MASS-MARKET LIDAR:
FROM ADAS TO AUTONOMOUS DRIVING

LeddarTech®
MASTERING LIDAR SENSOR TECHNOLOGY

FROST & SULLIVAN

- **Praveen Chandrasekar, Consulting Director, Frost & Sullivan**
- **Michael Poulin, Director of Product Management, LeddarTech**

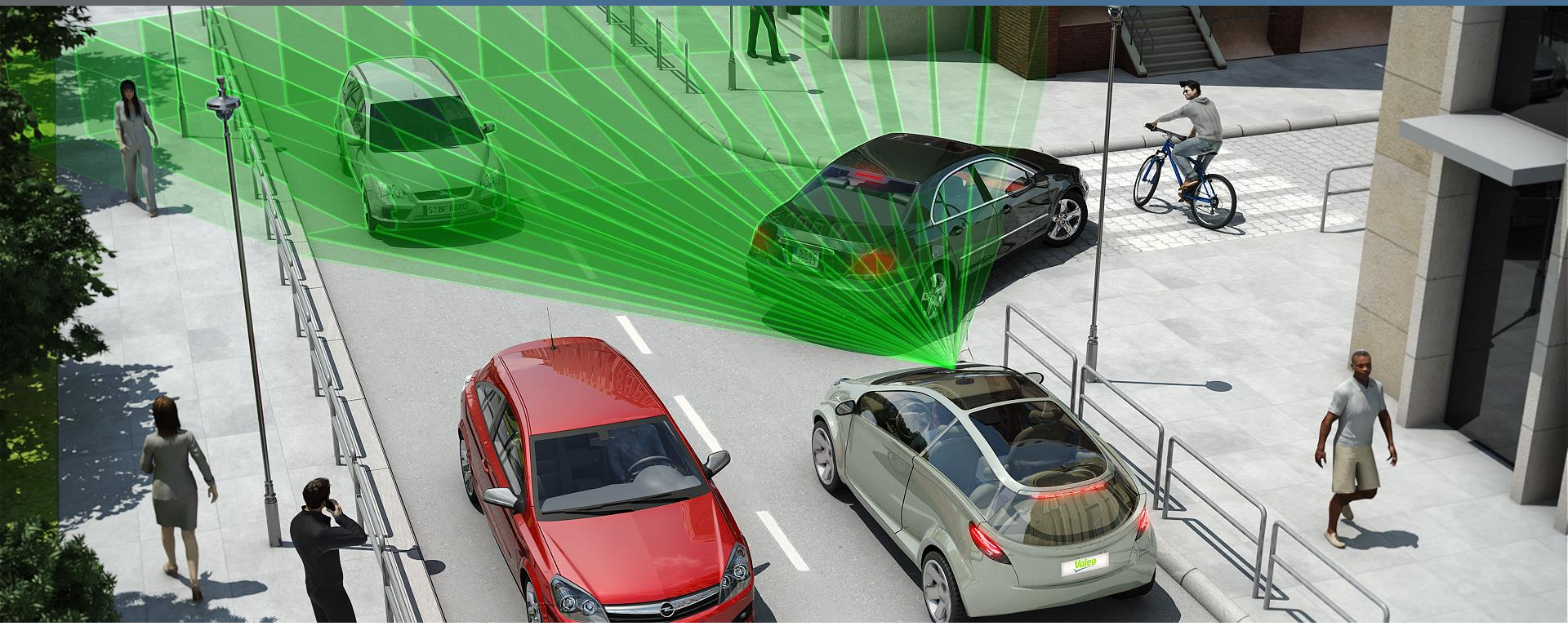
OUR SPEAKERS TODAY

Praveen Chandrasekar

Consulting Director, Frost & Sullivan

Michael Poulin

Director of Product Management, LeddarTech



- PART 1 –

FROM ADAS TO AUTONOMOUS DRIVING: MARKET TRENDS OVERVIEW

➢ **Praveen Chandrasekar, Consulting Director, Frost & Sullivan**

Realization of Level 2 and Level 3 Autonomous Driving

Beyond tech shows and exhibitions, automated driving will shake off the niche tag and break into the market through premium offerings.

Level 2

- Driver will still be in complete control over the vehicle's operation through monitoring.
- Market-ready products beyond the premium offerings of Tesla and Audi will enter the market.
- New Car Assessment Programme (NCAP) regulations in the EU and NA include functional safety features that define basic levels of automation.
- Automation capabilities will stick to highway driving with technologies such as Traffic Jam Assist proliferating into the market.

Level 3

- Automation with zero monitoring at specific operation conditions will be enabled in the next 3 years, opening new monetization opportunities.
- 2016 will be the tech years for autonomous driving with LIDAR/stereo camera based level 3 functions to be showcased by at least 7 OEMs.
- The first set of regulations defining operation of semi and fully autonomous mode will be defined.
- A high number of pilot projects with zero driver monitoring are required to exhibit the actual strengths of innovative Human Machine Interface (HMI) systems

Source: Frost & Sullivan

Disruption to Commercialisation

Outside the current market-dominant suppliers, new participants with strong capabilities in parallel industries are likely to enter the automated driving domain with industry-leading processing and sensing capabilities.

Why the autonomous world needs to look beyond RADARs and mono cameras

- Depth perception currently achieved by sensor fusion will need to respond faster to changing environments
- Works independent of the ambient light, providing a stream of point-clouds ensuring that objects are better analyzed, resulting in clearer distinction.
- Responsiveness and wider field of view is essential for broader vision and to eliminate multi-dependency

LIDAR

1

Velodyne, Quanergy and **LeddarTech** are at the forefront of commercializing the LiDAR technology beyond test projects through strong joint OEM projects and by mitigating cost and packaging challenges.

Active Gated Imaging

2

BrighWay Vision is seeking alternative routes to tap into the opportunities created by the drawbacks in RADAR and mono camera vision systems to be an autonomous enabler.

GPUs/Software

3

NVIDIA and **ADASWorks** are working on enhancing the intelligence of todays' DAS applications to empower complex data stitching and computational analysis for automated driving.

Stereo Camera

4

Bosch and **Continental and Autoliv** currently dominate the stereo camera space that could give them an edge in enabling autonomous capabilities that are currently unachievable by mono cameras.

Source: Frost & Sullivan

LiDAR

The first generation of LiDARs to be deployed commercially are likely to be fixed-beam LiDARs, with the market showing signs of moving toward solid-state scanning LiDARs in the mid-term.

Technology

- Solid-state LIDARs are the most logical technology direction that automotive-grade LIDARs would benefit from.
- At present, the LIDAR space is dominated by a wave of new entrants that are strengthening their market position through OEM or supplier alliance through testing.

