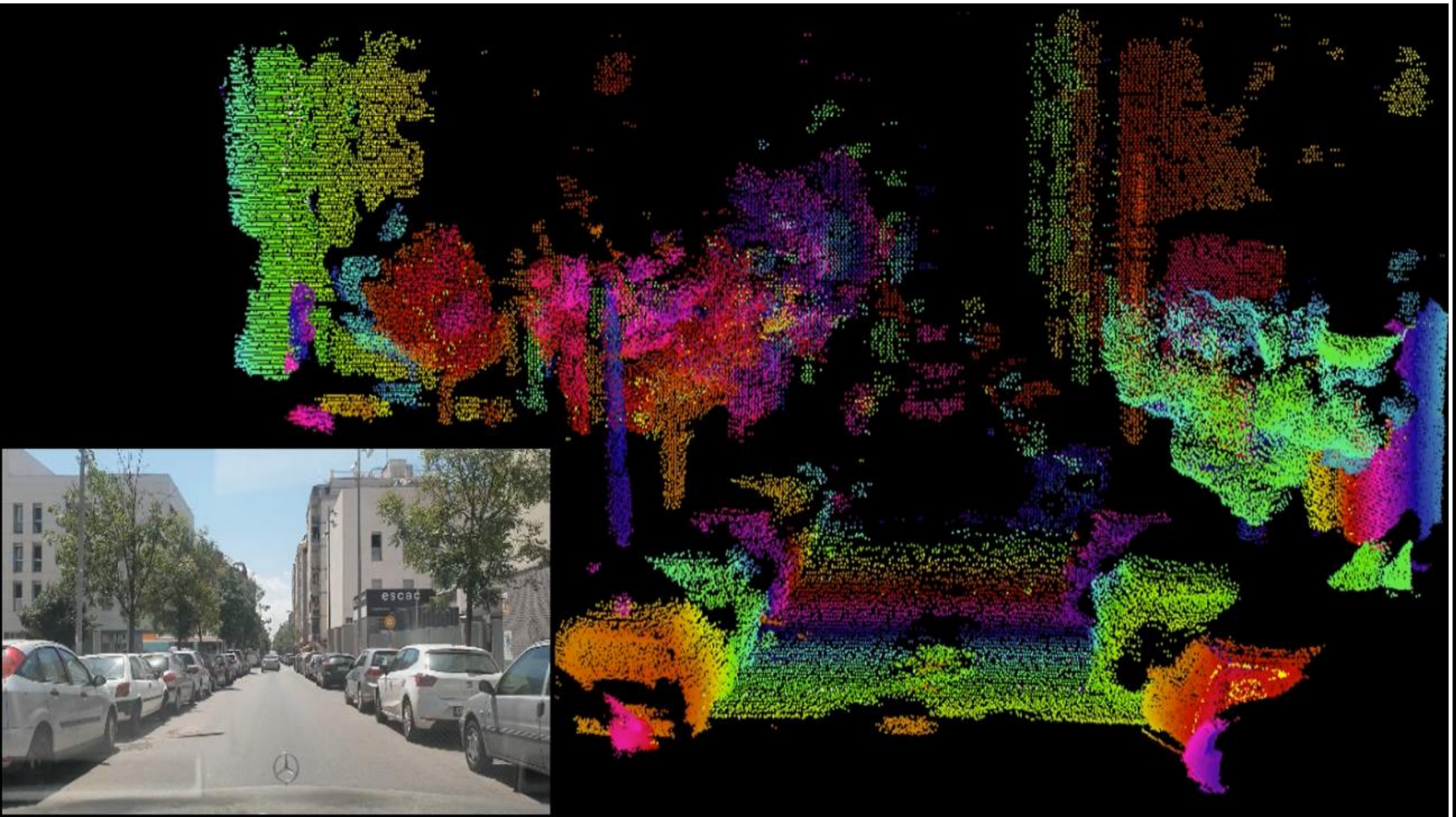
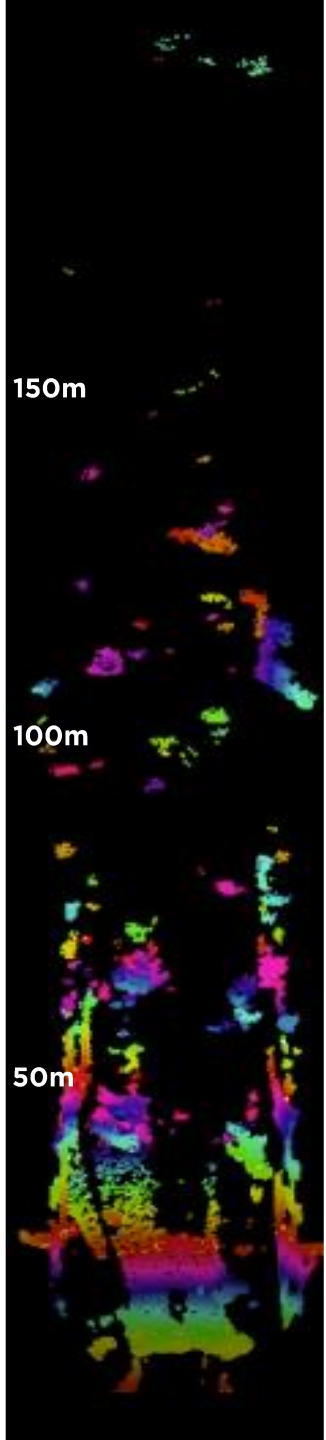
Tres Cantos, 07/05/2019

