



EPIC-Meeting on FMCW LiDAR Systems

How 3D Multi-channel Lidar Sensors Contribute to More Safety

From Logistics to Urban Traffic Space

Dieter Gabriel, Marketing EMEA

Velodyne Lidar[®]



YOUR SAFETY DRIVES US

The Velodyne Lidar History

1983

**Founded
Velodyne
Acoustics**

*Became World
Leader in Acoustics
Technology*



2004

**Completed
DARPA
Grand
Challenge**



2005

**Invented
Real-Time
3D Lidar**



2007

**Began
World's First
Commercial
Production
of Real-Time
3D Lidar**



TODAY

**Leading
Lidar
Technology**



Velodyne Today

WORLD CLASS R&D AND MANUFACTURING

Velodyne Labs
Advanced
Research Center
Alameda, CA



Velodyne Lidar
Global Headquarters
and Manufacturing
San Jose, CA

**Velodyne Lidar
Asia**
*Beijing, China
Seoul, Korea*



Velodyne Lidar Europe GmbH
*Rüsselsheim- Frankfurt area,
Germany*



**Velodyne Lidar
India**
Bengaluru

Entering Mass Production

MANUFACTURING AND PRODUCTION PARTNERS

San Jose, USA

Velodyne
Lidar.



Sendai, Japan

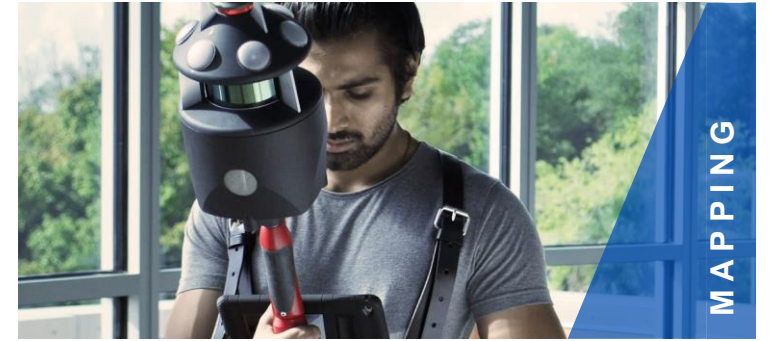


Chonburi, Thailand



- Powerful partnerships with production experts
- Global Manufacturing capacity to address growing demand
- Maintaining highest quality with optical and tooling precision
- Greater supply chain efficiency for stronger price negotiations
- Support for advanced manufacturing innovations
- Fully automated wafer-scale lidar manufacturing processes

Rapid Adoption of Lidar Across Industries



What's it all about ?



Velodyne Product Overview

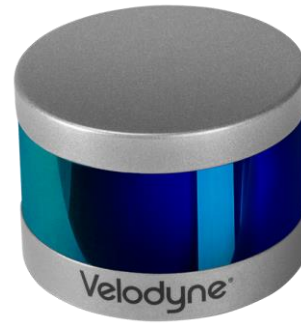
Sensors for the widest variety of applications