Direction

- There is no clear direction from an OEM standpoint toward adopting LIDARs into their product portfolio due to price and packaging factors.
- The potential of LIDARs has not been fully realized in the market, as some OEMs are looking at alternative solutions to 3D data (stereo camera) or active gating.

Relevance

- With the shift in market adoption from level 2 to higher levels of automation, there is a need for superior sensing capabilities and better image rendering of the surroundings.
- Suppliers that currently do not have LIDAR capability are seeking to expand their portfolio either through licencing the technology or through acquiring relevant capabilities.

Source: Frost & Sullivan

Competitive Positioning of Select OEMs

In the next 4 years, there is a possibility of commoditization of level 2 automation with volume OEMs such as Ford, Hyundai, and GM looking at introducing the technology in some of their premium offerings.

OEM	Currently Available		Future Offering				Supplier Tie-up
	Feature	SAE Level	Feature	SAE Level	Year	Models	
Audi	Traffic Jam Assist	Level 2	Traffic Assist, Piloted driving, and Piloted Parking	Level 3	2017 onwards	A8, A7 and Q8	Valeo, Mobileye, Continental, Bosch
BMW	Traffic Jam Assist, Assistive Parking	Level2	Active Assist and Remote Valet Parking	Level 3	2018 onwards	7-Series and 5-Series	Continental & ZF Lenksysteme
Cadillac	AEB, ACC	Level 1	SuperCruise	Level 3	2020 onwards	CTS and Escalade	Mostly in-house, TRW, Laird Tech
Ford	Adaptive Cruise Control, AEB	Level 1	Active City Stop	Level 2	2017 onwards	Fusion and Escape	Continental, Velodyne, Bosch, In-house
Mercedes-Benz	Traffic Jam Assist	Level 2	Distronic Plus with Steer Assist	Level 3	2019 onwards	S-Class and E-Class	Quanergy (For R&D)
Tesla	Autopilot	Level 2	Autopilot 2.0	Level 3	2019	Model S, X 3	Mobileye, Bosch, NVIDIA
Volvo	Pilot Assist	Level 2	City Safety	Level 3	2022 onwards	XC 90, S90	Continental, Autoliv

Source: Frost & Sullivan

Supplier Capability and Preference

In the next 4 years, 4 major suppliers are likely to introduce strong LiDAR capabilities to their portfolios, along with semi autonomous capabilities.

	ADAS Application				Sensor Suit				New Product
	ACC	LKA	TJA	Park Assist	Camera		Radar	LiDAR	
					Mono	Stereo			
Autoliv	✓	!	!	✓	✓	✓	✓	!	With mono camera based AEB systems coming to the market in 2017, Autoliv is likely to spike up its market share in entry-level automation capabilities.
Bosch	✓	✓	✓	✓	✓	✓	✓	✓	In CES 2016, Bosch unveiled its concept vehicle, showcasing the “highway pilot” semi-autonomous system which assumes all driving duties on open highways.
Continental	✓	✓	✓	✓	✓	✓	✓	✓	Continental pushed the boundaries of autonomous vehicles when it participated in a demo driverless travel in Virginia in a Chrysler 300c late last year.
Denso	✓	✓	!	!	!	✓	✓	!	Denso showcased its vision for the autonomous driving environment with augmented reality and autonomous driving technologies in the NAIAS 2016.
Delphi	✓	✓	!	!	✓ (HD CMOS)		✓	✓	Delphi recently unveiled its V2E concept in the CES 2016.
Valeo		✓	✓	✓	✓		✓	✓	Valeo introduced the Scala Laser Scanner in 2015 and announced a more robust and affordable solid-state LiDAR in May 2016 as part of its *Intuitive Driving*® initiative

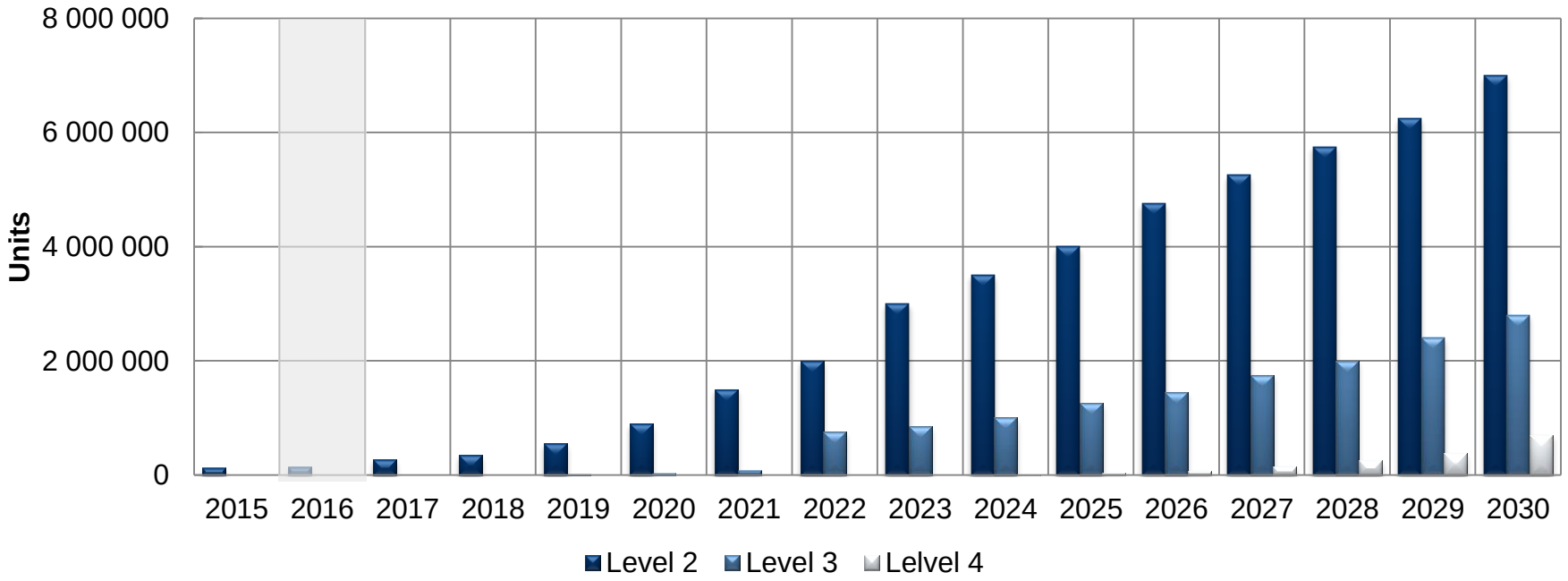
! - Limited Capability ✓ - Partial Capability ✓ - Full capability

Source: Frost & Sullivan

OEM Unit Shipment Forecast—North America

Considering the fast growth of testing infrastructure and alternate mobility solutions, North America is likely to have more than 3.5 million highly automated vehicles by 2030.