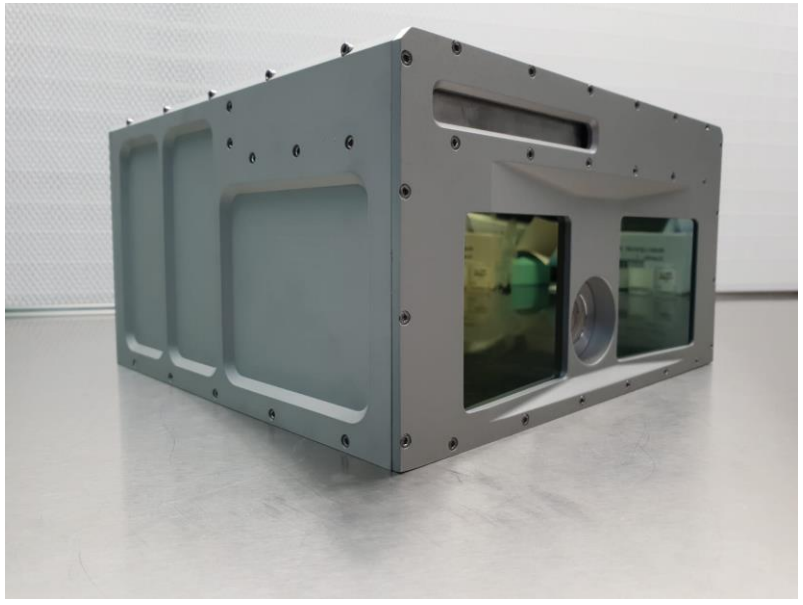
3D LIDAR point clouds

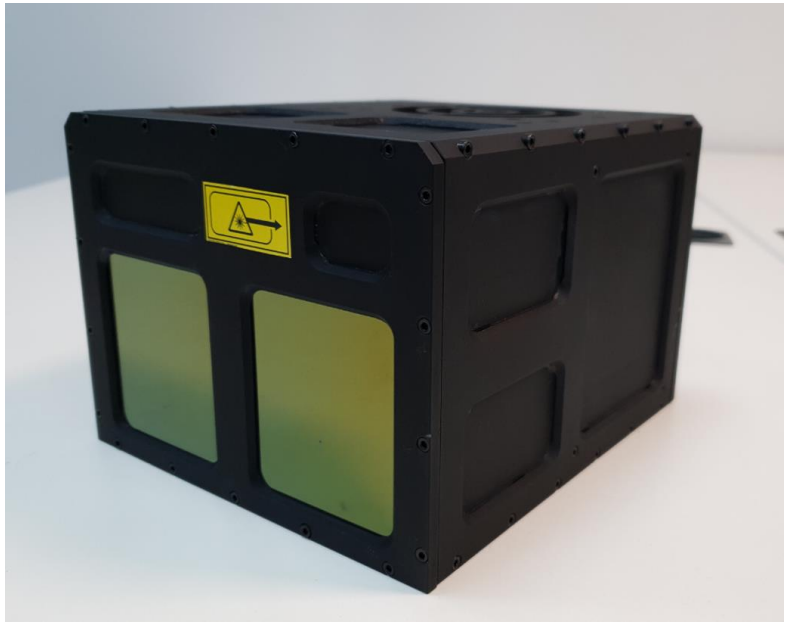




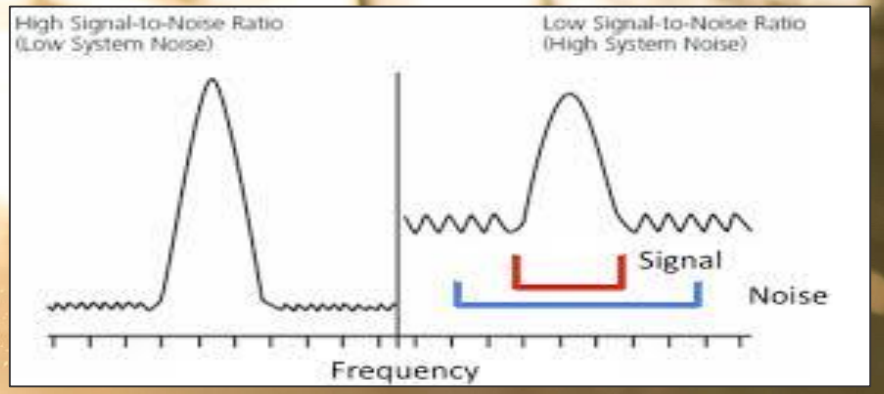
Performance figures

Specifications	VALUES
Electro-optical unit	Full solid state design based in MEMS
Wavelength, Classification	1064nm, Class 1 or 3R selectable by the user
Range	80m @ 10% reflectivity 180m @ 50% reflectivity
Point rate	600 Kpx/s
Image spatial resolution	- 600 x 200px @ 5 frames/s - 500 x 150px @ 10 frames/s
Field-of-view (HxV)	60 x 20º
Angular resolution	- 0,1º in both horizontal and vertical - 0,15º horizontal, 0,13º vertical
Range accuracy	±0,7 cm @ 10m ±1,5 cm @ 25m
Inertial sensor	Included
Mechanical	
Size (WxDxH)	26 x 23 x 13 cm
Weight	3Kg
Electrical	
Power consumption	15W
Supply voltage	12 VDC
Interfaces	UDP Ethernet packets
Software	
Integration	ROS driver for Linux L3CAM library for Windows
Test application	RVIZ and Beamagine Visualizer