Alpha Prime™



Ultra Puck™



Puck™

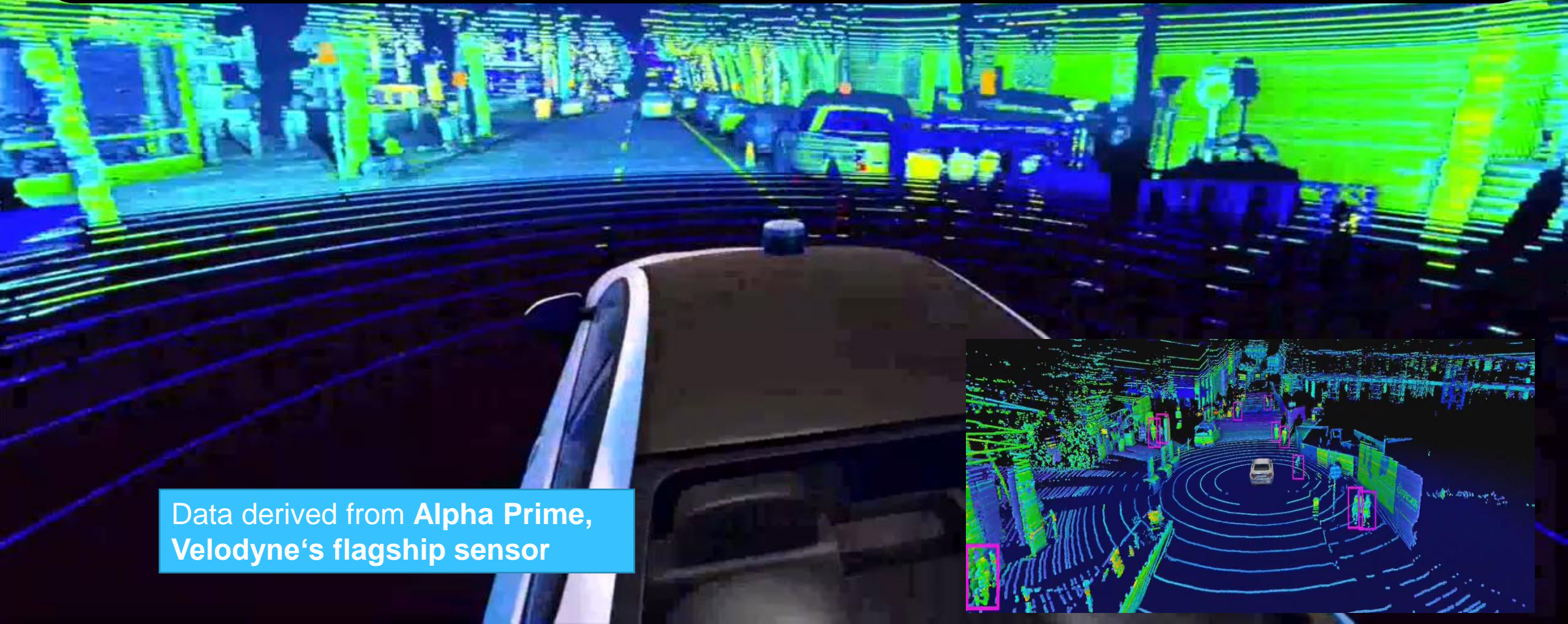


Velarray™



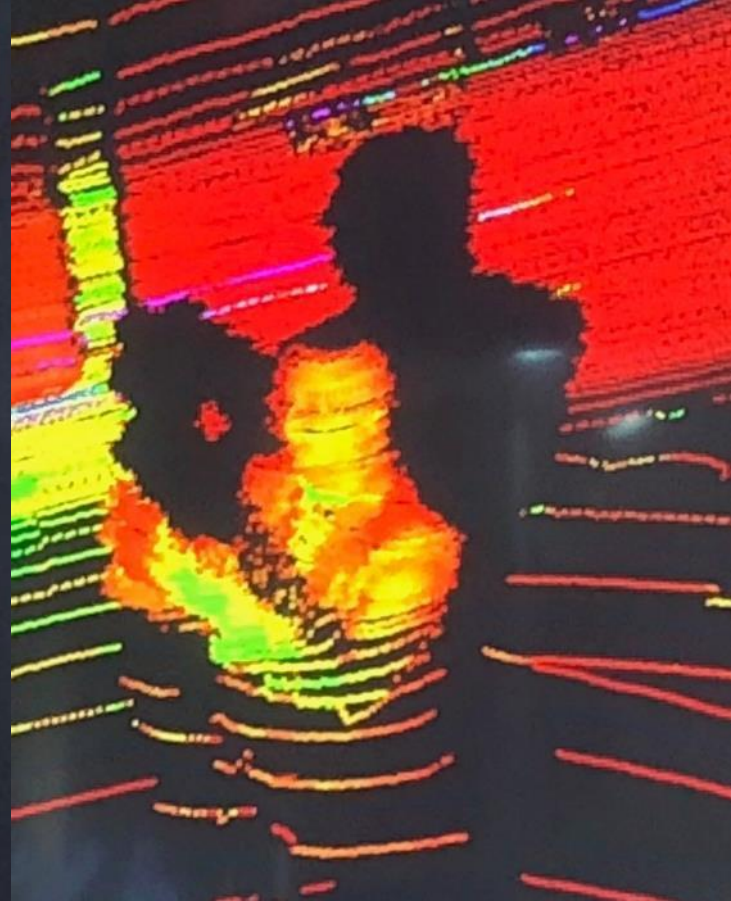
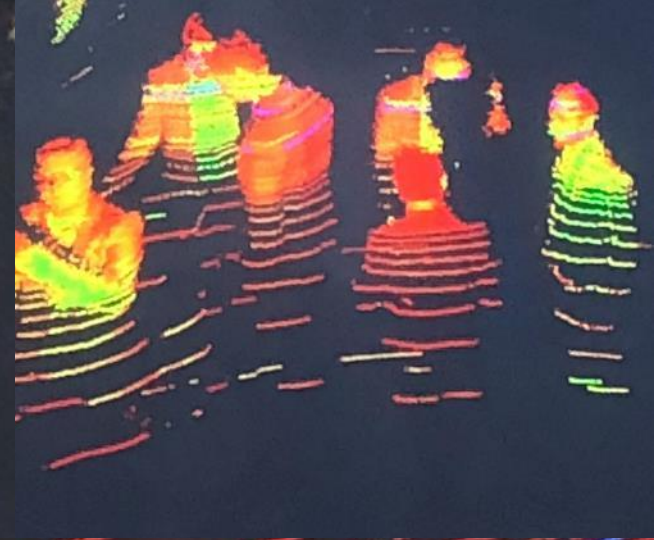
Velabit™

Great reflectivity, regardless of whether mounted on mobile platforms or as a stationary installation



Data derived from **Alpha Prime**,
Velodyne's flagship sensor

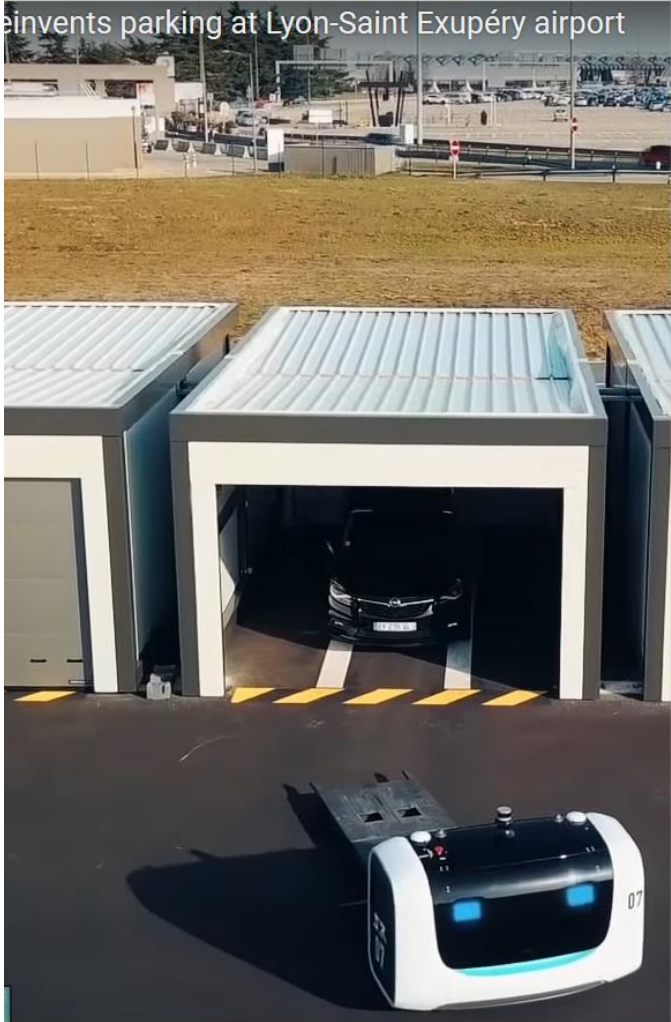




Solutions for industrial vehicles and mobile robot platforms

- Cost reduction by reducing the number of sensors on the platform / robot
- Highly flexible 3D navigation without markers or reflectors or high-performance support of camera sensors
- Navigation even on uneven ground
- Load-handling tasks (assisted order picking)
- Smart Safety: 3D object recognition and 3D collision avoidance ensure maximum environmental safety (180 to 360 degrees)

Example: Valet Parking– Stanley Robotics



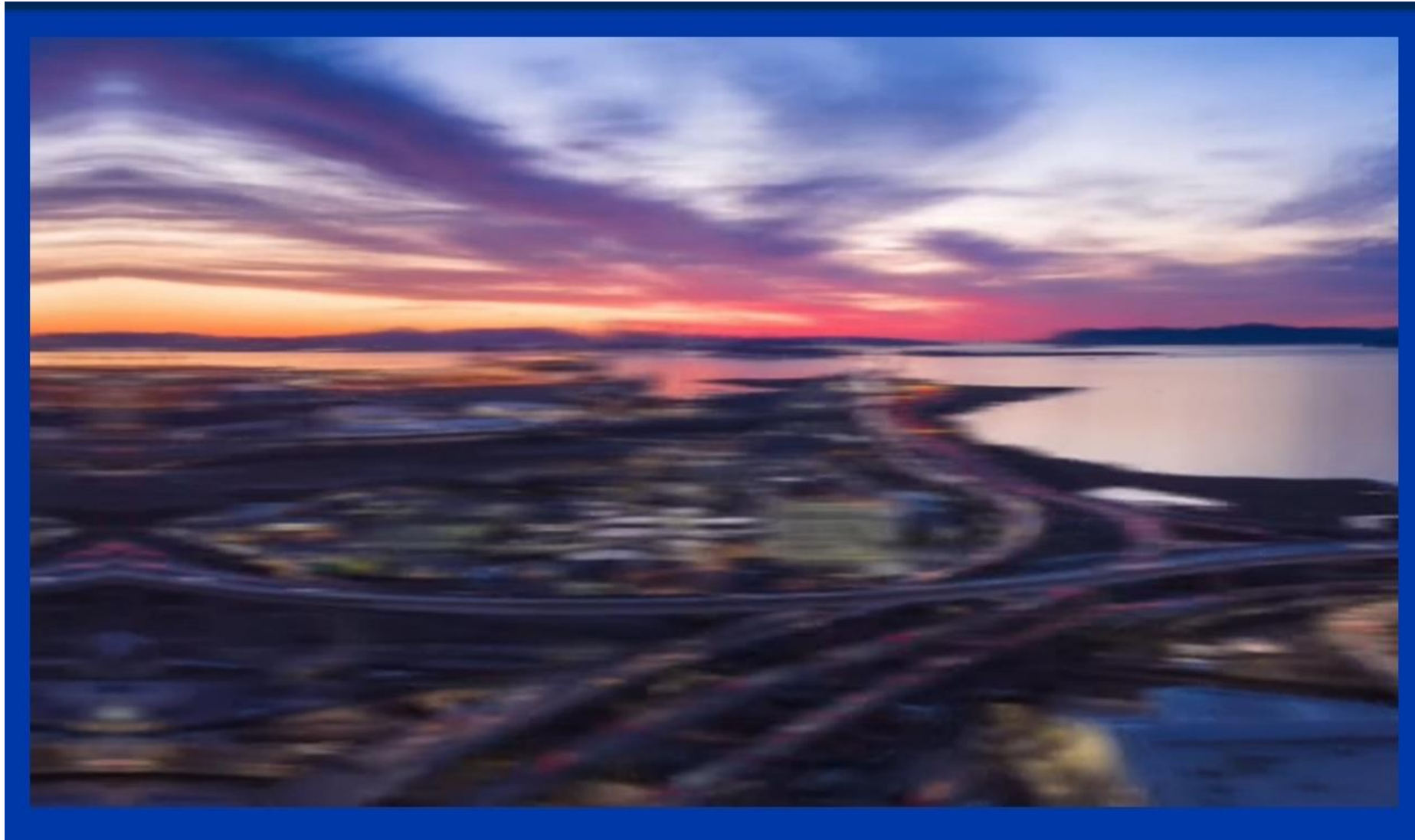
Example: Valet Parking– Stanley Robotics



