# ADAS and AD Industry Chain Report, 2019-2020 -- LiDAR

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## STUDY GOAL AND OBJECTIVES

This report provides the industry executives with strategically significant competitor information, analysis, insight and projection on the competitive pattern and key companies in the industry, crucial to the development and implementation of effective business, marketing and R&D programs.

## REPORT OBJECTIVES

- To establish a comprehensive, factual, annually updated and cost-effective information base on market size, competition patterns, market segments, goals and strategies of the leading players in the market, reviews and forecasts.
- To assist potential market entrants in evaluating prospective acquisition and joint venture candidates.
- To complement the organizations' internal competitor information gathering efforts with strategic analysis, data interpretation and insight.
- To suggest for concerned investors in line with the current development of this industry as well as the development tendency.
- To help company to succeed in a competitive market, and

## METHODOLOGY

Both primary and secondary research methodologies were used in preparing this study. Initially, a comprehensive and exhaustive search of the literature on this industry was conducted. These sources included related books and journals, trade literature, marketing literature, other product/promotional literature, annual reports, security analyst reports, and other publications. Subsequently, telephone interviews or email correspondence was conducted with marketing executives etc. Other sources included related magazines, academics, and consulting companies.

## INFORMATION SOURCES

The primary information sources include Company Reports, and National Bureau of Statistics of China etc.

# Abstract

**Research on Automotive LiDAR Industry: How five technology roadmaps develop amid the upcoming mass production of high-channel LiDAR?**

During 2020-2025, autonomous driving above L3 will be commercialized, for which LiDAR will become an important option. LiDAR vendors break through technical bottlenecks and work closely with OEMs to massively install high-channel LiDAR as soon as possible. Today, Audi has teamed up with Valeo/Luminar, BMW has cooperated with Innoviz, Volvo has collaborated with Luminar, Great Wall Motors has partnered with Ibeo, and Hyundai has joined forces with Velodyne. Even Mobileye, a proponent of visual ADAS, is developing its own LiDAR technology.

In early 2020, Bosch announced that it is making long-range LiDAR sensors production-ready-the first LiDAR (light detection and ranging) system that is suitable for automotive use. Continental delivers a 50-meter range 3D flash LiDAR sensor that's expected to find increasing application in commercial vehicles and off-highway machines in 2020. Valeo's 16-channel SCALA 2, which can detect objects up to a distance of 150 meters, has won orders from some production vehicle models, and its SOP is expected in 2021. This shows that high-channel LiDAR is on the eve of mass production.

**Major High-channel LiDAR Mass-production/Cooperation Projects**

| OEM | Level of Autonomy | Partner (s) | Model/Time |
|---|---|---|---|
| **Benz** | L3 | Valeo Scala | Mercedes S (launch in 2020) Mercedes C-Class (to be launched in 2021) |
| **Audi** | Above L3 | Luminar | To be launched before 2021 |
| **Toyota** | L3 | Denso | New Lexus LS (launch in 2020) |
| **Honda** | L3 | — | Legend (launch in 2020) |
| **Great Wall** | L3/L4 | ibeoNEXT | WEY (to be launched in 2021) |
| **BMW** | Above L3 | Innoviz | To be launched in 2021 |
| **Volvo** | L4 | Luminar /Waymo | To be launched in 2022 |

Still, the battle for technology roadmaps in the LiDAR field continues. There are now automotive LiDAR technology roadmaps encompassing mechanical, MEMS, FLASH, OPA and FMCW, among which FMCW is a coherent detection technology while the rest are pulsed ToF detection technologies.

