SENSORS FOR ROBOTIC VEHICLES 2018

Market & Technology report - February 2018

High end industrial sensors will win in the emerging robotic vehicle industry.

KEY FEATURES OF THE REPORT

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- 2017-2022
  - Robotic vehicle roll-out scenario
  - Sensor system volume forecast (in Munits)
  - Sensor semiconductor ASP forecast (in $)
  - Sensor semiconductor revenue forecast (in $M)
  - Sensor systems revenue forecast (in $M)
  - Total revenue forecast robotic vehicle (in $M)
  - Industrial IMU forecast (in $M)
- 2016-2032 Automotive and robotic vehicle Lidar market (in $B)
- 2016-2022 Automotive radar module forecast (in $M)
- 2013-2023 Automotive camera module forecast (in $M)

OBJECTIVES OF THE REPORT

To provide a scenario for sensors within the dynamics of the robotic vehicle market

- Sensor semiconductor average selling price (ASP) forecast, revenue forecast, shipment volume forecast
- Sensor system ASP forecast, revenue forecast, shipment volume forecast
- Application focus on the sensor suite: Lidar, radar, cameras, IMU, GNSS, and computing
- Provide in-depth understanding of the ecosystem and players
- Who are the players and how does the robotic vehicle ecosystem relate to the automotive ecosystem?
- Who are the key suppliers to watch and which technology do they supply?

To provide key technical insights about and analyses of future technology trends and challenges

- Key technology choices
- Technology dynamics
- Emerging technologies and roadmaps

THE ROBOTIC VEHICLE SUPPLY CHAIN IS NOW STARTING

Announcements are piling up from companies like Waymo, Uber, Lyft, Baidu and their automotive manufacturing partners such as Fiat Chrysler Automobiles, Mercedes, BMW and Renault-Nissan. 2018 will most probably be the initial launch year for robotic taxis in several cities around the globe. The move has direct consequences for technology providers in high-end sensing and computing equipment. The vehicle count that we can collect suggests several tens of thousands of vehicles on the road worldwide before end of 2022. As far as we know, each robotic vehicle will be equipped with a suite of sensors encompassing Lidars, radars, cameras, Inertial Measurement Units (IMUs) and Global Navigation Satellite Systems (GNSS). The technology is ready and the business models associated with autonomous driving (AD) seem to match the average selling prices for those sensors. We therefore expect exponential growth of AD technology within the next 15 years, leading to a total paradigm shift in the transportation ecosystem by 2032.

This will have huge consequences for high-end sensor computing semiconductor players and the associated system-level ecosystems as well.

This report depicts a vision of the transformations at stake and the consequences within the sensor and perception computing ecosystems. Most established players are ready to benefit from the huge expansion ahead. That includes Velodyne, Ibeo, Quanergy and Innoviz for Lidars, Continental, Delphi, and Denso for radars, Allied Vision, FLIR and First Sensor for cameras, and KVH, Physical Logic and Honeywell for IMUs. In the realm of AD computing Intel and Nvidia are the heavyweights, along with Xilinx and Renesas. Most of those players will play a significant initial role but there will be a window of opportunity for many other technology providers. Given the size of the opportunity, an enormous amount of capital has already been raised and will be necessary for what is set to be a hardware-based software revolution.

Robotic vehicle technology: Main players' sensor suites

Company	Lidar		Radar		Camera		IMU	
Waymo	LR x1 MR x1 SR x4	WAYMO	x4		x8		x1	x3 Google
Uber	LR x1	Velodyne	x4?		x7		x1	ZENUITY
Toyota	MR x4 SR x4	LUMINAR Velodyne	x4		x9	Allied Vision	x1?	
Cruise	SR x5	Velodyne	x8	DELPHI	x16		x1?	x2 drive.ai nuTonomy
Renault-Nissan	x4	QUANERGY	x5		x8		x1?	
Baidu	LR x1 SR x3	Velodyne	x4?		x2?	FLIR	x1?	AIMOTIVE
Navya	LR x3 SR x7	ibeo Velodyne	x4		x6	First Sensor	x1	

(Yole Développement, February 2018)

SENSORS FOR ROBOTIC VEHICLES WILL BECOME INDUSTRIES OF THEIR OWN

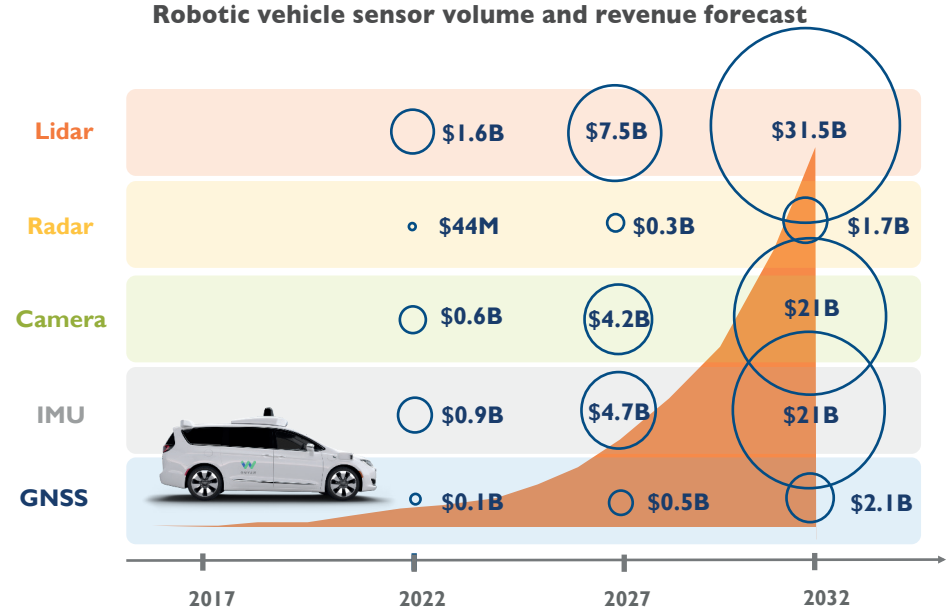
Growth rates are expected to be impressive. In 2017 production of robotic vehicles was in the range of a few hundred worldwide. We expect production volumes to reach 3.1M units annually, with cumulative production of 10.5M units, by 2032. That market growth in excess of 2,500-fold, or 58% compound annual growth rate (CAGR) for the next 15 years. By then, the total revenue associated with the production of robotic vehicles will reach $300B. 52% of that figure will originate from the vehicles themselves, 26% will come from sensing hardware, 17% from computing hardware and the remaining 5% will be from integration. This means that within 15 years complete industries will be structured around robotic vehicle technologies.