Solutions for industrial vehicles and mobile robot platforms



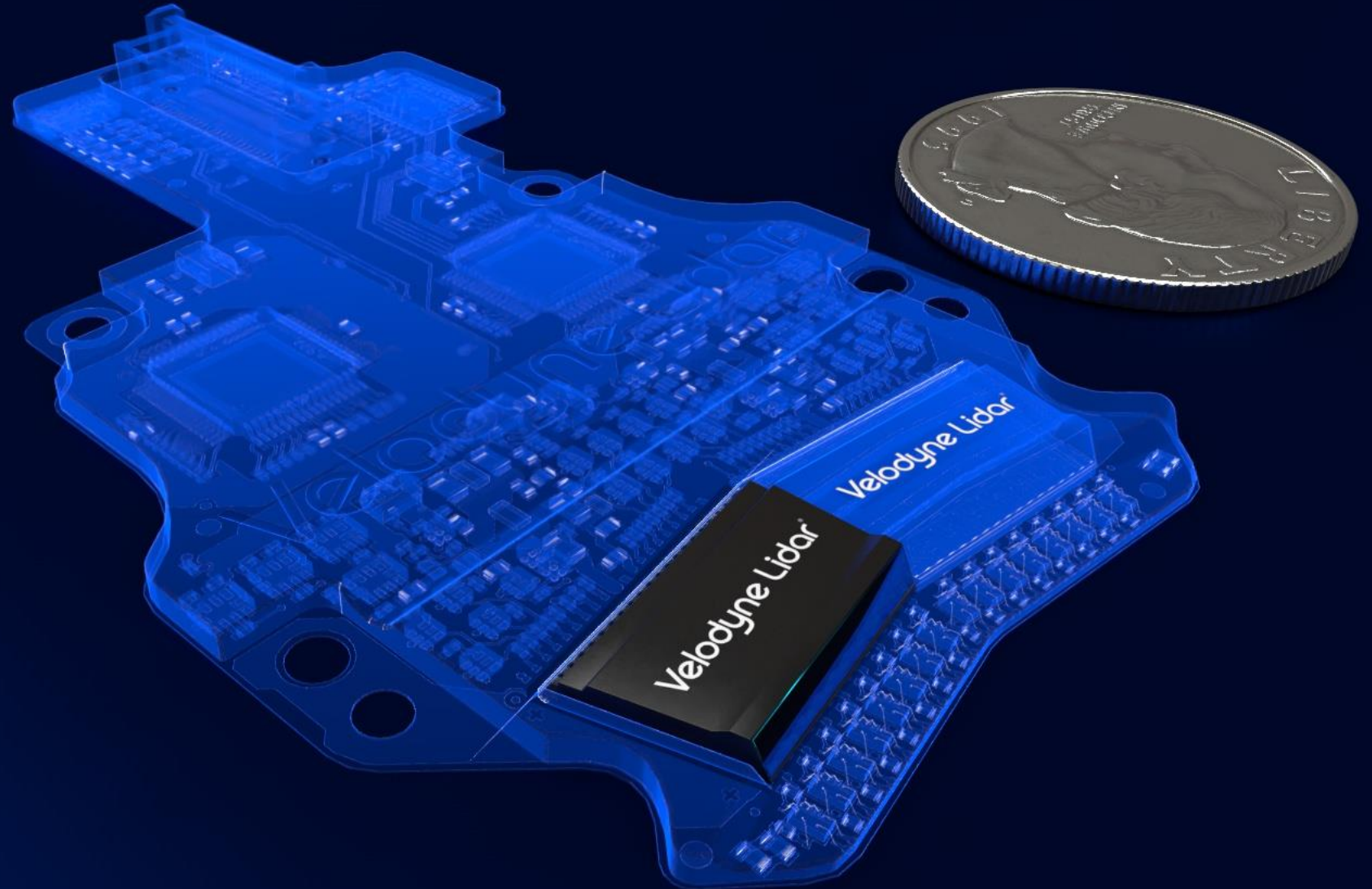
Solutions for industrial vehicles and mobile robot platforms



Micro-Lidar Array (MLA)

Proprietary chip-based technology

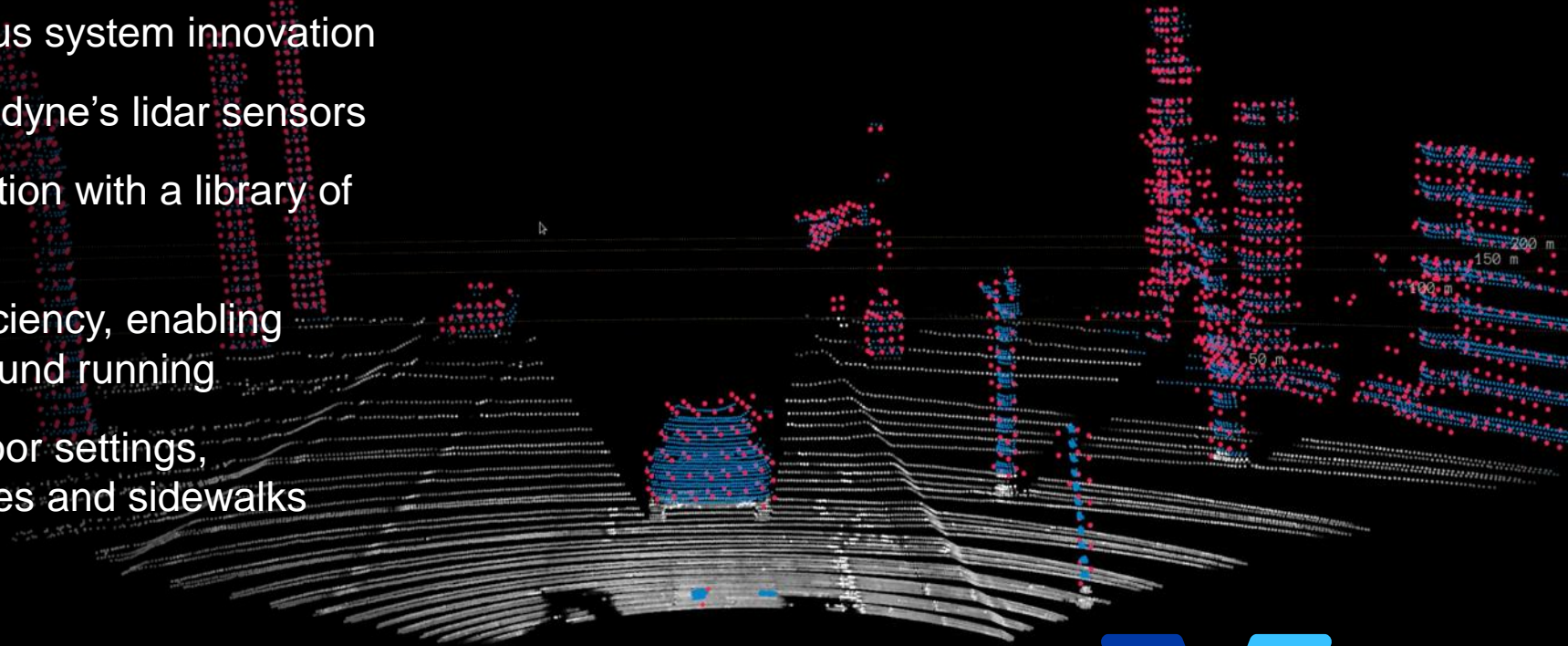
- Brings together the core elements that make lidar work: optical chip + Velodyne's ASIC (application-specific integrated circuit) technology
- 8 lidar channels are miniaturized to the size of a penny, forming the "engine" of the lidar sensor
- This miniaturization + Velodyne's proprietary, fully automated manufacturing process enables cost-effective, high-quality mass production