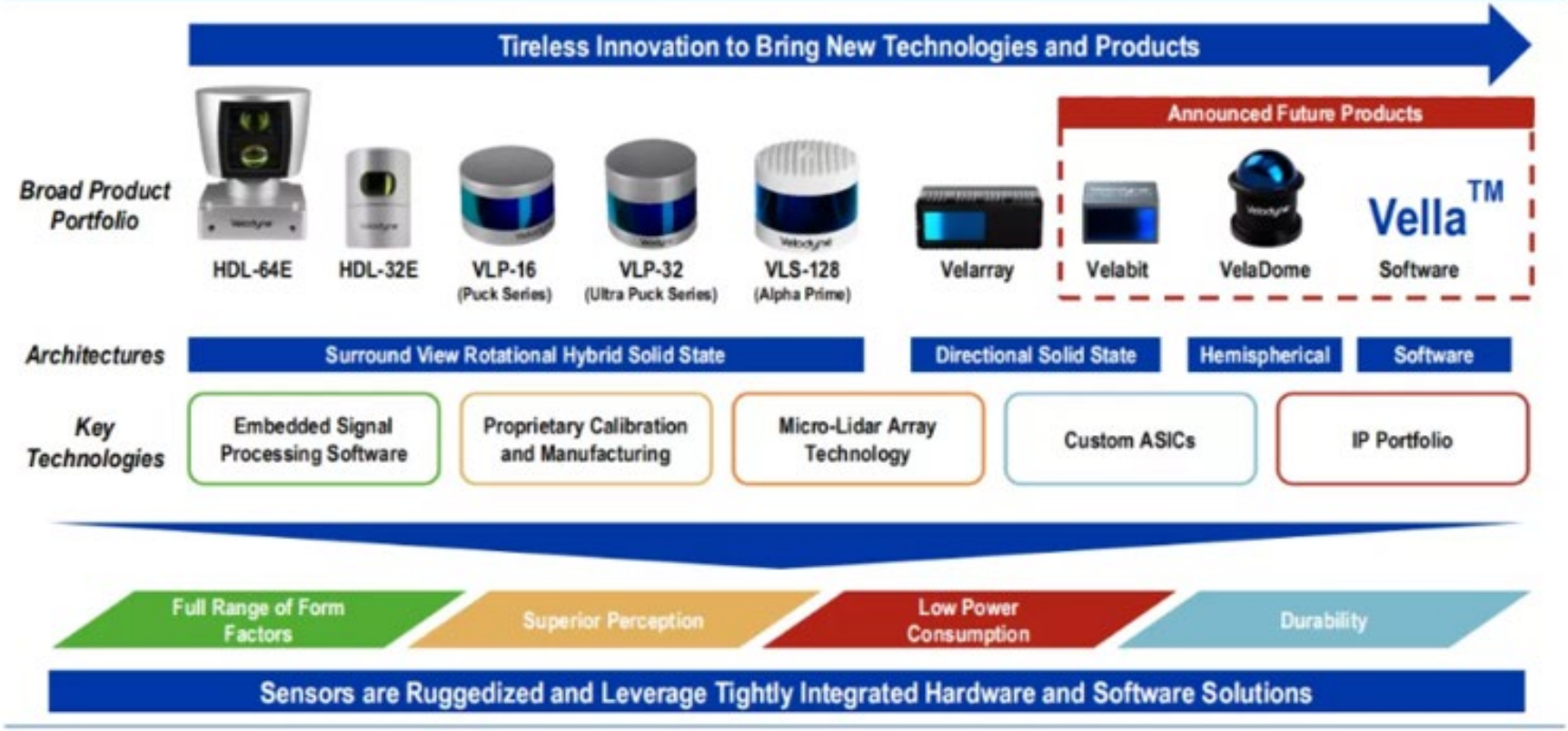
**Mechanical LiDAR**

Mechanical LiDAR is the earliest developed and most mature product. Waymo's Honeycomb LiDAR is also based on mechanical technology. Although it has been criticized a lot, mechanical LiDAR is still the mainstream on the market. Representative companies of mechanical LiDAR include Velodyne, Valeo, Ouster, Waymo, RoboSense, Hesai Tech, SureStar, LeiShen Intelligent System, etc.

Most mechanical LiDAR vendors are pushing forward two strategies concurrently. On the one hand, they improve the mechanical LiDAR product line, try to reduce costs and enhance performance; on the other hand, they actively expand the solid-state LiDAR product portfolios (MEMS, FLASH, OPA, etc.).

For example, Velodyne has rolled out the all-solid-state Velarray LiDAR, and short-range VelaDome LiDAR perfect for automotive applications such as blind spot monitoring. Velodyne has acquired Mapper.ai, a HD map startup with a team of 25 talents, for quicker development of Vella software. In January 2020, Velodyne unveiled the cheap Velabit LiDAR priced only at $100.

