

# AUTONOMOUS VEHICLE TECHNOLOGY & SUPPLIERS Global Study



How will autonomous cars actually work? Are we there yet?

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# FREE ABSTRACT

From sensors to processors, all the building blocks of automation analysed



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### Will AV technology and suppliers live up to the hype?



#### Dear reader,

Since Google floated its concept of a driverless car 10 years ago, Autonomous Vehicles (AVs) have appeared as the new paradigm of automotive.

All OEMs, after an observation period, have joined the race and come up with their own roadmap, investing billions in R&D and acquisitions.

In 2016-17, most car maker CEOs announced aggressive roadmaps, with commercial launches planned in 2020. But Uber's AV crash in Tempe, Arizona started to downgrade expectations. Waymo's and GM Cruise's recently announced delays prove that OEMs don't know what they don't know! Thus **doubts are surfacing on the very achievability of the vision.** 

#### **Time for soberness**

We believe that it is now time to stop announcing topdown, unrealistic launch dates. The next automotive revolution will not only come from CEO injunctions.

It is time to build a bottom-up, supplier-based roadmap of automation. It could also be a good idea to consider technology costs in assessing its take-up.

This is the point of this report, which attempts to respond to the *How?*, *How much?* and *When?* questions, viewed from the supplier side. It is complemented by our **OEM AV Readiness Global Study**, which is viewed from the car maker's side. As **Cruise** just announced that they will not be able to rollout robo-taxis in 2019, we predict more such announcements will follow.

On the other hand, **Daimler, backed by Bosch,** just received approval from **German regulators** to run an automated driverless parking function - the world's first **SAE level 4 parking function** to be authorised.

This gives weight to the claim we heard from most tech suppliers: "We are ready for primetime".

#### Who's right?

In truth, we believe that all will move from focusing on automation levels to focusing on automation use cases in different zones/areas. Robotaxis will be one of the first that will be ready for commercial launch from 2021. It will be followed by use cases such as Automated Valet Parking, Highway Drive, etc.

#### How will it actually work?

We are supposed to be close from launch time and the debate still rages on which technology will be used. What will be the relative role of sensors, HD maps, high accuracy GNSS, and AI?

Two years ago, most OEMs were adamant that sensors and AI would suffice. **But the safety imperative has pushed all to add extra layers of redundancy.** This report analyses the role each layer will play to build a resilient solution.

#### Who will win the AV supply battle?

Our global analysis of AV technology and supply proves that the building blocks of automation are improving fast. But what level of integration will be necessary and who will do it? Will **new players** such as HERE, NVIDIA and Velodyne win thanks to their focus on a single building block such as AI, LiDAR or HD maps?

Will traditional tier-1 suppliers such as Bosch, Lear Corp. and Valeo dominate thanks to their ability to integrate multiple suppliers and building blocks?

To write this report, **PTOLEMUS** has leveraged its **4** years of experience in tracking the AV industry, publishing the most comprehensive report on the subject in 2017\* and advising key suppliers.

In this 500-page study, you will find:

- An analysis of the role of **4 key technology building blocks** (road environment sensing, contextual information interpretation, hardware processing, AI)
- An appraisal of **13 sub-technologies** such as **LiDARs**, **HA GNSS**, **HD maps**
- In-depth profiles of 20 key technology vendors
- 13 use cases of supplier technical product offerings
- Volume forecasts for radars, LiDARs, HA GNSS and HD maps

With this research, we aim to bring a fact-based evaluation of the road towards AVs. **As consultants**, we also look forward to help you create your **next go-to market strategy** to position yourself as a key player in this swiftly evolving AV landscape.

Sincerely,

- Frederic Bruneteau
- Managing Director

## Full AV tech will not be deployed in cars but in robo-taxis first



"The only way to solve the problem of roadway safety, and the only way to deliver the opportunity of mobility for all, was to take the human completely out of the loop.

We committed then to full autonomy, no driver monitoring, nor driver's license, required"

John Krafcik

#### PTOLEMUS

# Initially, level 4 will not be deployed in private cars everywhere but in specific use cases



"The automated parking system shows just how far we have already progressed along this development path.