Key aspects of the Beamagine LIDAR technology



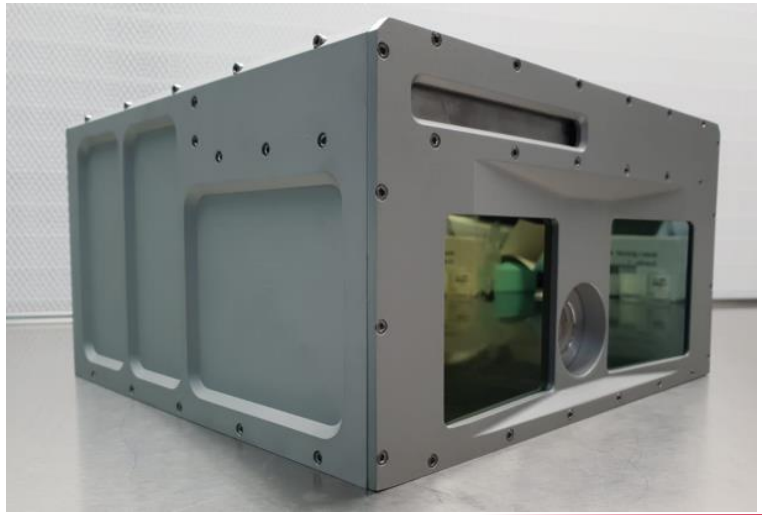
- **Wide FOV and solar radiation immunity**
- **Solid-state design with large entrance pupil for long range detection**
- **High resolution real-time video data**
- **Scalable for volume production**
- **Class 1 eye-safe**

Performance at the orbital environment

OPTICAL AND IMAGING PERFORMANCE

Field-of-view	50x50º
Image resolution	350x350 px
Frame rate	5 Hz
Point rate	612,5 Kpx/s
Angular resolution (x-y)	0.14 - 0.14º
Angular sampling accuracy	<0.01º
Range resolution	±1 cm
# of returns	4

- Sun Simulator: Arrimax 18/12 kW, 1370 W/m^2, 5778 ºK
- Halogen lamp 5 kW: 580 W/m^2, 3000 ºK



Class 1 – Full eye-safe

Irradiance (W/m^2)	Range @ 80% refl. (m)	Range @ 50% refl. (m)	Range @ 10% refl. (m)
No sun simulator	112	89	40
580 – Indirect	85	68	30
1400 – Indirect	78	61	27
580 – Direct	18	15	7
1400 – Direct	16	13	6

Class 3R

Irradiance (W/m^2)	Range @ 80% refl. (m)	Range @ 50% refl. (m)	Range @ 10% refl. (m)
No sun simulator	327	258	115
580 – Indirect	191	151	68
1400 – Indirect	174	137	61
580 – Direct	41	33	15
1400 – Direct	37	29	13

Class 3B

Irradiance (W/m^2)	Range @ 80% refl. (m)	Range @ 50% refl. (m)	Range @ 10% refl. (m)
No sun simulator	659*	586*	268
580 – Indirect	444*	351	157
1400 – Indirect	404	319	143
580 – Direct	96	76	34
1400 – Direct	85	67	30

*The maximum range is limited by the ambiguity distance between two consecutive laser pulses, which is fixed at 426m.

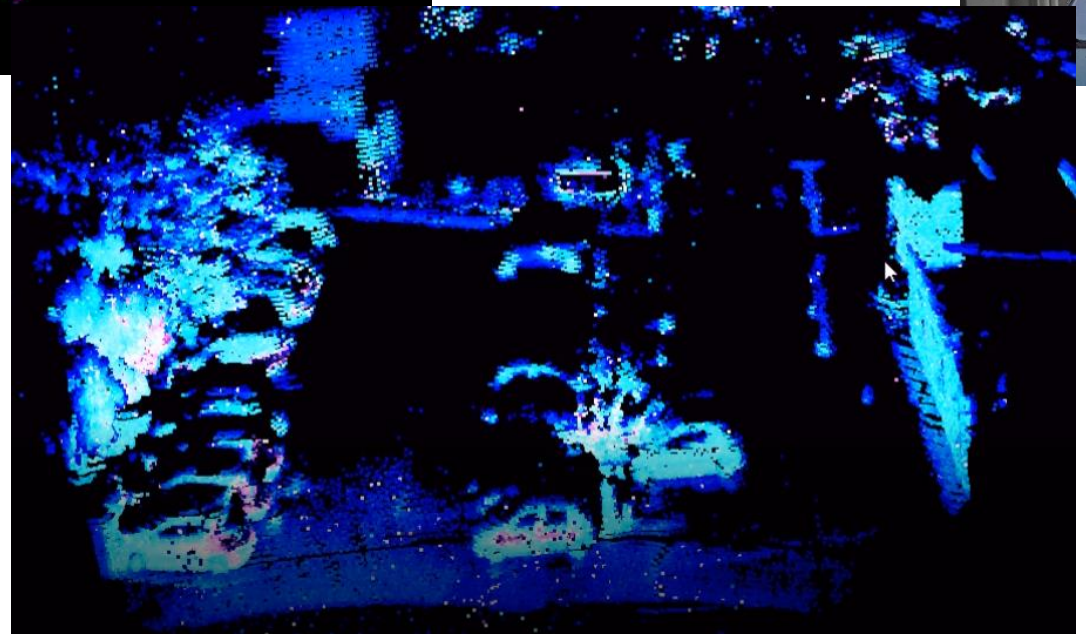
Kay aspects of Beamagine LIDAR for a space applications

- Full solid-state
  - *Normally imaging LIDAR devices are based on moving elements like spinning mirrors, galvanometric scanners or rotating heads. Macromechanical devices are sensitive to vibrations and shock. A space grade LIDAR device has to tolerate to this effects generated during the launching and this is only achievable by a solid-state device.*
- Solar background immunity
  - *Background radiation is the main source of noise of any LIDAR device. In space environment, the solar background can generate critical failures during operation.*
- High resolution and real-time frame-rate
- Small size & light weight
- Robust data fusion
  - *The LIDAR point-clouds have to be fused reliably with outer imaging sensor (camera images) without and kind of parallax error and with ultra-low computational cost.*

Space use cases:

- Orbital robotics
  - *Satellite docking and rendezvous*
  - *Spaceborn close proximity navigation*
  - *Satellite pose estimation*
  - *Space debris removal*
- Planetary exploration
  - *Rover navigation*
    - *Path planning*
    - *Terrain assessment*
    - *Obstacle detection & avoidance*
    - *Self-guiding*
  - *Terrain mapping landing aid*