When looking closer to the present, in 2022 we expect sensor revenues to reach $1.6B for Lidar,

$44M for radar, $0.6B for cameras, $0.9B for IMUs and $0.1B for GNSS. The split between the different sensor modalities may not stay the same for the 15 years to come. Nevertheless the total envelope for sensing hardware should reach $77B in 2032, while, for comparative purposes, computing should be in the range of $52B.

Today car sales account for $2.4T and are the natural target of internet giants like Google, Baidu, Amazon and Uber. They are mostly attracted by transportation as a service market, which we believe should reach the same value of $2.4T in 2032. With an additional $1.1T to be generated by sales of personally owned AD vehicles, the added value of autonomous driving will reach a total of $3.5T. Due to the numbers at stake the stealth players in everybody's minds are Apple and Samsung, the latter of which is not so stealthy, having bought Harman in 2017. We should expect their entry at some point in time, with a possible "mobile to smartphone style" transformation of the industry.

Robotic vehicle sensor volume and revenue forecast



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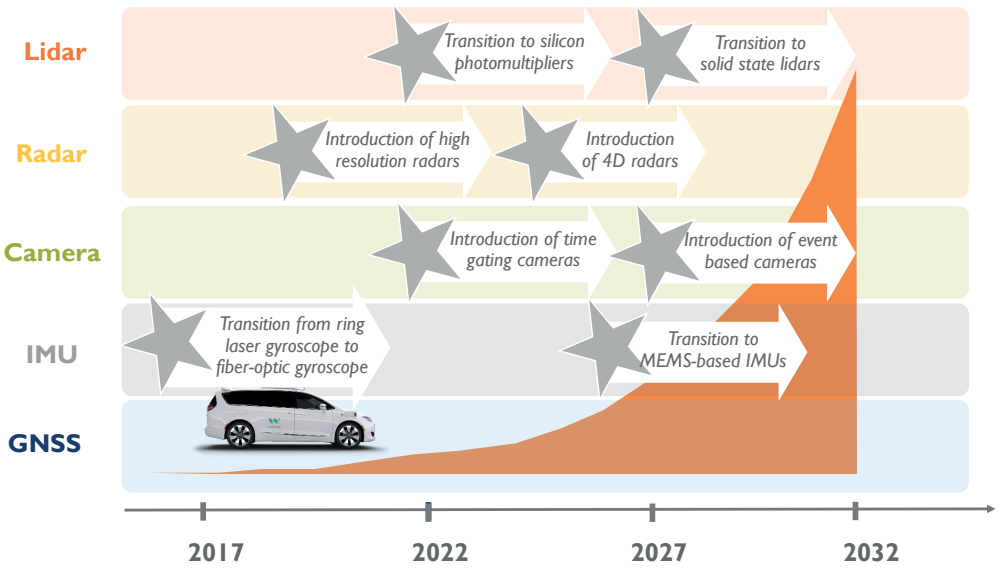
HIGH-END INDUSTRIAL SENSORS WILL WIN IN THE ROBOTIC VEHICLE SENSOR SUITE

There are key differences between automotive advanced driver assistance system (ADAS) technology and the equipment that will fit into early robotic vehicles. We warned about this very persistently in our previous reports on automotive technology. Now, this report provides the missing piece with which to complete your AD market understanding. Automotive ADAS has to focus on reliability and cost issues serving a market with sales of millions of units. The technologies to serve the robotic vehicle market will be mainly driven by performance and availability and will serve a market of only tens of thousands

Robotic vehicle sensor technology and market impact roadmap



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units by 2022. The orders of magnitude are in fact totally different between the two worlds. To generalize broadly, high end industrial sensors will win in the early robotic vehicle sensor suite.

The consequences for existing players and technologies will be huge, as some high-end markets such as Lidars or industrial grade IMUs will more than double in the next few years. The impact will also be strongly felt by industrial camera makers. Technologies are expected to specialize by 2022 and possibly merge partially with ADAS by 2027. Technology-wise 2032 is expected to be another world, with a complete paradigm shift. It is not often that we are facing such deeply transformative changes powered in part by sensing technologies. The robotic revolution is underway and this report is a thorough analysis of its market and technology implications.

COMPANIES CITED IN THE REPORT (non exhaustive list)

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Branch code: 00170
Account n°: 0170 200 1565 87
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