This decision by authorities (to permit this level 4 service) shows that innovations like automated valet parking are possible in Germany first"

> Dr. Markus Heyn Board Member, Bosch

### Some OEMs and tech suppliers may soon be exposed...



BERKSHIRE HATHAWAY INC. "Only when the tide goes out do you discover who has been swimming naked"

Warren Buffet

### PTOLEMUS



#### Suppliers are prepared, costs are falling, but are OEMs ready?

- PTOLEMUS research indicates that the USA will be the first country to deploy level 4 autonomous vehicles, winning the race of deployment versus Europe and China
- There have been significant improvements in all technologies for self-driving cars in the past 3 years, PTOLEMUS predicts:
  - Level 3 features such as Traffic jam and Highway drive will only be seen in private cars
  - Urban areas will be the first to see level 4 autonomy implemented, starting with low speed shuttles, robotaxis and automated valet parking
  - **Waymo** will lead the robotaxi market by launching **Waymo One** with **Lyft** as soon as 2020 in USA

**Vision sensors** 

- LiDAR technology will be required for the safe perception of the environment and it will be a vital part of the vision sensor suite from **SAE level 4**
- Some OEMs, such as Tesla, disagree. But whilst lidar is non-critical for level 2/3, from level 4 PTOLEMUS' findings, based on interviews with 20 of the leading suppliers, indicate otherwise

- The cost of **long range LiDARs** for level 4 will come down by **40% by 2022**
- As a result PTOLEMUS forecast **100%** growth in the market as the technology becomes more **accessible** for **OEMs**
- Vision sensors will contribute to 60% of the total costs of level 4 AV systems
- Computing units will be **responsible for 30%** of the total costs
- HD maps, HA GNSS and AI will be responsible for 10%

#### Processors

- Some OEMs are developing in-house processors for their computing units such as Tesla and Waymo to create tailored applications and improve power efficiency
- This trend is giving rise to **centralised computing units as OEMs** look to simplify **processing systems**

#### **Artificial Intelligence**

- Machine learning (ML) will be required from **level 3** in prediction and planning routes

- Most OEMs are using ML for computer vision
- However, applying ML to prediction and planning is only at an **experimental stage**
- **Waymo** is the best in class because:
  - ✓ It is the only player to experiment with machine learning in the prediction and planning of routes
  - **√ \$6 billion** in R&D,
  - ✓ 16 million real world km of testing
  - ✓ 16 billion simulated km of testing

#### Connectivity

 Contrary to reports in the media PTOLEMUS' research proves that 5G technology is not essential for the rollout of L4 vehicles



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- B. Supplier appraisal & ranking for each building block & across them
- 5. How tech giants will change the rule of the game
- 6. Forecasting the sensor suite market
- 7. Conclusion



## We respond to numerous strategic questions



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To order the study or enquire about our new subscription model, contact AV@ptolemus.com

# A unique report that zooms in on the microscopic view of technologies & zooms out on the big supplier picture



#### PTOLEMUS

# We researched the AV landscape & highlighted the key technologies









## PTOLEMUS Source: PTOLEMUS



#### PTOLEMUS Source: PTOLEMUS

# We mapped all the ADAS/AVs technologies in circulation







PTOLEMUS Source: PTOLEMUS

AV Technology & Suppliers Global Study

# We Explain why Traffic Jam L3 will be deployed in various markets as early as 2020

Use cases timeline and cost analysis



#### Timeline

AV Technology & Suppliers Global Study



## We explain why software developers & system integrators are the real game changers of the industry



#### AV technology onion

- Hardware layer refers to all the hardware used from sensors to processors and connectivity modules
- Connectivity software layer allows the vehicle to exchange data with the cloud, other vehicles and the infrastructure
- **Integration software layer** is composed of the software required to safely manage the software stack by isolating the safety critical components
- Data layer comprises the contextual data received by the AV such as HD maps or GNSS corrections and observations
- Core software layer includes all the software required by the AVs such as the development of prediction- and decision-making neural networks/ reinforced learning rules-based model, navigation software or computer vision algorithms