Autonomous Driving Market: Unit Shipment Forecast, North America, 2015-2030



- Early introduction of level 3 automation in North America, driven by OTA updates from Tesla, will influence the take rates for the technology initially, followed by piloted driving offerings from Audi, BMW, and Mercedes-Benz that will drive the product into the premium market.
- By 2020, level 2 automation is expected to get commoditized with 4 major volume OEMs aiming at introducing the technology to their top spec models, but take rates will be minimal due to the optional packaging of these solutions.

Source: Frost & Sullivan

High Definition Mapping

More complex driving scenarios faced by high automation would require a new layer of data validation and redundancy that can be provided by HD maps that are capable of providing static data at high precision.

HD Maps = **Navigational Layer:** Used to calculate routes from points A to B + **Localization layer:** Used to calculate position within a lane + **Planning Layer:** Contains lane 3D information about road geometry

Technology Approach		Key Participants	Capability
Road Attribute Content	OEM	• Toyota • Tesla	Use positional sensors and in-vehicle vision systems to generate road data and correct or update the data points on a cloud server.
	OEM - Supplier	• VW-Mobileye-GM	Crowdsourced data mapping, using small bandwidth in mobile-Internet enabled vehicles, with a shared platform to generate HD mapping
End-to-end HD Road Mapping		• HERE • Google • Tom Tom • GeoDigital	Uses specific fleet vehicles designated for data collection, borne with a wide array of sensors for data stitching and transfer to the cloud for attribute overlaying and transmission

Source: Frost & Sullivan

Deep Learning

Complex driving scenarios faced by highly automated driving would require finer level of detail on map-based data beyond the vehicles' sensory vision range and a need for higher precision.

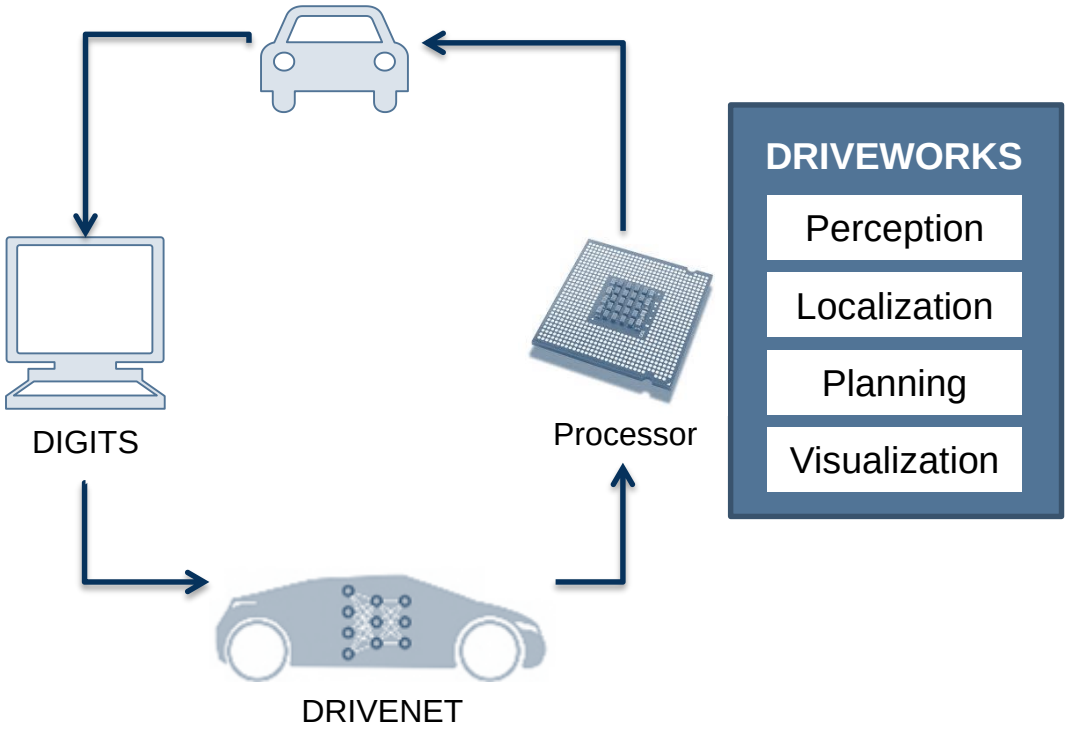
Deep Learning

Self machine learning from millions of images of actual driving situations

Machine Learning

Uses hand-coded rules to define vehicle surroundings

- Combination of big neural networks, Big Data, and powerful GPU platforms have dramatically accelerated the advance of AI.
- In 2015, GPU-powered deep learning systems exceeded the human level of perception for the first time and direct adoption of this technology in the passenger car market is likely in 2016.
- Deep learning modules are most likely to move toward single scalable platforms capable of housing more generic DAS applications to complex autonomous driving functionalities.



Source: Frost & Sullivan

Key Takeaways & Conclusions

1. LIDAR is more effective than most ADAS sensors in terms of accurately profiling static or dynamic objects approaching at average velocity over large distances. In addition, the ability to fairly lower the chances of false or missed alerts make LIDAR sensors more reliable.

2. As LIDAR is challenged by bad weather operations, complementing it with cameras, V2X, and radar can help minimize manual interference by reducing human error.

3. Post-processing software is an integral part of automated systems developed as per the specific requirements of OEMs. This software processes data required for embedded object tracking, autonomous emergency braking, and free space detection.

4. Given the massive potential for LIDAR demand in the future, several automotive suppliers are trying to develop a LIDAR portfolio. Suppliers with a LIDAR portfolio for other industries are coming up with automotive-grade products to make use of this opportunity.