Range and intensity mode point clouds

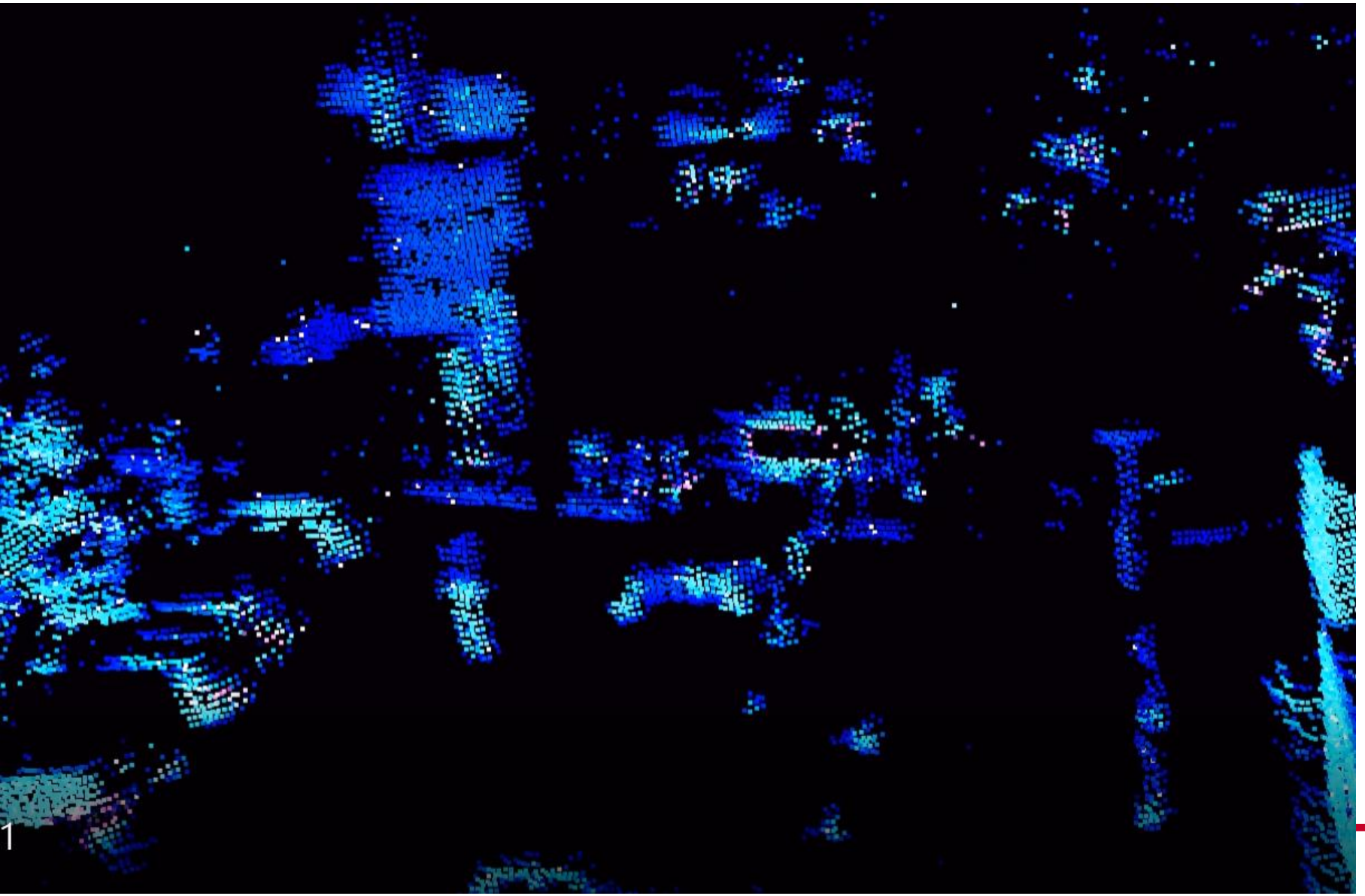


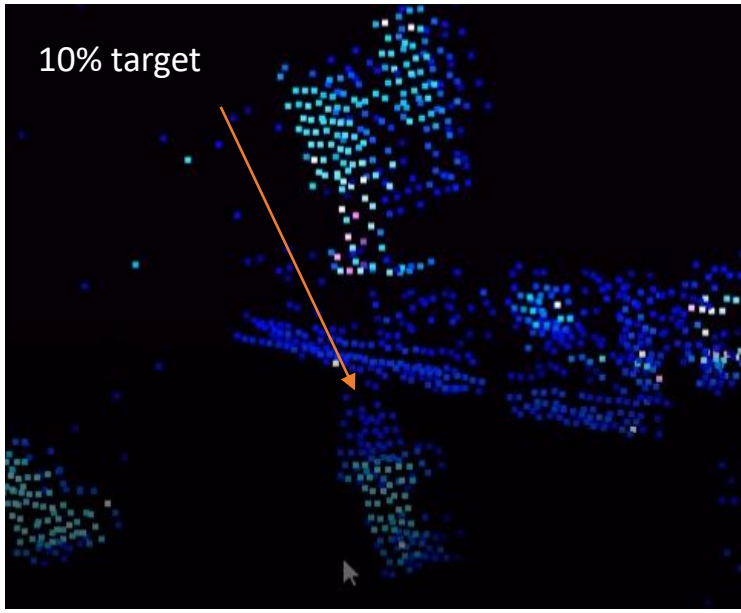
Raw data, no filtering applied

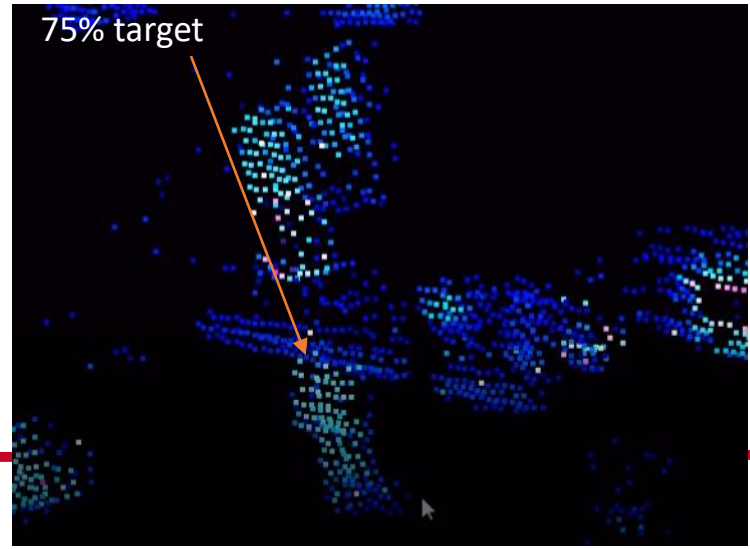
Performance test

- Double reflectivity target (10%-75%)
- Tests up to 80m (Google Maps) 10% reflectivity
- Range and Intensity images obtained
- Some objects (buildings) visible at 200m