#### PTÓLEMUS Source: PTOLEMUS

## We have analysed 80 tech suppliers and profiled 20 of them



# This study is the first cross-technology, cross-supplier assessment of the autonomous vehicle industry



"Your comprehensive companion to understand and win AV tech markets" **Over 550 pages** on the AV tech landscape, based on:

- 4 years of market monitoring
- The 2017 Autonomous Vehicle Global Study
- More than **20 interviews** with key stakeholders
- 5 months of desk research and interviews by a team of 4 consultants
- Expert knowledge from consulting assignments in the **AV and technology markets**

#### The report covers:

- A holistic appraisal of the AVs ecosystem, including factors such as:
  - ✓ Perception
     ✓ Decision and planning
     ✓ Control and chassis
     ✓ Operating systems
     ✓ Security layers
- A fully re-designed automotive value chain fit for the AV industry including:
  - AV sensor vendors
  - AV software developers
  - Neural net developers

- Traditional automotive suppliers
- Appraisal of the 6 most important use cases including:
  - Robotaxis
  - Automated valet parking
  - highway drive
  - shuttles
  - Also including a forecasted timeline of this rollout in each road types

### In-depth analysis of 4 key technology building blocks:

- Road environment sensing
- Contextual information interpretation
- Al development
- Software & hardware platforms

#### • 13 technologies including

- LiDARs, radars, cameras, HA GNSS/INS, HD maps, V2X, supervised learning, imitation learning, reinforcement learning, software stack, middleware, OS and computing hardware
- A mapping of all key suppliers in each category

- An assessment of key trends & technologies
- 13 case studies
  - Pertaining to each of the 13 technologies discussed
- 80 supplier KPIs analysed, including:
  - Strategic positioning
  - Product offerings
  - Activities and partnerships in the industry
  - 20 AV suppliers profiled
- A **ranking** of the best-in-class suppliers including:
  - A **bottom-up assessment** of the key activities of suppliers in the AV industry

### 2018 - 2030 market forecasts including:

- Revenues and volumes of the following global markets:
  - ✓ LiDARs
  - ✓ Radars
  - ✓ Cameras
  - ✓ Computing units
  - ✓ HD maps
  - ✓ HA GNSS

## The report was written by a team of world-class experts



#### Frederic Bruneteau

Managing Director, Brussels

Frederic Bruneteau is the **founder** of PTOLEMUS Consulting Group.

He has accumulated **23 years of experience** of the mobility / transport domains and 15 years of strategic and financial advisory.

He has become **one of the world's foremost experts of connected mobility & automation** and is interviewed on the subject by publications such as the *Financial Times*, *Forbes*, the *Wall Street Journal* and *The Economist*. He has also spoken at many conferences on the subject.

He is the **President of The Autonomous Club**, an European think tank on connected & autonomous vehicles focused on industry and regulatory evolutions. Frederic directed the global research for our last reports on mobility and AV such as the **Augmented Mobility 2030 Global Study** and the **Autonomous Vehicle Global Study 2017** 

He has helped many world leaders define their strategic & innovation plans and implement them including Abertis, AGC Automotive, A-to-Be, BP, Bridgestone, CNES, Danlaw, DMP, ESRI, the European Commission, HERE, the Netherlands' Ministry of Transport, Octo Telematics, Michelin, Pioneer, Qualcomm, Scania, Société Générale, TomTom, Toyota and WEX.

Frederic directed and reviewed the research for this report.



**Alberto Lodieu** Manager, Paris

A Mexican citizen, Alberto has **9 years** of experience in strategy and operations consulting in Europe and America.

He has assisted organisations such as Abertis, AGC Automotive, AXA Partners, CNES, the French space agency, CVC Capital Partners, DMP, Europ Assistance, the European Commission, Liberty Mutual, Silver Lake, Société Générale and Telespazio. He participated in over 30 projects around connected mobility, ADAS & autonomous vehicles, payments, transportation and usagebased insurance.

Alberto recently led our landmark research Augmented Mobility 2030 Global Study. He also integrated this supplier research in our mobility research.



**Spardha Taneja** Business Analyst, Brussels

Spardha has **more than 2 years** of experience in the **automative and insurance industry**.