Source: Frost & Sullivan

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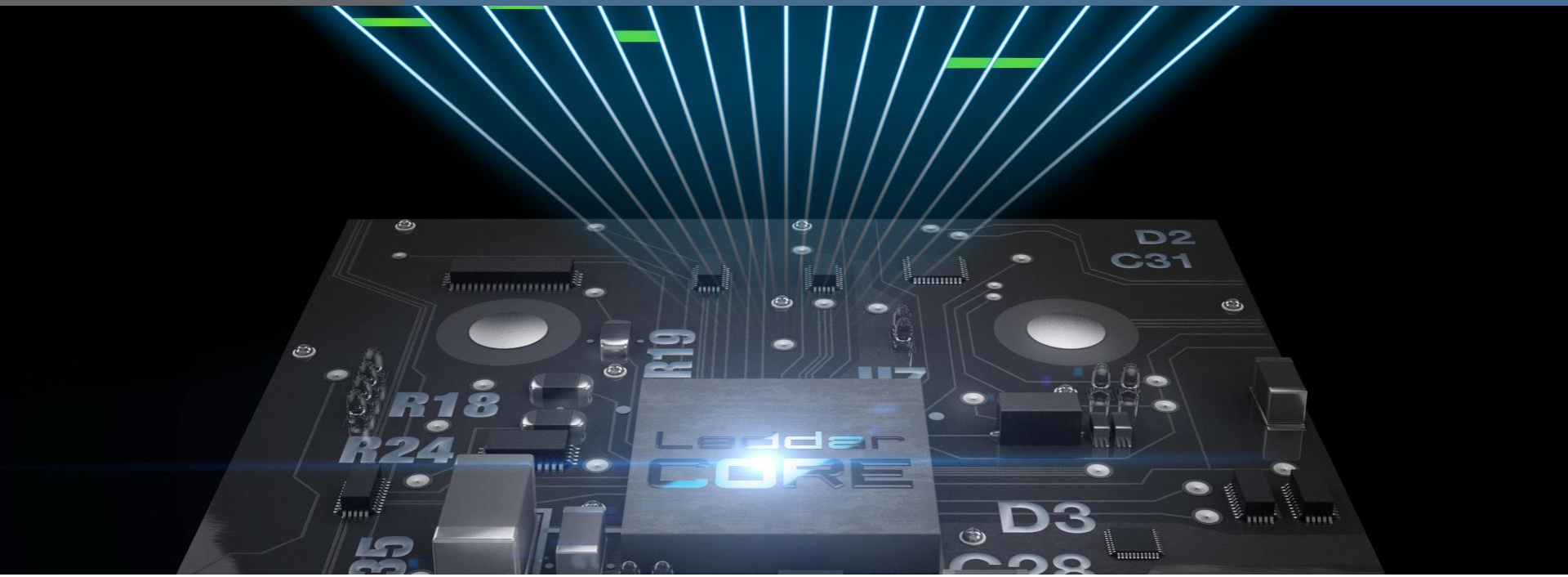
MASTERING LIDAR SENSOR TECHNOLOGY



- PART 2 –

THE NEXT GENERATION OF LIDAR TECHNOLOGY:
Enabling Lidar Deployments for ADAS and Autonomous Driving Applications

➢ **Michael Poulin**, **Director of Product Management, LeddarTech**

ABOUT LEDDARTECH

Quebec City Headquarter, Canada

- **Extensive expertise in Lidar sensing & application development**
- **Proprietary technology (Royalty free) protected by 54 patents up to 2031**
- **Partnerships with industry-leading global companies (i.e. Valeo, Morpho, Transcore)**
- **20,000,000 hours of operation in 24/7, outdoor environment**
- **Automotive development since 2011 with Valeo**

SELECT AUTOMOTIVE LIDAR SUPPLIERS

- **Very few Lidar suppliers - aiming to meet automotive requirements**

Company	Price level	Offering	a) Integration b) Customization	Current Status in Automotive	Target Applications
 **LEDDARTECH**	Low	ASSP	a) High b) High	Commercialized in ADAS	ADAS + Autonomous Driving
 **CONTINENTAL**	Medium	Finished Product	a) Limited b) Complex	Commercialized, Deployed	Basic ADAS
 **VALEO SCALA**	High	Finished Product	a) Limited b) Complex	Commercialized	ADAS
 **VELODYNE**	Very High	Finished Product	a) Limited b) Complex	Commercialized as prototype in automotive	Autonomous Driving
 **QUANERGY**	High	Finished Product	a) Limited / b) Mostly unknown for now	R&D and Concept stage, Uncertainty on specs and timeline	Autonomous Driving

LEDDARTECH ALREADY IN ADAS/AD MARKET WITH VALEO

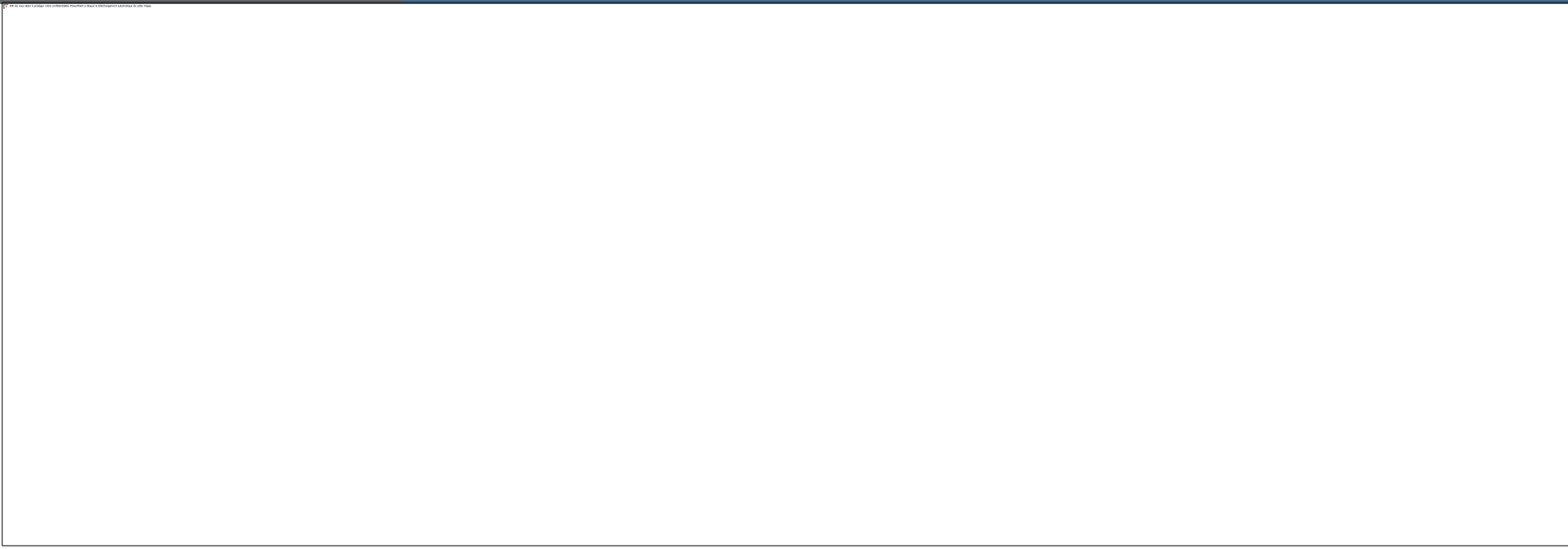
January 2014-
Non-exclusive agreement

- Non-exclusive license
- Development of an ASIC for ADAS based on LeddarTech's technology

May 2016-
Valeo product announcement

Valeo announced the addition of a new low-cost, solid-state LiDAR based on Leddar technology to its portfolio of driving and parking assistance solutions.