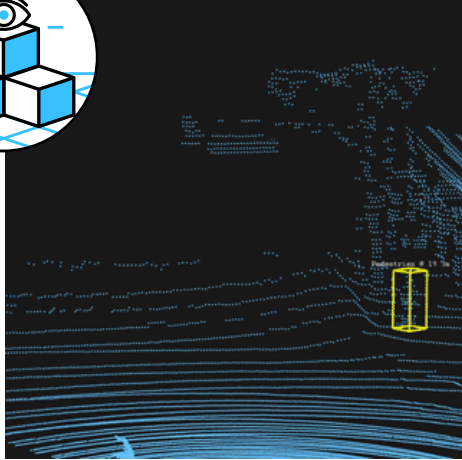
Vella software

Turn data into action

- Fast track full-stack autonomous system innovation
- Seamless integration with Velodyne's lidar sensors
- Plug and play, end-to-end solution with a library of software functions
- Deploy lidar with ease and efficiency, enabling teams of all sizes to hit the ground running
- Optimized for indoor and outdoor settings, including roadways, warehouses and sidewalks

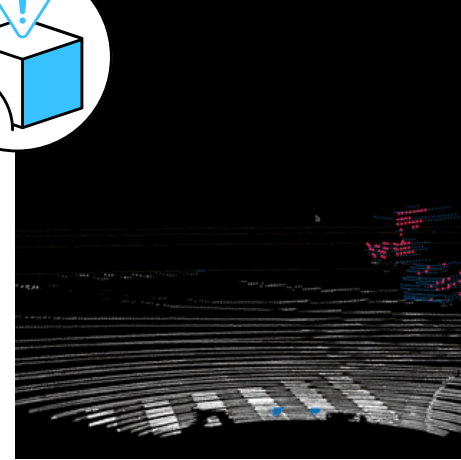


Software features



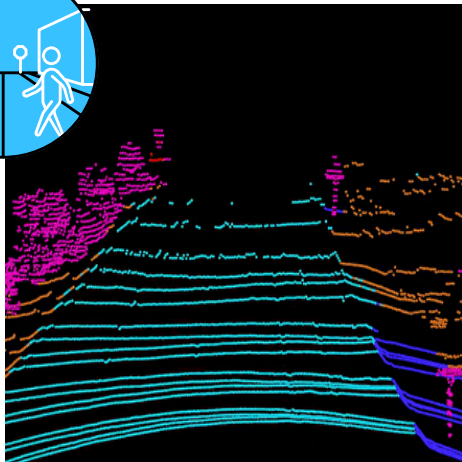
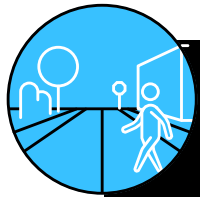
3D Object List

- 9 object categories
- Object velocity
- 3D bounding box
 - Size
 - Position
 - Orientation



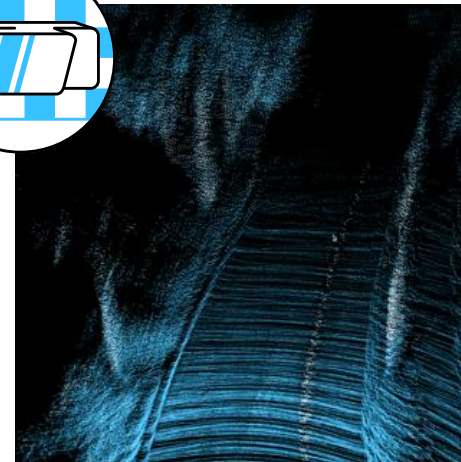
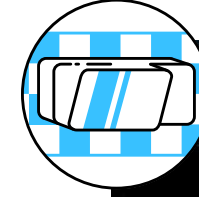
Obstacle/Free-Space Detection

- Occupancy grid
- Lidar odometry
- Collision alert
- Enables path planning



Scene Segmentation

- Dense pixel-wise labels
- 5 segment categories
 - Drivable
 - Terrain
 - Sidewalk
 - Fixed obstacles
 - Movable obstacles



Extrinsic Calibration

- Cloud-based service
- YAML calibration file
- Lidar pose estimation w.r.t. vehicle coordinate frame



Lidar Enables Advanced GDPR compliant Smart City Applications To Increase Security

Intelligent Infrastructure Solution

Transforming infrastructure to make communities smarter and safer today

- Full stack technology solution
- Designed to solve challenging and pervasive infrastructure problems, improve traffic and crowd flow, advance sustainability and protect vulnerable road users
- Monitors traffic networks and public spaces, generating real-time data analytics and predictions



The Problem: Traffic



Inefficient

\$305B in costs of congestion
just in US



Unsafe

1.35 million people are killed on roadways globally
94% of collisions are caused by human error



Unaware

Not taking into account
vulnerable road users

The Problem: Legacy Traffic Monitoring Technology Doesn't Work



Expensive

Costly to install and maintain, typically multiple sensors



Limited Conditions

Fail to operate in different weather and lighting conditions



Limited Road Users

Systems designed for vehicle traffic, limited data about other types of road users



No Analytics

Converting data to actionable insights is costly, slow, requires third party involvement



Loop



Radar



Camera

Current traffic solutions require multiple technologies to address the cities data needs

- Extremely expensive to install and maintain
- Requires road closure
- Limited data about presence of cars
- No other type of road users
- Requires underground wiring
- Requires 4 sensors per intersection
- Requires road closure
- Limited data about presence of cars
- No other type of road users
- Unreliable under adverse weather and lighting conditions.
- Privacy concerns.
- Mainly used for planning/surveillance

OVERVIEW



Reliable

Collect data in any lighting or weather conditions.



Multi-modal

On-board AI classifies your data between vehicles, pedestrians and bikes.



Non-Intrusive

Single-sensor solution to cover whole intersection.



Connected

Powered by LTE/5G, Explorer delivers real-time access to your data.