Within PTOLEMUS, she has developed an expertise in Mobility-as-a-Service, the UBI market and the autonomous vehicles industry. She has also worked on big data analytics project with a road and safety client to develop a model that can predict accidents on various road stretches, She recently participated in the **ADAS Sensors 2019 conference** conducted by MEMS in Detroit.

Spardha has managed this report. She interviewed over 15 suppliers and focused her analysis on the road environment technologies such as LiDARs, radars and other sensors. She structured the analysis of the complex ecosystem.



#### Annie Reddaway Business Analyst, London

Annie Reddaway has **5 years of** experience in the connected vehicle industry, specifically in the areas of connected car, cybersecurity and mobility services. She has researched and run various events and webinars on these topics.

She has worked with companies including Aioi Nissay Dowa, car2go, Zipcar, General Motors, Ridecell, Ford, Fontinalis Partners and WirelessCar In 2018, Annie was awarded "Best New Mobility Leader, Analyst or Spokesperson" in the Tech Cars Awards from Auto Connected Car News.

For this report, Annie conducted an overall review of the document



# The report mentions more than 150 companies in 29 industries (1/3)

Industry	Company	Country	Industry	Company	Country	Industry	Company	Country
AI for supply chain	Scale.ai	Canada	Automotive OEM	Porsche	Germany	Engineering company	Bertrandt	Germany
Automotive OEM	Alliance Renault- Nissan	France	Automotive OEM	PSA	France	Geospatial data & analytics	Maxar Technologies	USA
Automotive OEM	Audi	Germany	Automotive OEM	Rolls-Royce	UK	HD map provider	Carmera	USA
Automotive OEM	BMW	Germany	Automotive OEM	Subaru	Japan	HD map provider	Civil Maps	USA
Automotive OEM	Daihatsu	Japan	Automotive OEM	Suzuki	Japan	HD map provider	Dynamic Map Platform (DMP)	Japan
Automotive OEM	Daimler	Germany	Automotive OEM	Tesla	USA	HD map provider	HERE	Germany
Automotive OEM	FCA	Italy	Automotive OEM	Toyota	Japan	HD map provider	Mapbox	USA
Automotive OEM	Ford	USA	Automotive OEM	Volvo	Sweden	HD map provider	NavInfo	China
Automotive OEM	General Motors	USA	Automotive OEM	VW	Germany	HD map provider	Netradyne	USA
Automotive OEM	Hino Motors	Japan	Autonomous shuttle provider	EasyMile	France	HD map provider	TomTom	Netherlands
Automotive OEM	Honda	Japan	Autonomous shuttle provider	Local Motors	USA	HD map provider	Ushr	USA
Automotive OEM	Hyundai	South Korea	Autonomous shuttle provider	Navya	France	HD map provider	Zenrin	Japan
Automotive OEM	Infiniti	Japan	Computing	NTT Data	Japan	INS systems	Aceinna	USA
Automotive OEM	lsuzu	Japan	Data training	Playment	India	INS systems	SBG Systems	France
Automotive OEM	Jaguar Land Rover	UK	Electronics and electrical equipment	Mitsubishi Electric	Japan	LiDAR & software provider	Innoviz Technologies	Israel
Automotive OEM	Mazda	Japan	Embedded software provider	Elektrobit	Germany	LiDAR & software provider	Quanergy	USA