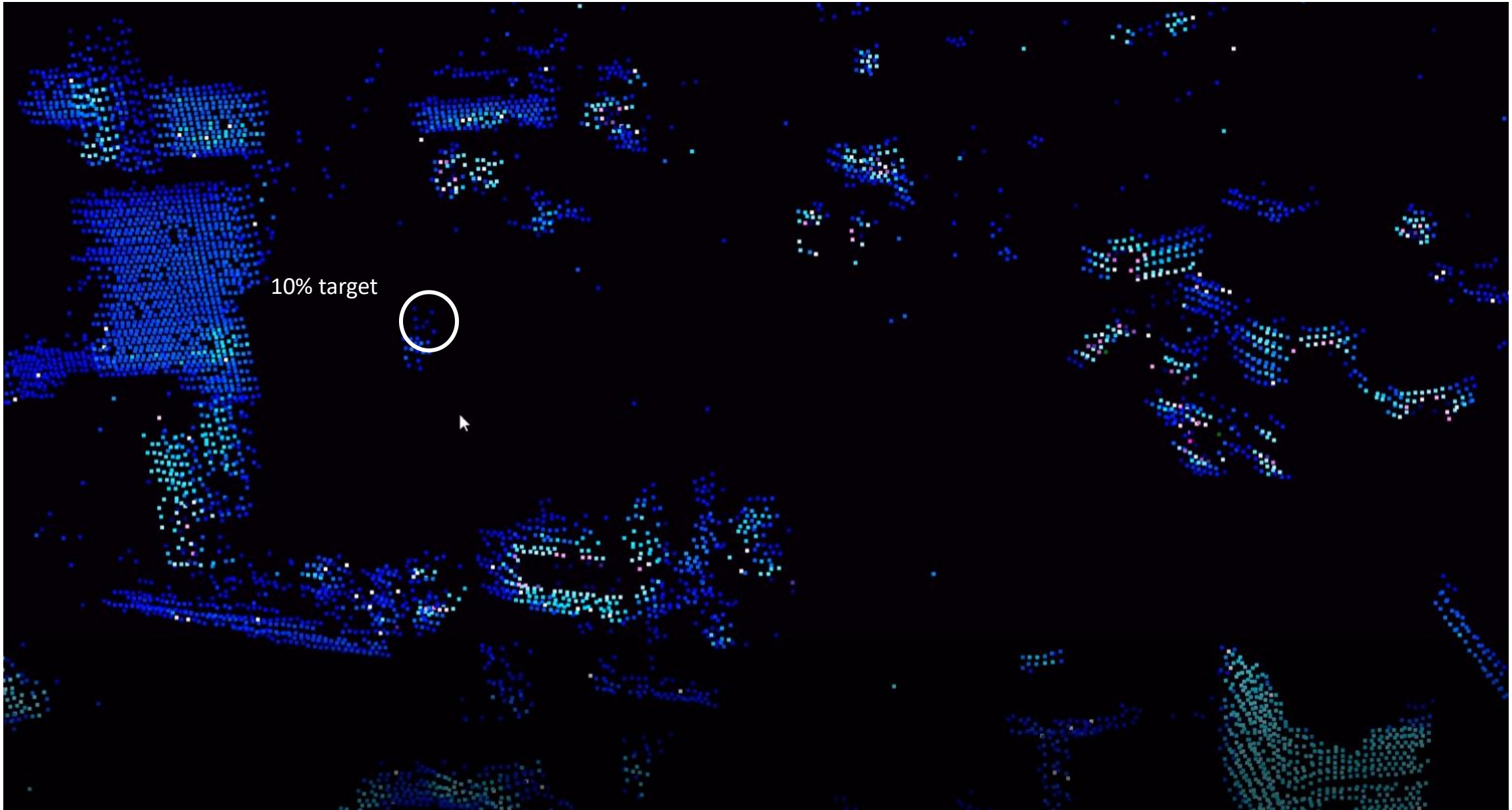
Performance test: 50m @ 10% reflectance