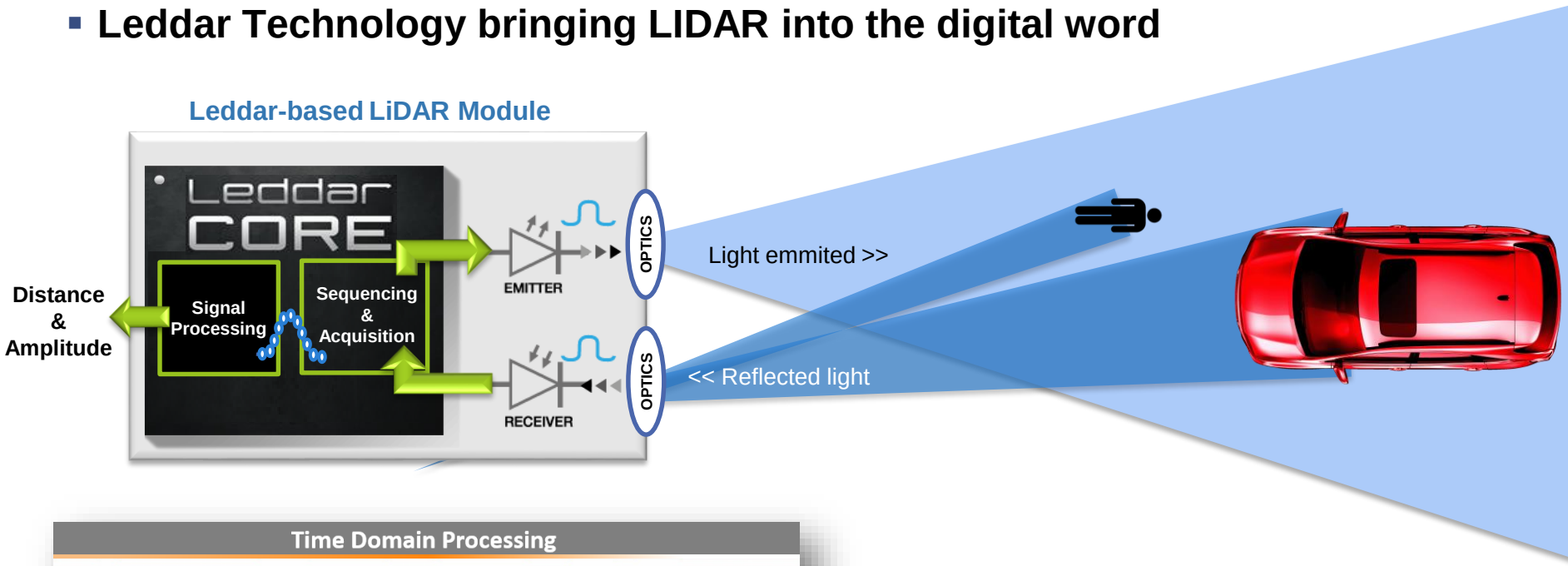
- Lowest cost solid-state LiDAR sensor on the market
- Accurately detect pedestrians, bicycles, motorcycles and cars
- Detection range of up to 100 meters, which is unique in this segment
- Enables various functions from Autonomous Emergency Braking (AEB) to Right Turn Assist (RTA) features (for commercial vehicles)
- Can contribute to automated driving functions, such as traffic jam assist or automated parking.