# The report mentions more than 150 companies in 29 industries (2/3)

Industry	Company	Country	Industry	Company	Country	Industry	Company	Country
LiDAR provider	Blackmore	USA	Online sale	Meituan Dianping	China	Pharmaceutical company	Roche	Switzerland
LiDAR provider	lbeo automotive	Germany	Optics and imaging	Nikon	Japan	Positioning solutions provider	Geo++	Germany
LiDAR provider	LeddarTech	Canada	OS and software provider	Green Hills	USA	Positioning solutions provider	Hexagon Positioning (incl. NovAtel)	Canada
LiDAR provider	Luminar	USA	OS and software provider	Polysinc	USA	Positioning solutions provider	Point One Navigation	USA
LiDAR provider	Ouster	USA	OS and software provider	QNX	Canada	Positioning solutions provider	Sapcorda	Germany
LiDAR provider	Velodyne	USA	OS and software provider	Renovo	USA	Positioning solutions provider	Septentrio	Belgium
LiDAR solid-state chip provider	ABAX sensing	China	OS and software provider	Wind River	USA	Positioning solutions provider	Swift Navigation	USA
LiDARs solid-state chip provider	Hamamatsu	Japan	OS and software provider	Wittenstein	UK	Positioning solutions provider	Teria	France
Mobility services	CAR2GO	Germany	Part manufacturer	Ficosa	Spain	Positioning solutions provider	Trimble	USA
Mobility services	DiDi	China	Part manufacturer	Grupo Antolin	Spain	Positioning systems & Telematics	GMV	Spain
Mobility services	Lyft	USA	Part manufacturer	Knorr-Bremse	Germany	Positioning systems & Telematics services	Lear Corporation	USA
Mobility services	MyTaxi	Germany	Part manufacturer	Magna International	Canada	Processor and software provider	Mobileye	Israel
Mobility services	OLA	India	Part manufacturer	ZF	Germany	Semiconductor & telecommunication	Qualcomm	USA
Mobility services	ReachNow	USA	Perception AI	Ауе	USA	Semiconductor company	AMD	USA
Mobility services	Uber	USA	Pharmaceutical company	Johnson & Johnson	USA	Semiconductor company	ARM	UK
Mobility services	Zipcar	USA	Pharmaceutical company	Merck	USA	Semiconductor company	Broadcom	USA

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# The report mentions more than 150 companies in 29 industries (3/3)

Industry	Company	Country	Industry	Company	Country	Industry	Company	Country
Semiconductor company	Global Foundries	USA	Tech company	Ambarella	USA	Tech company	Yandex	Russia
Semiconductor company	Infineon	Germany	Tech company	Apple	USA	Tech company	ZOOX	USA
Semiconductor company	Intel	USA	Tech company	Argo Al	USA	Technology integrator	Aptiv	USA
Semiconductor company	Kalray	France	Tech company	Aurora	USA	Technology Integrators	Tier IV	Japan
Semiconductor company	Neousys Technology	Taiwan	Tech company	Automotive Artificial Intelligence (AAI)	Germany	Telecom operator	Orange	France
Semiconductor company	Nvidia	USA	Tech company	Baidu	China	Telecom operator	SK Telecom	South Korea
Semiconductor company	NXP	Netherlands	Tech company	CloudMade	UK	Telecommunication & network	Huawei	China
Semiconductor company	Renesas	Japan	Tech company	Cruise	USA	Tier-1	Bosch	Germany
Semiconductor company	STMicroelectronics	Italy	Tech company	Drive.ai	USA	Tier-1	Continental	Germany
Semiconductor company	Texas Instruments	USA	Tech company	Microsoft	USA	Tier-1	Denso	Japan
Semiconductor company	U-Blox	Switzerland	Tech company	SAIPS	Israel	Tier-1	Harman	USA
Semiconductor company	Xilinx	China	Tech company	Samsung	South Korea	Tier-1	Pioneer	Japan
Sensors and platforms for robotics	Carnegie Robotics	USA	Tech company	TRI-AD	Japan	Tier-1	Valeo	France
Tech company	AID	Germany	Tech company	Varden Labs	Canada	Tier-1	Veoneer	Sweden
Tech company	Alphabet	USA	Tech company	Voyage	USA			
Tech company	Amazon	USA	Tech company	Waymo	USA			



## The study comes with a single, worldwide company licence

PTÓLEMUS Consulting Group	AUTONOMOUS VEHICLE TECHNOLOGY & SUPPLIERS Global Study
FULL VERSION	
From sensors to processors, all the building blocks of automation analysed	How will autonomous cars actually work? Are we there yet?
From sensors to processors, all the building blocks of automation analysed	How will autonomous cars actually work? Are we there yet?