# Velodyne Product Roadmap



Velodyne branches out to ADAS and other fields aggressively. Nowadays, the autonomous driving business only contributes a quarter of Velodyne's revenue, whereas the remaining earnings come from ADAS, robotics, surveying and mapping, smart cities, shuttles, and unmanned distribution, among which unmanned delivery, Robotaxi and ADAS will become main revenue contributors for Velodyne in the next four years. It is estimated that Velodyne will ship 8 million units by 2025.

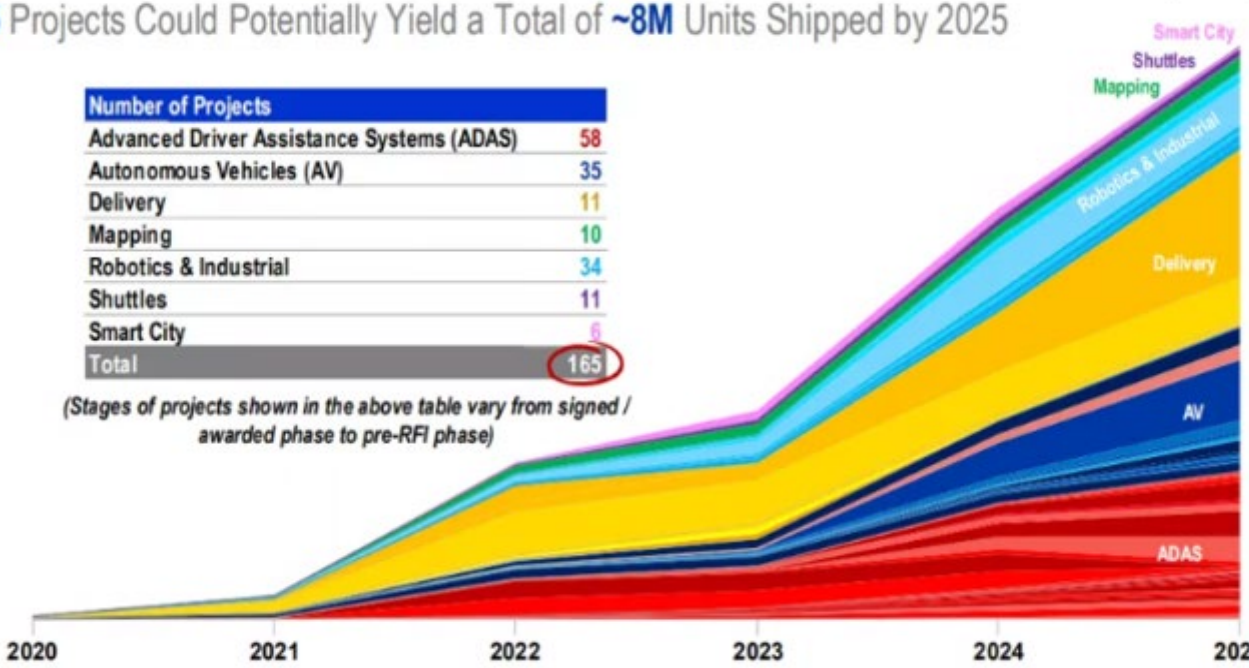
## Highly Diversified Projects Across Industries

*(Chart represents sensor units)*

**165** Projects Could Potentially Yield a Total of **~8M** Units Shipped by 2025

| Number of Projects | |
|---|---|
| Advanced Driver Assistance Systems (ADAS) | 58 |
| Autonomous Vehicles (AV) | 35 |
| Delivery | 11 |
| Mapping | 10 |
| Robotics & Industrial | 34 |
| Shuttles | 11 |
| Smart City | 6 |
| Total | 165 |

*(Stages of projects shown in the above table vary from signed / awarded phase to pre-RFI phase)*




*Note: The chart above reflects a visual representation of how we believe the market is developing based on multi-year commercial demands that we currently see from customers and is not indicative of projected revenue or unit shipment. Signed and awarded contracts represent agreed terms and conditions of supply, but do not reflect firm orders unless and until purchase orders are received. To date, shipments under and revenue from these signed contracts have not been material. Based on data as of June 1, 2020.*

**MEMS LiDAR**

Typical suppliers of MEMS LiDAR include Innoviz, Innovusion, Pioneer, Blickfeld, RoboSense, Hesai Tech, etc.. Using micro galvanometers, MEMS LiDAR is limited in size, vibration reliability and operating temperature range.