Privacy-Protected

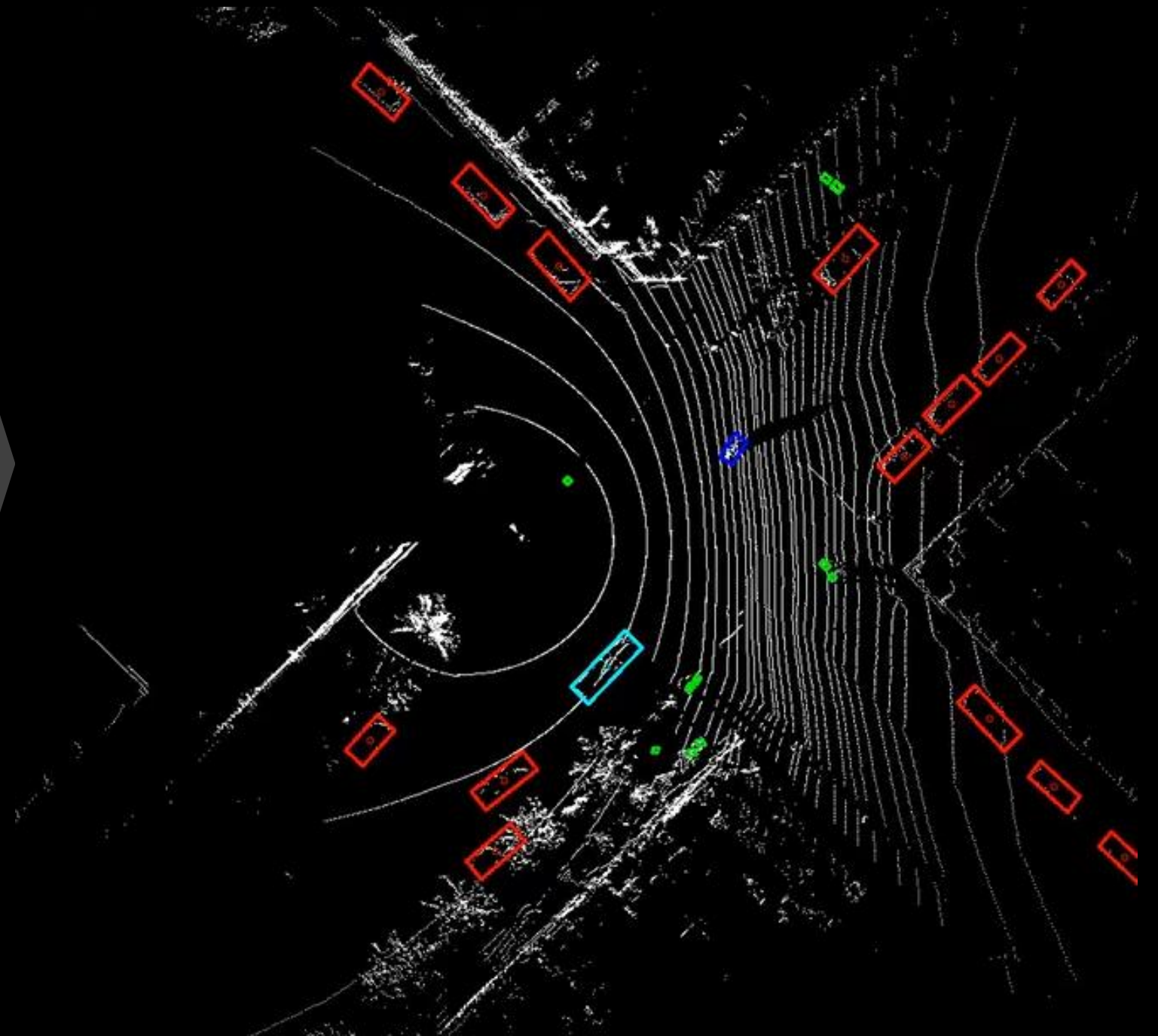
No privacy concerns



How a single Lidar sees an entire intersection?

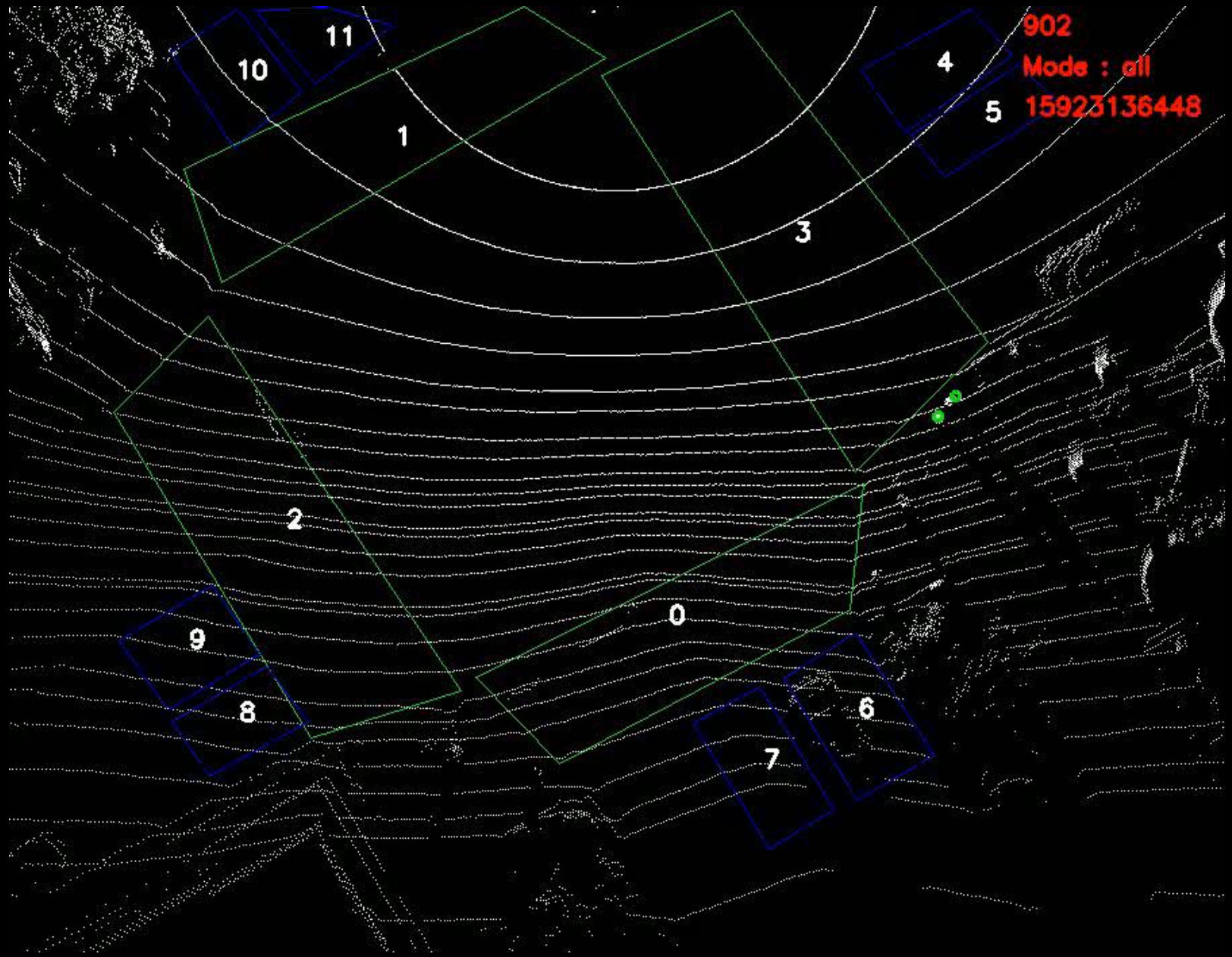


Real-time
object
detection,
classification
and tracking



A replacement for costly to maintain technologies

Virtual loops for all road users



Real-Time Communication with Traffic Controller

The screenshot shows the PEEK ATC interface with the following components:

- Terminal Window:** Displays real-time traffic data including date (Wed 10-Mar-2021), time (16:47:45), and various status indicators like RING STATUS, ACTIVE PRE, and RECORDING.
- System Outputs Menu:** A list of expandable sections including Phase Outputs, Overlap Outputs, Phase Ons/Nexts, Channel Outputs, Pedestrian Overlap Outputs, Transit Signal Priority, Local Slots, Ring Status, Special Functions, Preemption, and Circuit Outputs.
- Vehicle Calls Panel:** A grid of 48 toggle switches (numbered 1-48) for controlling individual vehicle calls, all currently set to 'OFF'.
- Control Panel:** A numeric keypad (0-9, A, B, C) and function keys (HME, ENT, PRV, YES, NO, CLR ESC, HLP, MNU, NXT, *).
- Traffic Debug Tools:** A section with playback controls (play, pause, stop, fast forward, fast reverse) and a 'Not Recording' indicator.