Performance test: 80m @ 10% reflectance



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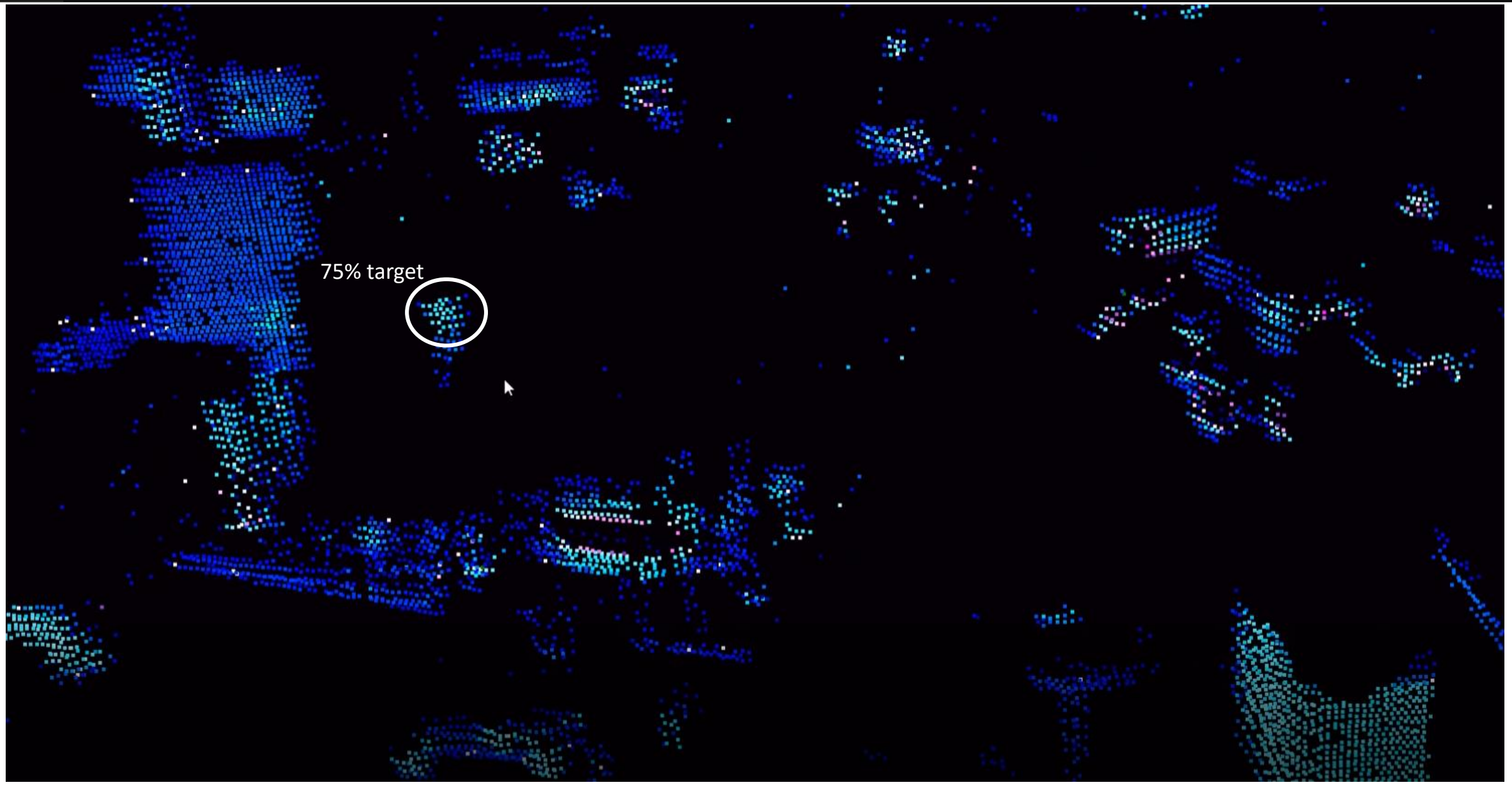