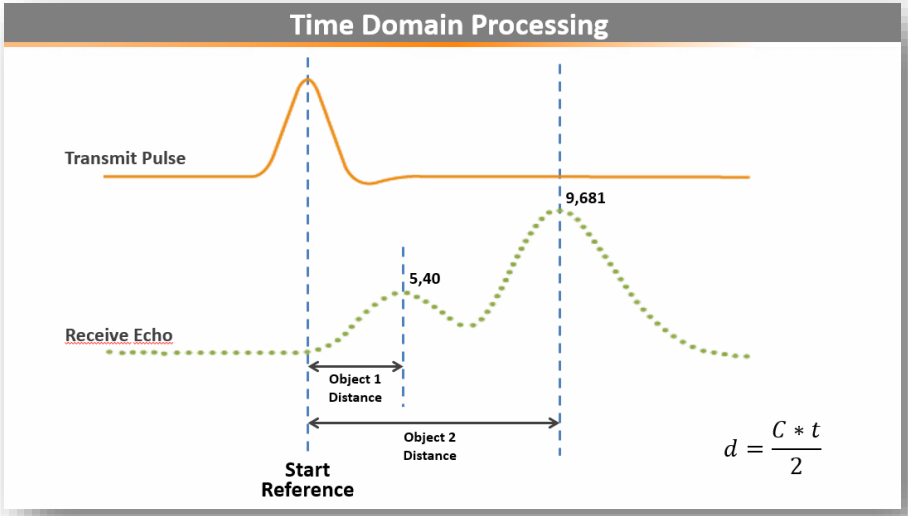


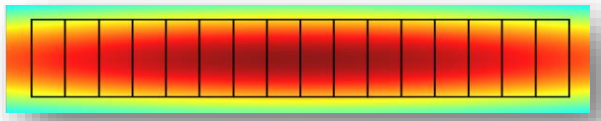
LEDDAR IMPLEMENTATIONS FOR ADAS/AD APPLICATIONS

MULTI-SEGMENT SOLID-STATE LIDAR SENSOR

- **Leddar Technology bringing LIDAR into the digital word**

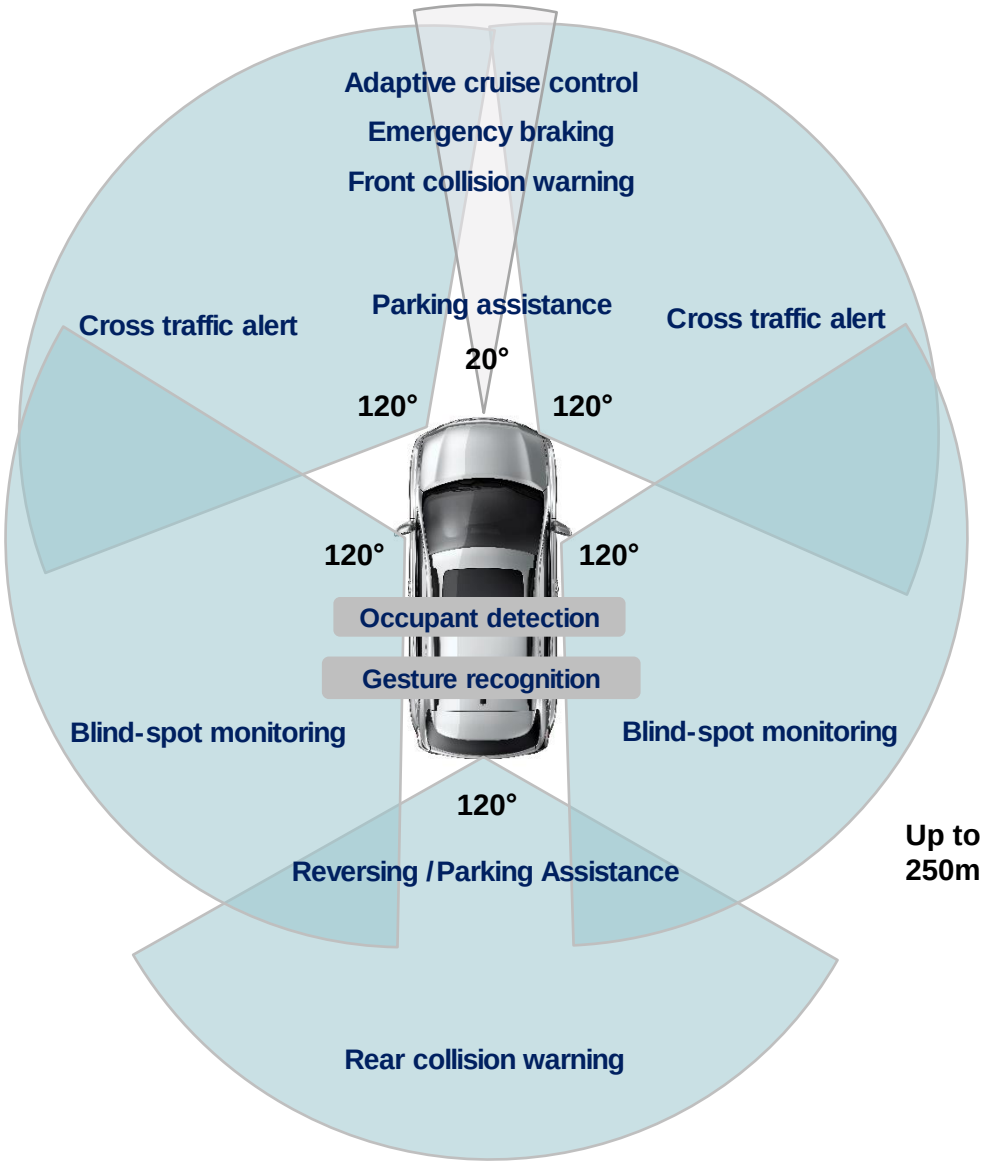






Multi-segment detector configurations provides various FoV options

MULTI-SEGMENT SOLID-STATE LIDAR SENSOR



- Range up to 250 m
- Resolution down to 0.25º, horizontal and vertical
- From 1 to 32,000 points
- Field of view up to 140º

SUPERIOR VALUE VS RADAR

Stand-alone ADAS

- Passive and active safety

Sensor Fusion

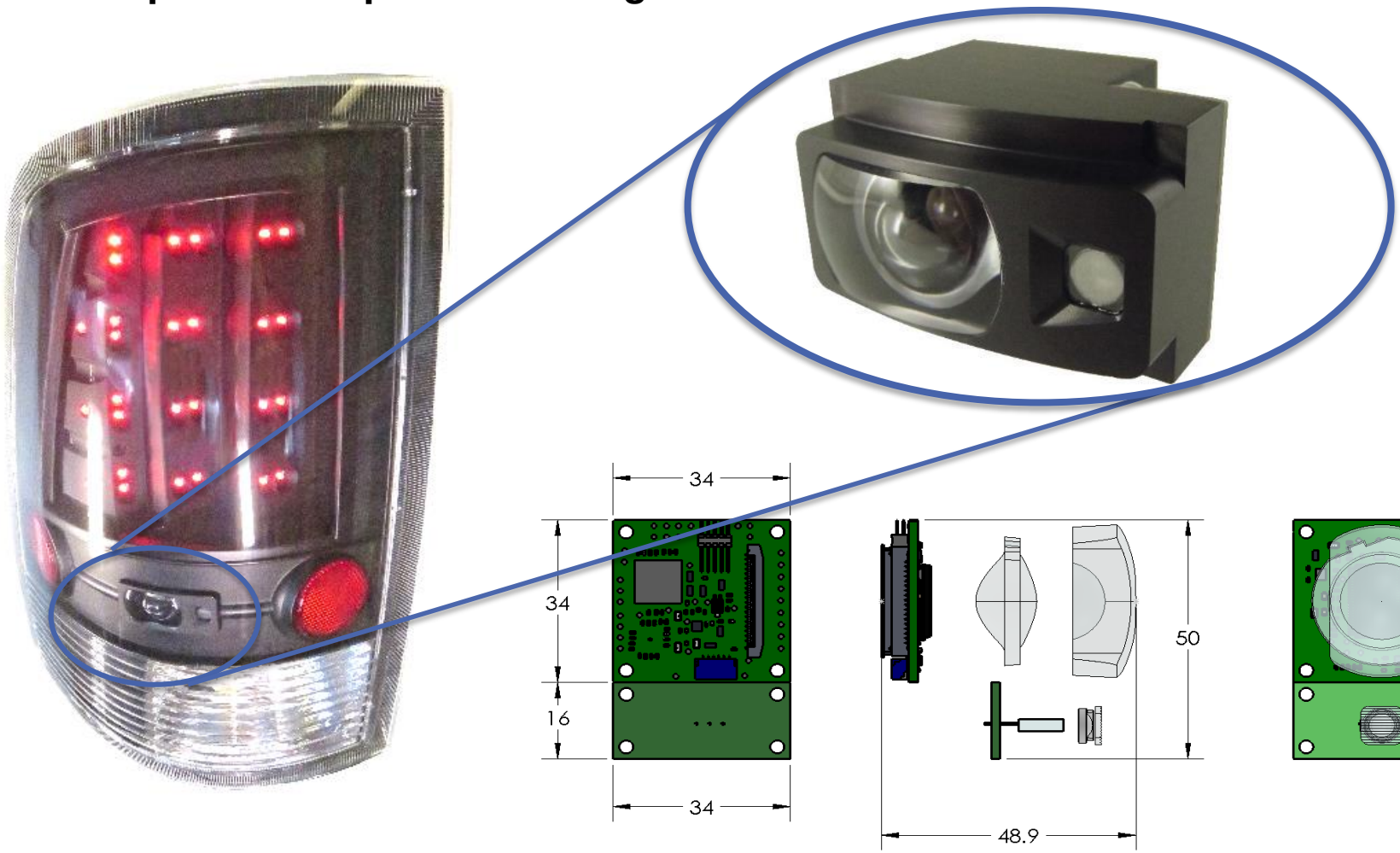
Sensor Redundancy

- Overcoming technologies limitation
- Preventing system failures
- Operation in any environmental conditions