The 'Define Loops' interface displays a map with several colored rectangular overlays (purple, green, blue, orange) placed over road segments, representing the configuration of virtual loops for traffic control. A timestamp '2020-11-20 21:00:51' is visible at the bottom of the map area.

Fully customizable
virtual loops

Speed Analysis

- Use Cases:
 - Driver Behavior Analysis
 - Traffic Light Timing Efficiency
 - Effect of weather/lighting conditions on speed distribution
 - Monitor over speeding

Velodyne Lidar Intelligent Infrastructure Solution Powered By iBluecity

Dashboard Map Log Out

1 1 + Create Speed Chart Counts Speed

Search...

BCT_3D_5G_0101003
2/12/2021, 12:00:00 AM - 2/13/2021, 8:00:00 PM

Line Chart Box Plot

Speed (km / h)

Time

Download CSV Edit Delete

BCT_3D_5G_0101003
2/12/2021, 12:00:00 AM - 2/13/2021, 8:00:00 PM

Line Chart Box Plot

Speed (km/h)

BCT_3D_5G_0101003 - EW BCT_3D_5G_0101003 - NS

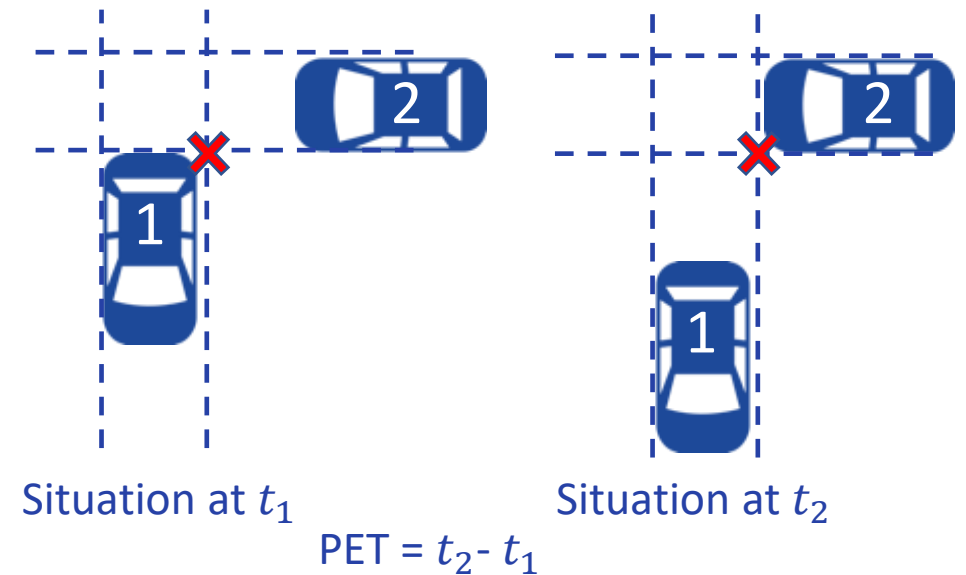
Download CSV Edit Delete

- 0 BCT_3D_5G_0101001 Bernard_Pandosy, Kelowna, BC, ...
- 0 BCT_3D_5G_0101002 Bernard_Water, Kelowna, BC, Ca...
- 1 BCT_3D_5G_0101003 Gordon Dr_Springfield Rd (north...
- 0 BCT_3D_5G_0101004 Gordon Dr_Springfield Rd (south...
- 0 BCT_3D_5G_0101005 Queensway_Pandosy St, Kelown...
- 0 BCT_3D_5G_0100001 Notre-Dame_Peel, Montreal, QC,...
- 0 BCT_3D_5G_0102003 Saint-Catherine_Guy, Montreal, ...
- 0 BCT_3D_5G_0103001 University Blvd_Acadia Rd, Vanc...
- 0 BCT_3D_5G_0103002 (EastSouth) University Blvd_Wes...
- 0 BCT_3D_5G_0103003 (NorthWest) University Blvd_Wes...
- 0 BCT_3D_4G_0104001 104 Ave NW - 109 St NW, Edmo...
- 0 BCT_3D_5G_0101001 Bernard_Pandosy, Kelowna, BC, ...
- 0 BCT_3D_5G_0101002 Bernard_Water, Kelowna, BC, Ca...
- 1 BCT_3D_5G_0101003 Gordon Dr_Springfield Rd (north...
- 0 BCT_3D_5G_0101004 Gordon Dr_Springfield Rd (south...
- 0 BCT_3D_5G_0101005 Queensway_Pandosy St, Kelown...
- 0 BCT_3D_5G_0100001 Notre-Dame_Peel, Montreal, QC,...
- 0 BCT_3D_5G_0102003 Saint-Catherine_Guy, Montreal, ...
- 0 BCT_3D_5G_0103001 University Blvd_Acadia Rd, Vanc...
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- 0 BCT_3D_5G_0103003 (NorthWest) University Blvd_Wes...
- 0 BCT_3D_4G_0104001 104 Ave NW - 109 St NW, Edmo...