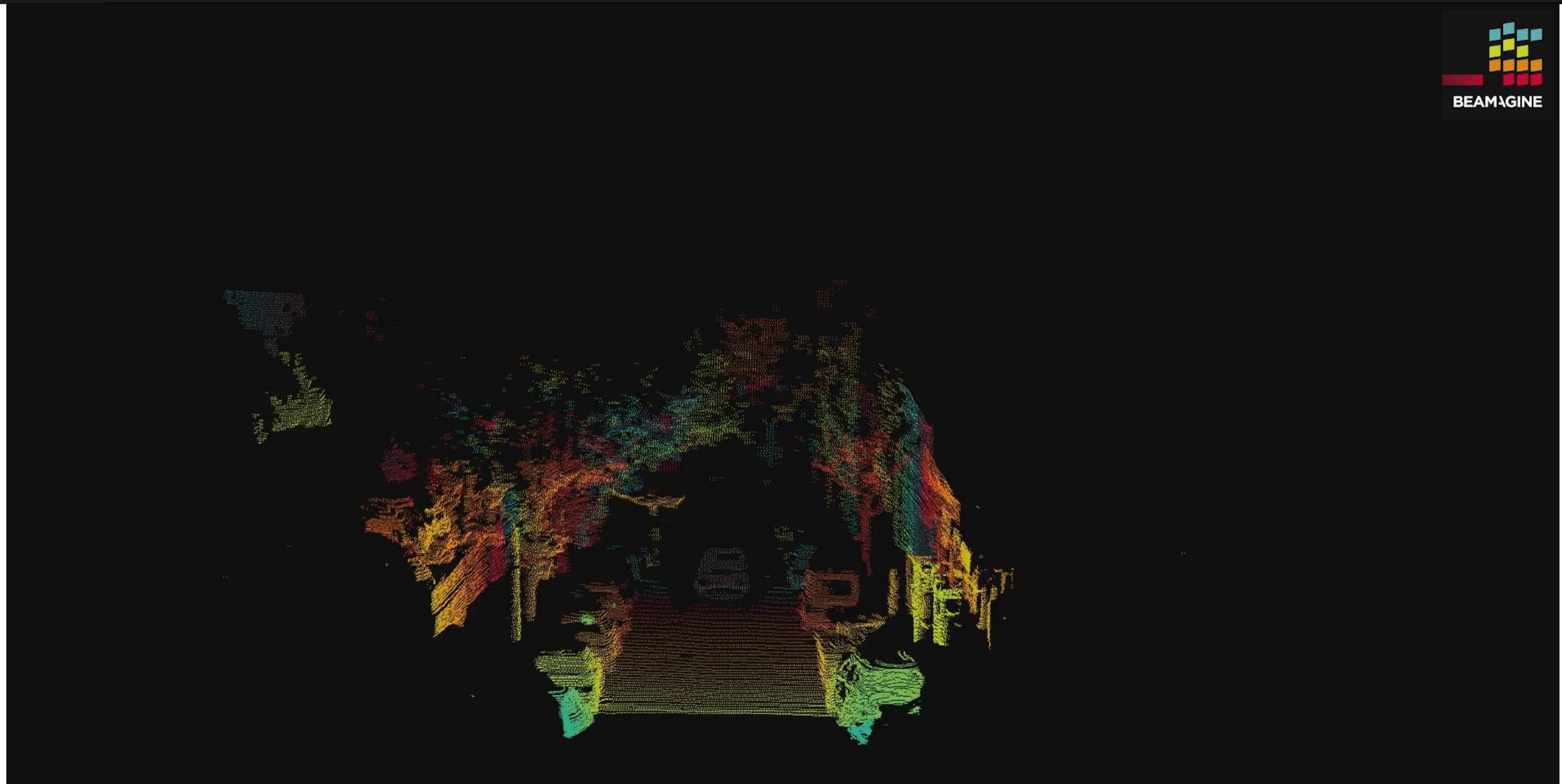
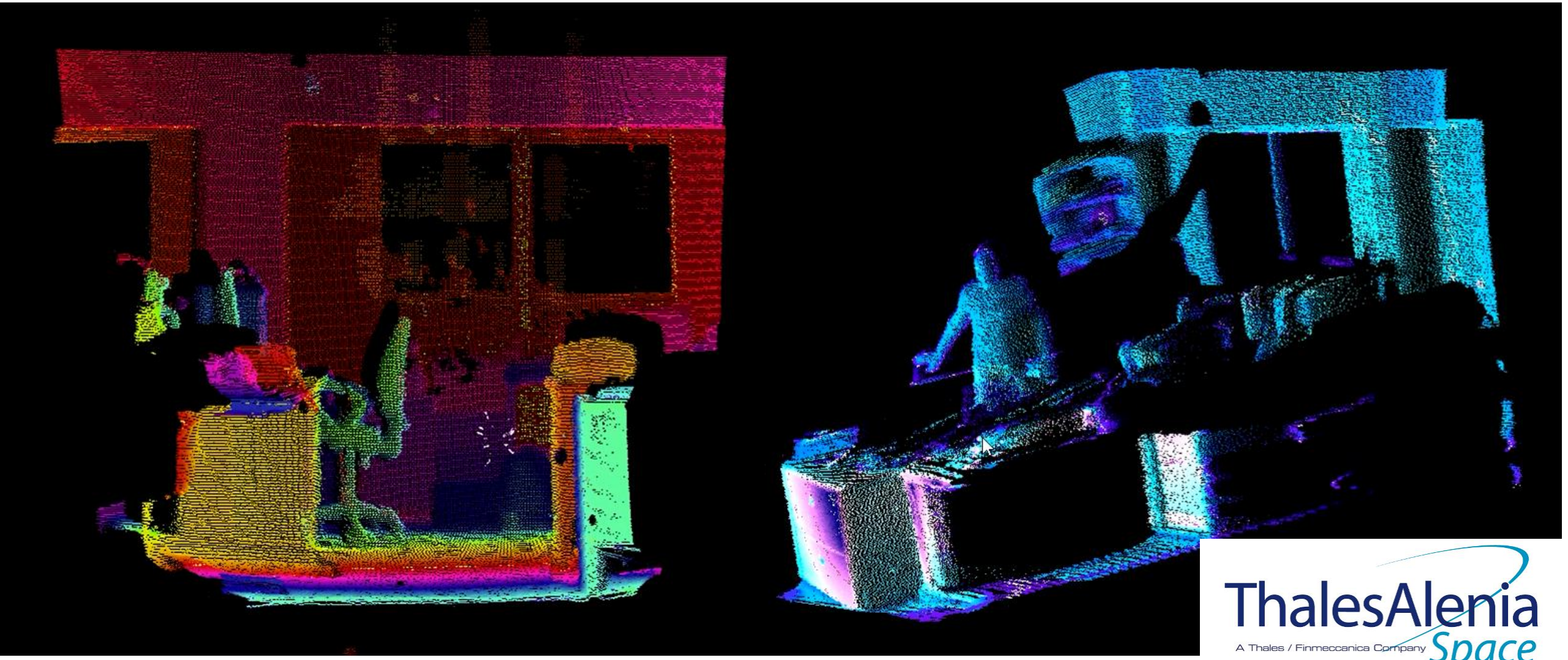