360-degree point-cloud for autonomous driving

MULTI-SEGMENT SOLID-STATE LIDAR SENSOR

- **Concept Tail Lamp Sensor Integration**



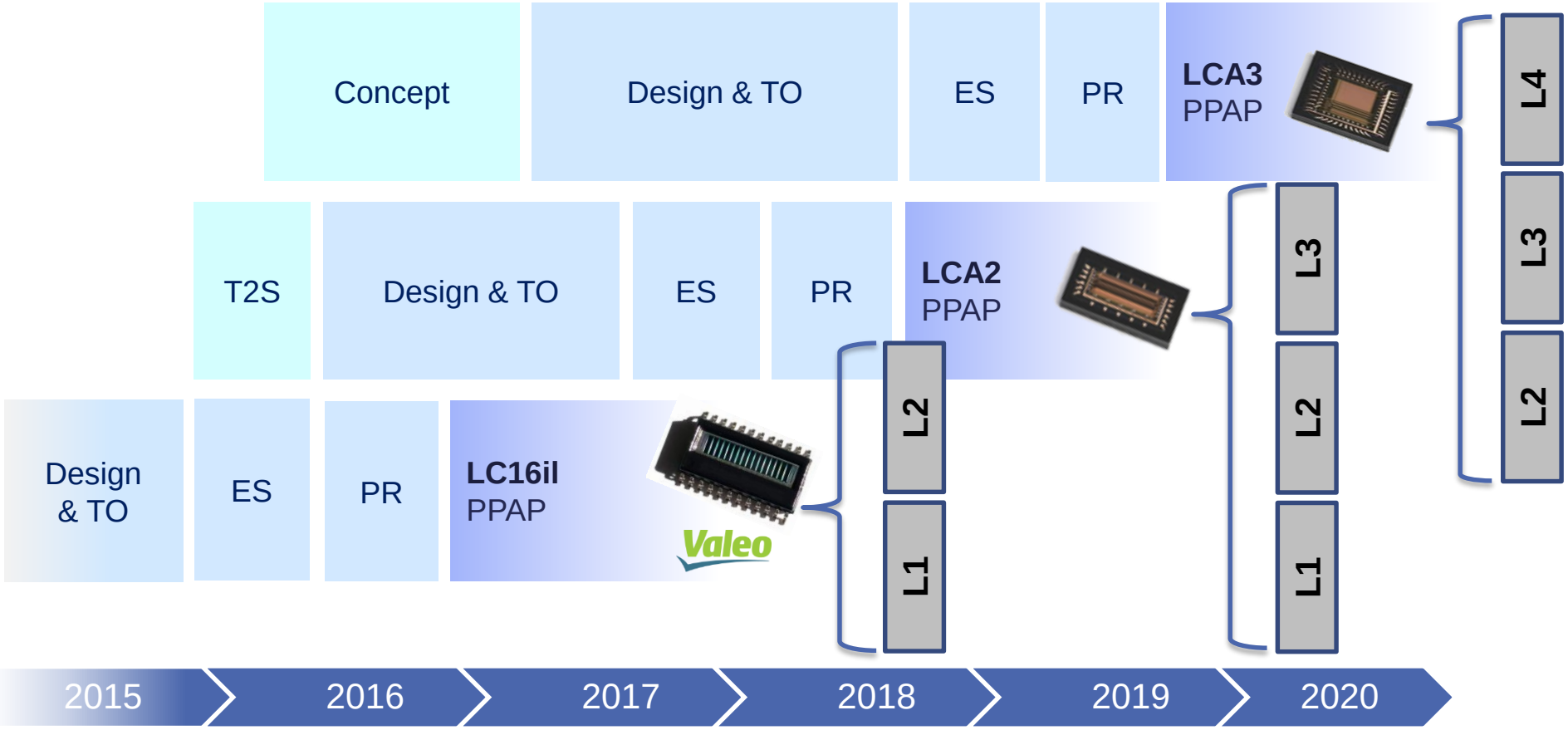
MULTI-SEGMENT SOLID-STATE LIDAR SENSOR

- **Concept Head Lamp Sensor Integration**

VIDEO

https://www.youtube.com/watch?v=5rtpwDmFguo

LEDDARCORE IC ROADMAP: FROM ADAS TO AD

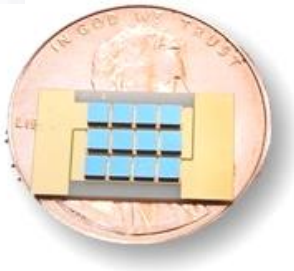


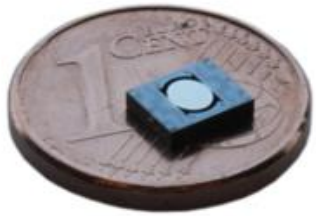
T2S: Tier-2 (IC Mfg) Selection
ES: Engineering Sample
PR: Production Ready Components

HIGH RESOLUTION LIDAR

Several compatible complementary technologies:

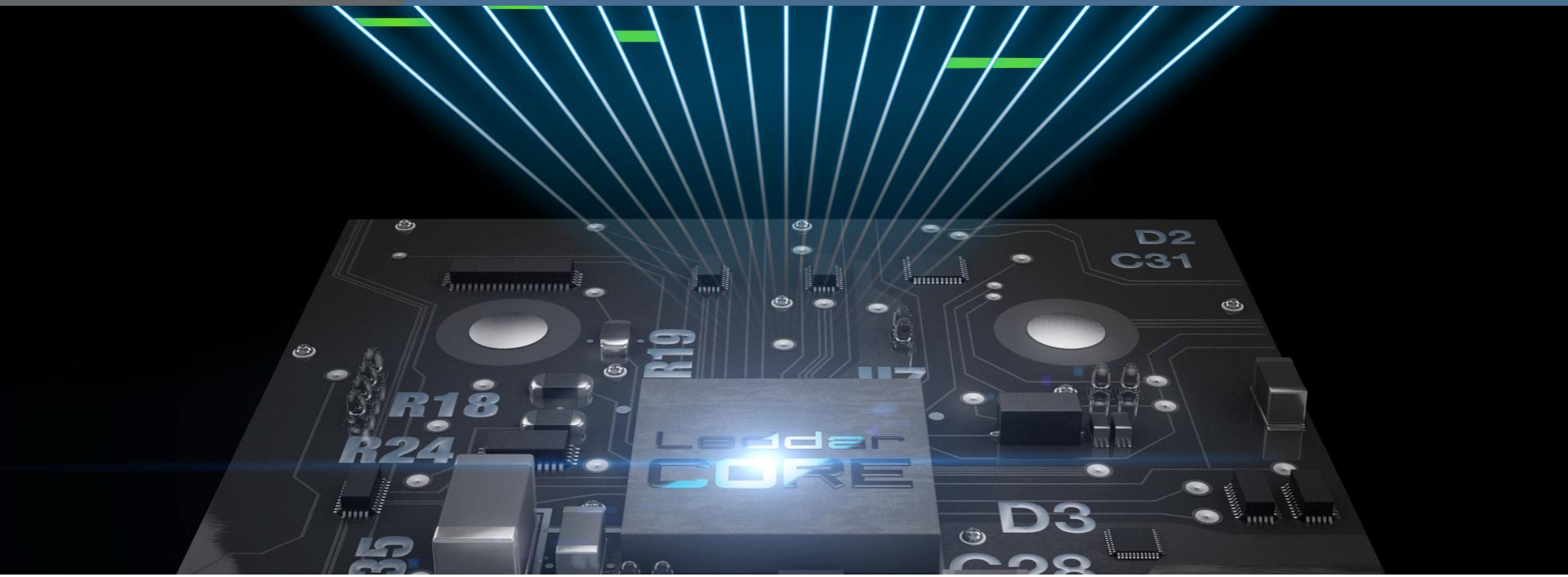
- Receiver matrix
- Emitter matrix
  - Ex: VCSEL arrays
- Scanned emitter
  - Ex: MEMS micromirrors
- Combinations





Images from Hamamatsu, Trilumina & Innoluce websites

Example from FORD



LEDDAR TECHNOLOGY: KEY DIFFERENTIATORS

LEDDAR TECHNOLOGY: DIFFERENCIATORS

Higher Sensitivity | Immunity to noise | Powerful Signal Processing

- ✓ **Sensitivity up to 25x higher than competing technologies**
  - Increased range (up to 5x)
  - Lower power consumption
  - Lower cost
  - Fixed diffuse illumination
  - Smaller optics
  - Improved ocular safety

Vendor	Product	Technology	Sensitivity
LeddarTech	M16	Leddar	**0.13 pJ/mm²**
SICK	TiM310	Direct time-of-flight	**0.79 pJ/mm²**
Texas Instruments	OPT8241	Phase detection	**1.54 pJ/mm²**
ESPROS	epc610	Phase detection	**3.19 pJ/mm²**

- ✓ **2.5x FOV + 5x range compare to Continental SRL**

LEDDAR TECHNOLOGY: DIFFERENCIATORS

Higher Sensitivity | **Immunity to noise** | Powerful Signal Processing

- ✓ **Superior performance in high ambient light and direct sunlight without expensive optical filters**
  - **50 dB rejection** of the photodiode shot noise
- ✓ **No performance degradation from sensors' overlapping fields of view**
- ✓ **High robustness to inclement weather**
  - Demonstrated performance under heavy rain (**up to 180 mm/hr)** and dense fog (**visibility less than 100 m**) in controlled lab test
  - **>20 million system hours** in outdoor environments

LEDDAR TECHNOLOGY: DIFFERENCIATORS

Higher Sensitivity | Immunity to noise | **Powerful Signal Processing**

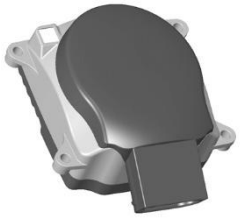
- ✓ **Measurement of natural and reflective targets independently of distance** (down to 0 m)
- ✓ **No Range ambiguation** (typical 1500m separation)
- ✓ **High dynamic range, 80-100dB** (60 dB more than comparable products)
- ✓ **Multiple object discrimination in each segment** (down to 15 cm separation)
- ✓ **Extended application-level capabilities:**
  - Object discrimination, classification and tracking
  - Dynamic detection threshold adjustment
  - Detection of environmental conditions
  - Detection of signal degradation (e.g. due to window obstruction)

LEDDAR TECHNOLOGY: ADVANTAGES

- **Unique & Complementary Advantages vs. Competing Technologies**

Leddar
Vs.
Cameras

- Robust operation in all lighting conditions
- Higher range
- Higher accuracy
- Higher performance in inclement weather
- Higher resistance to dust/dirt



Leddar
Vs.
RADARs

- Higher reliability of detection
  - Pedestrians
  - Static objects
  - Laterally moving objects
  - Very low false positives
  - Works in tunnels
- Higher resolution
- Higher object discrimination capability
- Easier beam forming

Leddar
Vs.
Other LiDARs

- Higher range to power ratio
- Higher performance to cost ratio
- Diffuse light signal for robust target detection
- Higher robustness - no moving part (vs. scanning)
- Smaller form factor

KEY TAKEAWAYS

- LiDARs set to become **an essential element** of ADAS / Autonomous Driving systems
- **Solid-state LiDARs are** more suitable for automotive-grade applications, considering robustness, performance, price, and size
- **Next Gen LeddarCore** ASSPs enable
  - ADAS solutions with superior performance and value vs RADAR and conventional LiDAR
  - Affordable high density 3D point cloud LiDAR
  - Support for both flash and beam steering LiDAR
- Access to reference designs and support from LiDAR experts enables Tier-1s to **develop and secure ownership of differentiated, custom-designed LiDAR products** optimized for the target application(s)
- **Close collaboration** between complementary technology partners and automotive suppliers is key to providing enhanced LiDAR solutions to OEMs

THE NEW BENCHMARK IN LIDAR TECHNOLOGY FOR AUTOMOTIVE APPLICATIONS

- ✓ Proven
- ✓ Optimized
- ✓ Adaptable
- ✓ Cost-Effective