Near-Miss Analytics

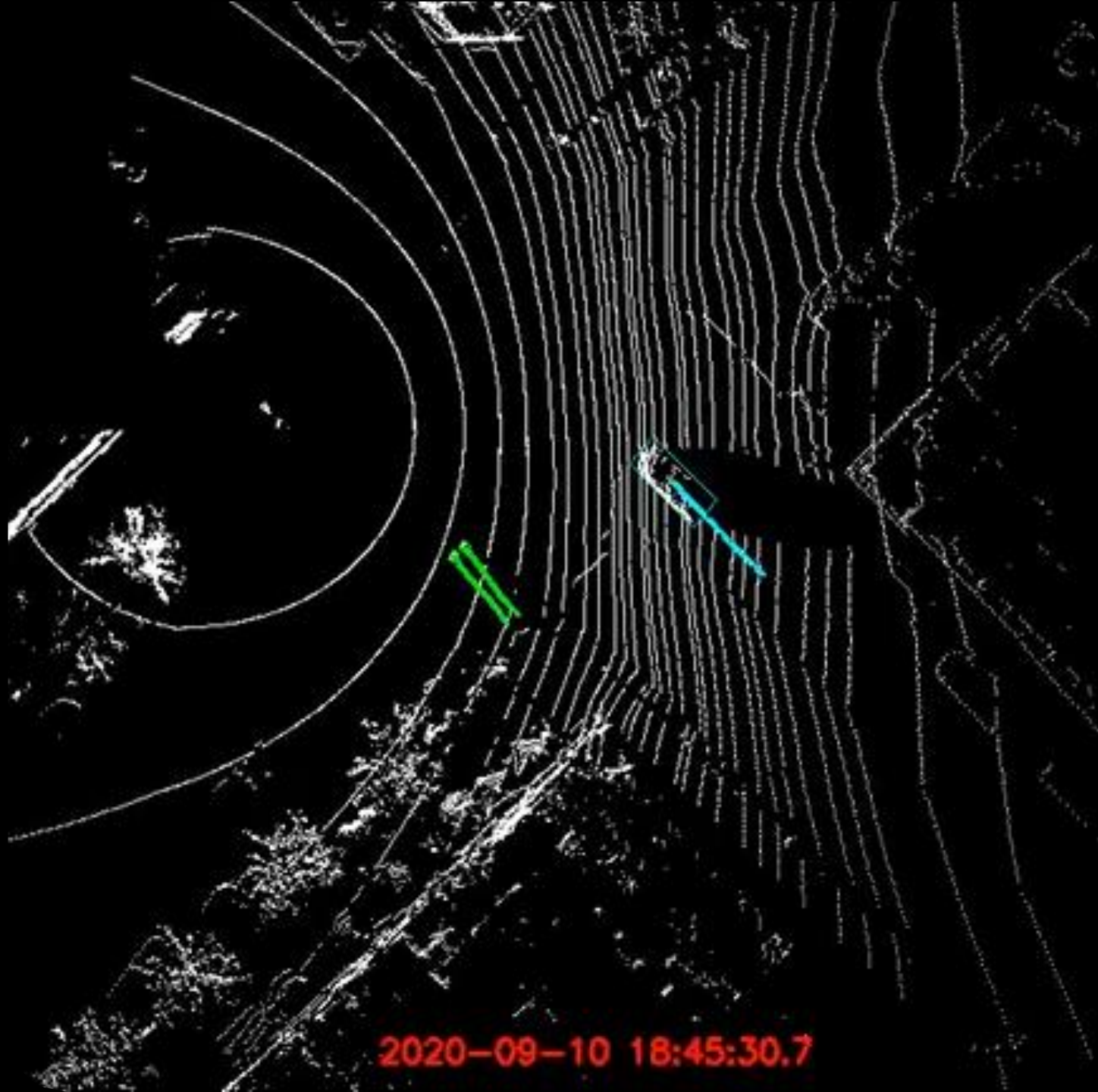
Conflict analysis using estimation of Post Encroachment Time (PET)

- Post Encroachment Time (PET) represents the time difference between a vehicle leaving the area of encroachment and a conflicting vehicle entering the same area.
- PET is a factor that is used as a measure of conflict, it is highly correlated to the risk of accidents.
- PET values less than 2 seconds classifies as **critical** and from 2 to 4 seconds as **unsafe** conflict.



Conflict Analysis

Near miss detection
PET estimation

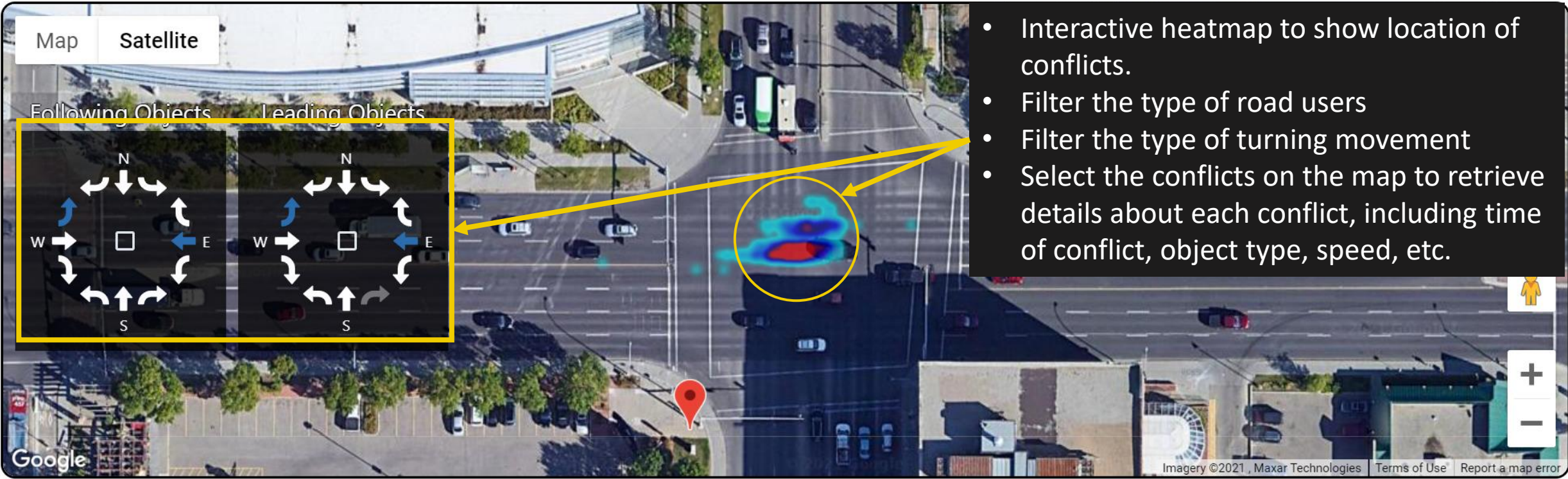


BCT_3D_4G_0104001

4/27/2021, 12:00:00 AM - 4/28/2021, 11:59:59 PM

- Bicycle - Passenger Vehicle (0)
- Passenger Vehicle - Pedestrian (0)
- Passenger Vehicle - Bicycle (3)
- Passenger Vehicle - Passenger Vehicle (108)
- Passenger Vehicle - Truck (0)
- Passenger Vehicle - Bus (1)
- Truck - Pedestrian (0)
- Truck - Passenger Vehicle (8)
- Bus - Pedestrian (0)
- Bus - Passenger Vehicle (1)

Average PET PET Count



PET (seconds)