As concerns MEMS mirrors, foreign companies are at the forefront, such as Innoluce acquired by Infineon based in Germany, Mirrorcle and MicroVision in the United States, Hamamatsu in Japan, and STMicroelectronics in Switzerland. Their Chinese counterparts include Xi'an ZhiSensor, Taiwan Opus, Silicon Vision Microsystem, among others. A few LiDAR companies supply MEMS mirrors through alliances or independent development. For instance, RoboSense has invested in Silicon Vision Microsystem to deploy MEMS LiDAR; Hesai Tech PandarGT 3.0 uses self-developed MEMS mirrors.

MEMS LiDAR will be spawned by most vendors as early as 2020-2021.

Innoviz, which adopts the MEMS technology roadmap as a typical provider, has received more than USD210 million in financing within only four years since its inception. Innoviz is to date competent for mass production and has fetched orders from OEMs. BMW has selected Innoviz for series production of its autonomous vehicles, starting in 2021. Besides, Innoviz has allied with Tier1 suppliers Harman, HiRain Technologies and Aptiv. The latest Innoviz One has a detection range of 0.1-250 meters and will be produced on a large scale in 2021.

Zvision, a Chinese MEMS LiDAR company, secured RMB70 million in Series A+ round of financing in April 2020.

**Flash LiDAR**

Typical Flash LiDAR vendors are LeddarTech, Sense Photonics, Continental, IBEO, Benewake, Xenomatix and Ouster. Sense Photonics as the first one to overcome technical challenges has introduced Osprey, its first modular FLASH LiDAR which was sold on the market in January 2020 at a price of $3,200. Continental's Flash LiDAR, HFL110 featuring 1,064nm laser and hybrid InGaas/CMOS focal plane array, is expected to be spawned in 2020. IBEO's NEXT LiDAR is about to be mounted on Great Wall VV7 in 2021.

Another company LeddarTech stands out for building Leddar Ecosystem. In July 2020, LeddarTech acquired VayaVision, a sensor fusion and perception software company. Their cooperative solution enables the fusion of camera, radar, and LiDAR for faster time-to-market, and allows for fusion of up to 15 different sensors for Level 2 to Level 4 autonomous driving applications. Two well-known sensor vendors First Sensor and Sunny Optical Technology also join LeddarTech Leddar Ecosystem.

**OPA LiDAR**

For OPA LiDAR, Quanergy previously released S3 but has yet to commercialize it. Some players like Analog Photonics and Shenzhen Litra Technology are in the phase of development and exploration. It will expectedly take them over 5 years to launch the technology.

OPA LiDAR enables precise stability and discretionary direction control, without using inertial devices. Yet technical problems such as scanning angle, process, accuracy and range remain to be settled. Current integrated OPA technology fails to offer large aperture needed by mid- and long-range LiDAR, due to complexity, high power consumption or low optical efficiency. In August 2020, researchers at University of Colorado Boulder developed a serpentine optical phased array (SOPA) chip which can enlarge optical aperture for LiDAR.

**Typical Companies in Five Technology Roadmaps and Their SOP Time**

| Technical Direction | Technical Features | Typical Companies | SOP Time |
|---|---|---|---|
| **Mechanical** | Mechanical devices drive the emitter to rotate and pitch accurately, but with high technical complexity and cost. | Velodyne, Valeo, Ouster, Waymo, RoboSense, Hesai Tech, LeiShen Intelligent System, SureStar, etc. | 2018 |
| **MEMS** | Use micro scanning galvanometer to enable certain integration, but limited by range of deflection of the galvanometer. | Innoviz, Innovusion, Pioneer, Blickfeld, RoboSense, Hesai Tech, etc. | ~2020-2021 |
| **FLASH** | Use mature transmitter technology without mobile parts, but with low laser power, limited field of view, low scanning speed and short range. | LeddarTech, Sense Photonics, Continental, IBEO, Benewake, Xenomatix, etc. | ~2020-2021 |
| **OPA** | Feature precise stability and discretionary direction control, without using inertial devices. Yet technical problems such as scanning angle, process, accuracy and range remain to be settled. | Quanergy, Analog Photonics, Litra Technology, etc. | ~2025 |
| **FMCW** | Feature higher detection sensitivity and accuracy, but with high technical complexity and low maturity. | Blackmore, Aeva, Insight LiDAR, SiLC, Bridger Photonics, etc. | ~2023 |

**FMCW LiDAR**

Coherent LiDAR is still in its infancy compared with pulsed ones. The leading technology for the LiDAR is frequency modulated continuous wave (FMCW), into which about 10 players worldwide get involved, including Aeva (invested by Porsche), Blackmore (acquired by Aurora in 2019), Strobe (acquired by Cruise in 2017), SiLC Technologies (invested by Dell), Bridger Photonics (invested by Carl Zeiss) and AODTBJ.