Sample video



Sample point clouds



Challenges in data fusion

Challenges in data fusion

Problem:

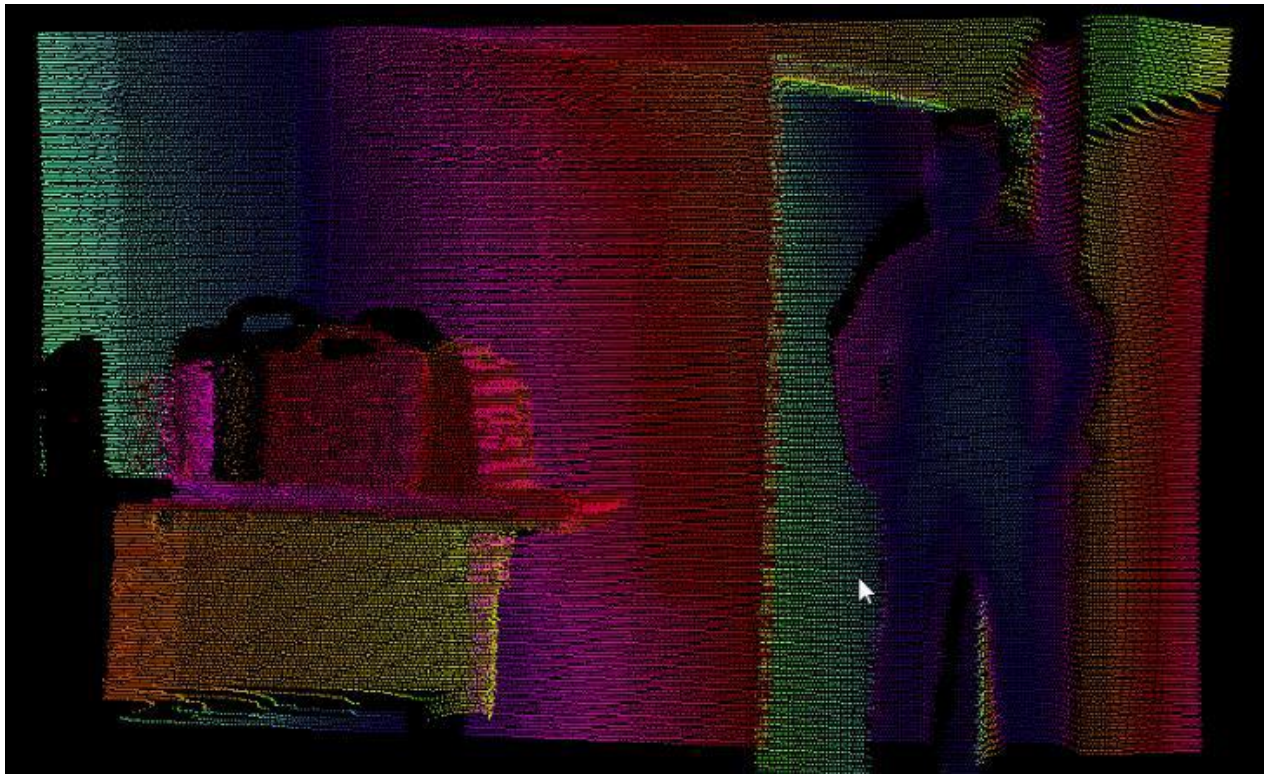
- Different update frequencies of LIDAR and camera
- LIDAR and camera points do not match exactly, e.g. pole of the traffic light

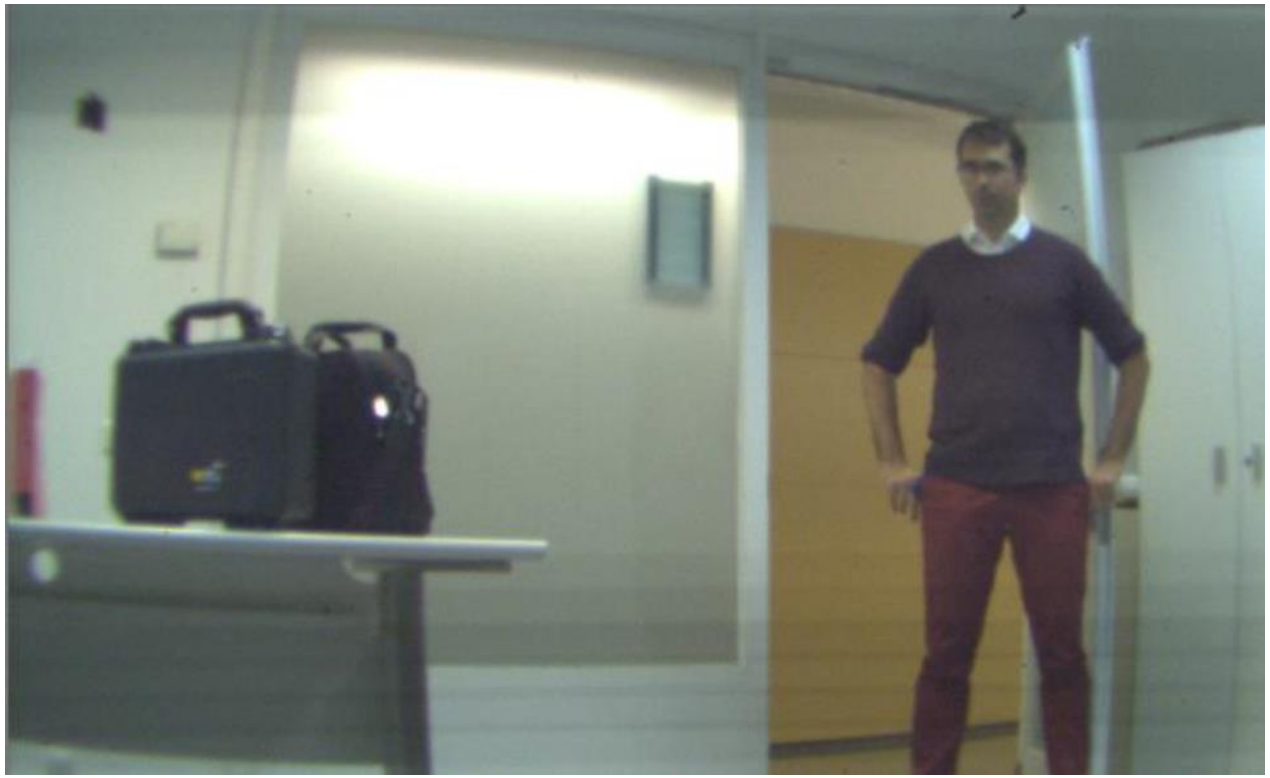
Traditional solution:

- Transform LIDAR points into camera image using vehicle ego-motion information.
  - Parallax errors
  - High computational cost

Direct data fusion

Beamagine technology enables a unique feature: a self-registered 3D lidar image with another 2D imaging mode (**RGB, NIR, SWIR, polarimetric, hyperspectral or thermal**). This is enabled by a patented technique that collects both imaging modes through the same optics which enables a hardware based automatic registration that **avoids complex data fusion algorithms and parallax error**.





THANKS FOR YOUR ATTENTION!

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