The first cross-technology report on AV solutions and suppliers

		Full Study	Global market forecasts	Additional workshop	
Contents	<ul> <li>550-page analypowering the Abuilding blocks</li> <li>20 AV supplier strategy, market</li> <li>Architecture and Independent rapproviders in the</li> <li>20 interviews of Cost analysis reamaps, HA GNS</li> </ul>	ysis of the complex AV industry with focu s as assessment incluce at offering and place and value chain of the anking of the top te e AV industry conducted with the elated to LiDARs, ra S and computing u	<ul> <li>Excel file with outputs and charts</li> <li>2019-30 projections of sensors, HA GNSS, HD maps and processors</li> </ul>	<ul> <li>The full study presented to your board or strategy team</li> <li>Half-day workshop at your office*</li> </ul>	
Company- wide licence	Less than 100 employees € 2,950 Approx. \$3,300	<b>100-10,000</b> employees € <b>3,950</b> Approx. \$4,400	Over 10,000 employees € 5,950 Approx. \$6,600	<b>€ 2,000</b> Approx. \$2,300	<b>€ 2,000</b> Approx. \$2,350

For more information, customisation of the report and to order the study or enquire about our new subscription model, contact <u>AV@ptolemus.com</u>

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Note: Prices in Euros excluding VAT (VAT only applicable to clients located in Belgium) - \* Conditions apply



Strategy consulting services

# The first strategy consulting & research firm entirely focused on augmented mobility & automation

#### **Micro-mobility** Car pooling **Mobility** Smart parking Car sharing Ride hailing services Tax refund Investment Procurement Strategy MAAS Shared mobility definition assistance strategy **bCall** Tracking **Navigation** Vehicle eCall VRM **Speed cameras FMS** In-car Wi-Fi services **Traffic information** Innovation **Business** Project SVT / SVR Parking development management management BEV New Fuel cells PHEV EV charging energies Hydrogen Vehicle-to-grid **Fuel cards UBI / PAYD Car As A Service** Mobility-as-a-**Usage-based** Service Vehicle rental **Market research services** Electronic Toll charging Collection Road charging Vehicle leasing AI Driving behaviour Remote Vehicle data **CAN-bus** OBD diagnostics **Crowd-sourcing** & analytics Predictive **xFCD** analytics **Data protection** Custom Vehicle **Off-the-shelf Subscription** ADAS **Robo-taxis** Autonomous market trucks **Shuttles** reports automation Autonomous cars services research Positioning (GNSS **Telematics** Enabling / WiFi / cellular) **Smartphones** devices technologies M2M / Sensors V2X connectivity

#### Fields of expertise

### Our clients are across the mobility & automation ecosystem



# Our team of 25 consultants, experts & researchers with 15 nationalities serves our clients worldwide



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For more information on our consulting services, contact <u>contact@ptolemus.com</u>

# The Autonomous Club (TAC) has become a successful platform to shape the future of autonomy in Europe

#### Status

International, non-profit association created by PTOLEMUS and Lysios Public Affairs

#### Scope

- Connected & autonomous vehicles
- All topics at the crossing of technology, business, & regulatory domains

#### Key objectives



## THE AUTONOMOUS CLUB



#### **Recent speakers**



#### **Recent subjects**

- Who will control & access connected autonomous vehicle data?
- Status of the Autonomous Vehicle market and key implications
- Fostering a European-wide liability framework for AVs
- Is V2X required to make AVs a success?

#### Members



# PTOLEMUS can help your organisation define and achieve its AV strategy in fast moving times

- Strategy definition
  - Future vision in mobility and AV
  - Board coaching
  - Market entry
  - Strategy shaping workshops
  - Impact of ADAS & AVs on the business

#### Innovation strategy

- Market assessment on mobility and AV
- Product definition
- Go-to-market strategy
- Data analytics strategy
- AV tech evaluation

#### Investment assistance

- M&A strategy
- Commercial due diligence
- Technology due diligence
- Feasibility studies
- AV & ADAS market sizing
- Business case development
- Cost benefit analyses
- Post-merger integration

#### Innovation delivery

- Proof of concept design & launch
- Architecture definition
- Project management

#### Procurement

- Sourcing strategy
- Specifications
- Supplier selection
- Assistance to tenders

#### Business development

- Partnership strategy definition
- Assistance to tender response

# PTOLEMUS Consulting Group

OTHER DESIGNATION OF THE PARTY OF THE PARTY

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10 years of experience in shaping future mobility

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