The reason why BMW, Toyota, Porsche, GM and Aurora select FMCW LiDAR lies in FMCW's edges over pulsed ToF, on ability to directly detect speed (4D information) and high resolution range and permission to use cheap photoelectric detectors (e.g., PIN). The biggest challenge before FMCW technology is the need for being integrated with a plurality of optical components, e.g., laser, amplifier, phase and amplitude controlled low-noise photodiode, mode converter and optical waveguide, all of which should be further integrated into a commercial-scale compact FMCW LiDAR.

From the latest progress, it can be seen that Aeva's Aeries FMCW system irons out the dependency between maximum detection range and point cloud density, and integrates multiple beams on a chip, achieving full range performance of over 300 meters for objects in addition to the ability to measure instant velocity for every point with a 120-degree field-of-view. The product is projected to be available for use in 2020, costing less than $500 once mass produced.

Furthermore, FirstLight, a LiDAR co-developed by Blackmore and Aurora, allows the Aurora Driver to see well beyond 300 meters even on targets that don't reflect much light, such as a pedestrian wearing dark clothing at night. Aurora has installed its Aurora Driver in six different vehicles, ranging from sedans and Chrysler Pacifica minivans to self-driving trucks. Aurora plans to use its FirstLight LiDAR in its fleet of self-driving development vehicles in 2020.

## Typical FMCW LiDAR Vendors and Their Developments

| Company | Founded | Funding | Product | Developments |
|---|---|---|---|---|
| **Aeva** | 2017 | A round: $45 million invested by Canaan Partners, etc., in Oct. 2018; invested by Porsche in late 2019 | Aeries (max. range: 300m) | ◆In April 2019, partnered with Audi AID to equip e-tron test fleet with Aeva's LiDAR. ◆ VW plans to use Aeva's LiDAR in ID Buzz AV, its first autonomous car for mass production. |
| **Insight LiDAR** | 2016 | – | Digital Coherent LiDAR (range: 200m) | ◆ at CES 2020, rolled out Digital Coherent LiDAR, a chip-scale, long-range LiDAR. |
| **Blackmore** | 2016 | $18 million invested by BMW i Ventures, Toyota AI Ventures, etc., in Sept. 2018; acquired by Aurora in May 2019 | FirstLight (maximum range: 300m) | ◆ In July 2020, introduced FirstLight developed with Aurora. The LiDAR will be mounted on Aurora's next-generation autonomous test vehicle which is to be taken on road in 2020. |
| **SiLC** | 2018 | Seed round: $12 million from Dell (leading investor), Decent Capital and ITIC Ventures in Mar. 2020 | FMCW chip | ◆In late 2019, cooperated with Varroc to integrate LiDAR into headlamps. ◆The funds raised in seed round will be spent on further improvement of 4D+ Vision Chip LiDAR sensor. |
| **Bridger Photonics** | 2006 | A round: invested by ZEISS in Nov. 2018 | — | ◆ In November 2018, closed Series A funding rounds. The raised funds all from ZEISS, an optics giant, will be used for developing and commercializing FMCW LiDAR. |
| **AODTBJ** | 2019 | Angel round: RMB5 million in Jan. 2019 | SH2100 (range: 250m) | ◆ At CES 2020, displayed SH2100 4D coherent Doppler LiDAR; plan to put on sale the first products during 2020Q3-Q4. |

Actually, OEMs tend to choose more than one technologies. For example, Audi investing Blackmore, a typical FMCW firm, installed Valeo's 4-channel mechanical LiDAR into Audi A8 in 2018 and also has a plan to pack the to-be-produced cars in 2021 with Luminar’s solid state LiDAR.

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