Delete

BCT_3D_4G_0104001

Location of the conflict

PET value in seconds

Speed of leading object

PET Details

Date/Time that conflict happened

Sensor: BCT_3D_4G_0104001 Location:-113.50848°, 53.54626°

Monitor Critical Conflicts
Validate it with watching a 10-second video clip

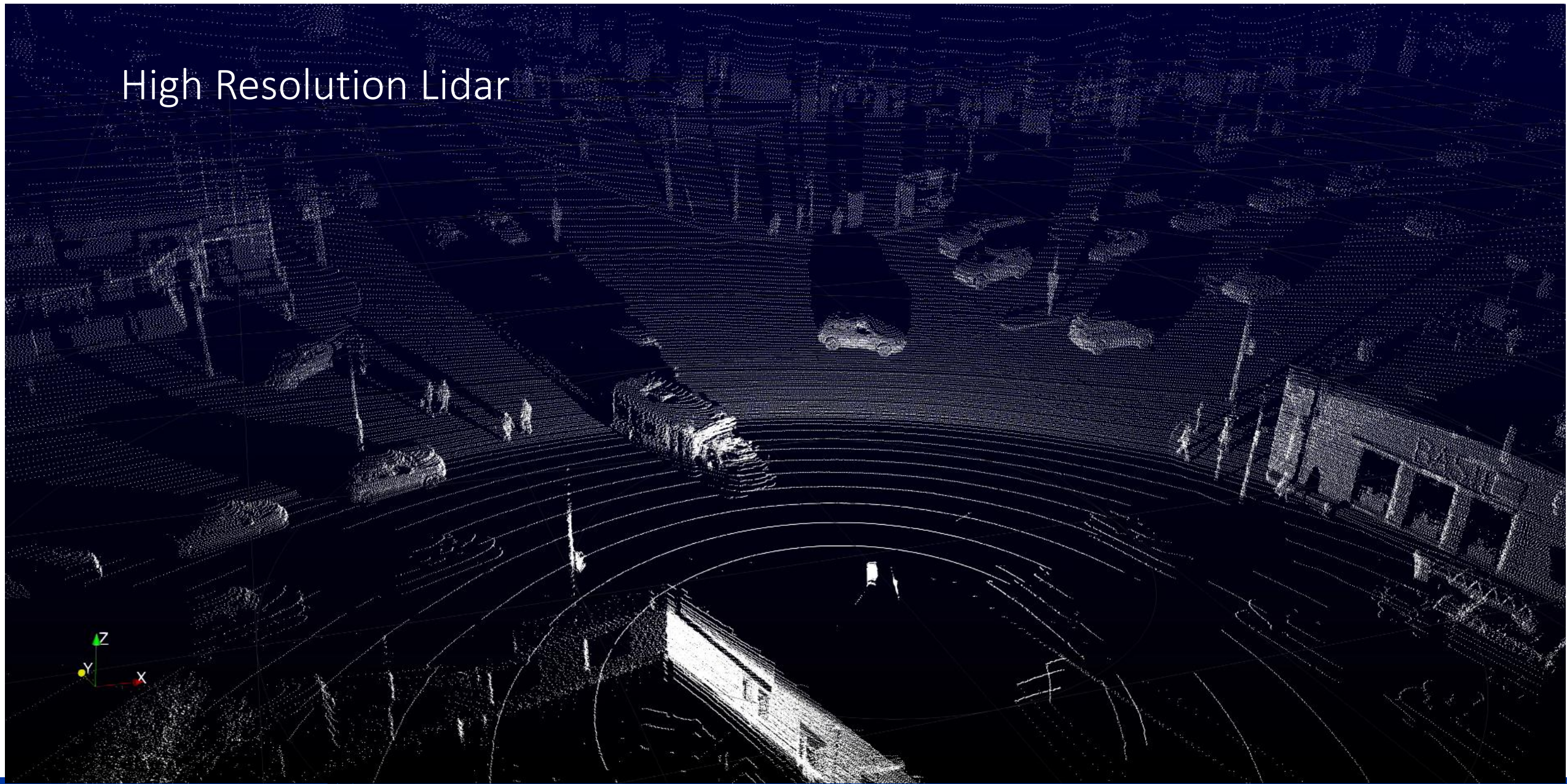
Recording of selected conflict

PET VALUE (s)	SPEED (km/h)	VIDEO CLIP	FOLLOWING OBJECT	LEADING OBJECT	FOLLOWING MOVEMENT	LEADING MOVEMENT	TIMESTAMP
2.3	20.2	Play MP4	Car	Car	WN	EW	4/27/2021, 11:12:31 AM
3.5	22.1	Play MP4	Car	Car	WN	EW	4/27/2021, 1:44:20 PM
1.9	23.6	Play MP4	Car	Car	WN	EW	4/27/2021, 4:25:52 PM
2.9	18.6	Play MP4	Car	Car	WN	EW	4/27/2021, 4:36:43 PM
1.8	22.8	Play MP4	Car	Car	WN	EW	4/27/2021, 6:02:50 PM
3.4	22.5	Play MP4	Car	Car	WN	EW	4/27/2021, 9:07:34 PM
1.9	17.7	Play MP4	Car	Car	WN	EW	4/28/2021, 8:16:26 AM
1.6	19.8	Play MP4	Car	Car	WN	EW	4/28/2021, 9:42:37 AM
2.4	19.5	Play MP4	Car	Car	WN	EW	4/28/2021, 12:19:16 PM
1.9	22.3	Play MP4	Car	Car	WN	EW	4/28/2021, 5:08:05 PM



Close

High Resolution Lidar

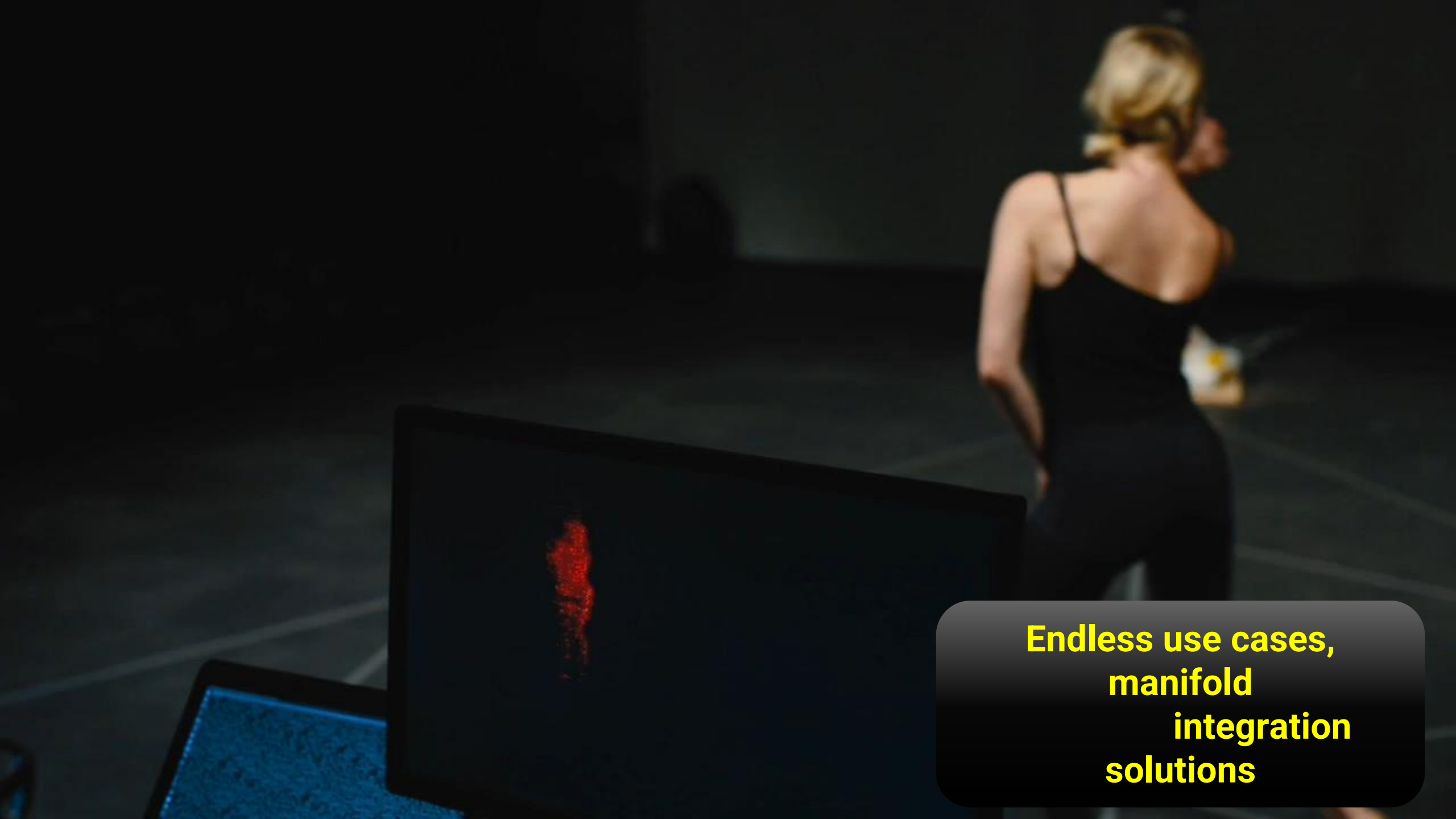


Alpha Prime 128 cCHANNEL Lidar

Integrated with IIS

300m (600m total) coverage with a single sensor & real-time detection





**Endless use cases,
manifold
integration
solutions**



Velodyne Lidar[®]

THANK YOU!

dgabriel@velodyne.com