Autonomous Vehicle: Future of Automotive Industry

Zinnov Point of View

July, 2018
Autonomous Vehicles (AV) have huge potential to impact global economies, markets and industries.

$2.2 Trillion
Potential savings in the areas of fuel efficiency, cost of life and productivity gains enabled through AV based business models in US by 2020.

$87 Billion

1 Million

12%
Expected AV market share as percentage of total worth of Auto industry, in 2020.

2,000
Number of global AV start-ups in 2020, a five-fold increase from present day.

Note: DRAUP - The platform tracks engineering insights in the automotive ecosystem using our proprietary machine learning algorithms along with human curation. The platform is updated in real time and analysis is updated on a quarterly basis.
The traditional automotive industry is getting disrupted due to technology providers across diverse industry segments.

### Automotive Ecosystem has been disrupted through digital mega innovations

#### Smart Mobility
- **Telecom**: 5G Infrastructure
- **Insurance Providers**: Usage based Insurance
- **Cloud Platforms**: Data Management & Security
- **New Age Suppliers**: ADAS Systems & Components

#### Internet Age
- **Data Services**: Connected Car
- **Mobility Services**: Alternative Ownership
- **Tech Mafia**: Car OS, HMI

#### Silicon Evolution
- **Consumer Electronics**: Infotainment OS
- **Semiconductor Giants**: SoC Processors

#### Traditional Suppliers
- **Telematics equipment**

#### Telecom: 5G Infrastructure
- **Data Management & Security**
- **ADAS Systems & Components**
- **Connected Car**
- **Alternative Ownership**
- **Car OS, HMI**
- **Infotainment OS**
- **SoC Processors**

**Note:** Each unit on Y-Axis represents a single type of ecosystem player.

**Ecosystem maturity trend during last 15 years**

- **Traditional suppliers** such as Bosch and TomTom have enabled advanced vehicle navigation and monitoring through specialised telematics equipment.
- **Semiconductor giants** such as Intel and Nvidia have developed **specialised SoCs** for processing and computing large amount of vehicle datasets.
- **Tech Mafia** have transformed the vehicle into a **software computing system** with capabilities to take autonomous decisions.
- **New age suppliers** have built capability into **Advanced vehicle control using deep learning, sensor systems and connectivity services**.
- The current **Autonomous Vehicle ecosystem** has been rapidly growing through a rich infrastructure of network, cloud & insurance providers enabling **new age business models**.

**Note:** The timeline above is illustrative of landmark events in the autonomous vehicle ecosystem during the last 15 years. The list above is non-exhaustive.

**DRAUP Engineering Module:** The platform tracks real time insights and developments in the Autonomous Vehicle Ecosystem such as global engineering footprint, product launch, Leadership Announcements, M&A, among other essential insights.

Source: DRAUP
Early autonomous vehicle prototypes were limited to experiments, but today more than 500 organizations are disrupting this space.

1. **Late 1990s**
   - **Experimental Period**
   - **Early Pioneers of Autonomous Vehicle**

2. **2003-2008**
   - **First big push towards autonomous driving**
   - **20+ Players**
   - **Universities teamed up for DARPA Urban Challenge**

3. **2009-2010**
   - **Software/Internet giant goes driving**
   - **100+ Players**
   - **Software Internet giants started working on autonomous technology**

4. **2011-2013**
   - **Government allowed autonomous testing**
   - **Nevada DMV issues 1st autonomous car testing license**

5. **2014-Present**
   - **500+ Players**
   - **Non-Automotive and new age players join in**
   - **New age Business Models driven by AV**

Note: Timeline above illustrates landmark events in the autonomous vehicle ecosystem during the last 20 years. The list above is non-exhaustive.

**DRAUP Engineering Module**: Consists of around 180 engineering organisations and nearly 100,000 start-ups working across Automotive, Software/Internet and other Hi-Tech verticals.

**German Pioneer Ernst Dickmanns** at Bundeswehr University Munich introduced vehicles with basic sensors and microprocessors.

**Universities** teamed up with OEMs such as GM and VW to test early prototypes such as LiDAR & navigation systems during the first DARPA Challenge.

**Google’s Self Drive Project** (Now Waymo) launched a fleet of 7 Toyota Prius hybrid in 2010 and tested for more than 140,000 miles on public roads.

**Currently 41 states in US** have considered legislations for autonomous vehicle testing. Germany, Japan and Israel have also allowed AV testing.

**New age disruptors** such as Otto launched autonomous truck delivery, Udacity open sourced self-driving vehicle data. Semiconductor Giants started acquiring mature AV providers through acquisitions and partnerships.

- The current AV ecosystem consists of 500+ players including Automotive, Semiconductor, Software/Internet and new age disrupters.

Source: DRAUP
Liberal government policies, technology advancement and ecosystem openness to co-innovate are the key enablers driving autonomous vehicle innovations.

1. **Technology advancement**
   - **Decline in cost of computing** and advancement in **processing power** have enabled processing large volume and variety of data such as image, voice, text etc.
   - Advances in machine learning have allowed **computer vision** to compute unstructured data and distinguish objects on the road and build 3-D maps of the surrounding area.
   - **Deep learning** and **artificial intelligence** have led to better algorithms for pedestrian detection, traffic control and other automation features.

2. **Political, legal and social drivers**
   - **State legislations** related to autonomous vehicles have gradually liberalised. In 2017, **33 states** have introduced legislation related to autonomous vehicles in USA, allowing testing of autonomous fleets under certain specified conditions.
   - **Extensive government investment** in key countries- US and UK governments plan to invest $4Bn and £38Mn over the next 5 years, on driverless cars technology.
   - **Projected 20% overall reduction in road accidents**- Elimination of drivers is expected to reduce driving accidents caused by human error.

3. **Open Ecosystem**
   - **Collaborative and open innovation**- Top player Tesla open-sourced its patents while Baidu and Lyft have open software platforms.
   - **Competitive landscape**- Entrance of technology mafias which are building a competitive environment in AV through their strong capability in software platforms.
   - **R&D partnerships between universities and automakers**- Toyota partnered with University of Michigan for autonomous innovation.

Note: The above analysis is based on the DRAUP’s proprietary engineering database and insights from industry stakeholders, updated as on Feb, 2018.
US states and several other nations are relieving the regulations around Autonomous Vehicle testing on public roads

| Autonomous Vehicles regulations by State and Central government organisations |
|----------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| **Michigan**                     | ✔               | ✔               | ✔               | ✔               | ✔               |
| **Florida**                      | ✔               | ✔               | ✔               | ✔               | ✔               |
| **California**                   | ✔               | ✔               | ✔               | ✔               | ✔               |
| **Singapore**                    | ✔               | ✔               | ✔               | ✔               | ✔               |
| **Netherlands**                  | ✔               | ✔               | ✔               | ✔               | ✔               |
| **China**                        | ✔               | ✔               | ✔               | ✔               | ✔               |
| **Germany**                      | ✔               | ✔               | ✔               | ✔               | ✔               |
| **Japan**                        | ✔               | ✔               | ✔               | ✔               | ✔               |
| **UK**                           | ✔               | ✔               | ✔               | ✔               | ✔               |
| **Israel**                       | ✔               | ✔               | ✔               | ✔               | ✔               |

**Regulations Passed**

- Legal for testing prototype with driver
- Legal for testing prototype on public roads with driver
- Legal for testing prototype without driver
- Legal for testing prototype on public roads without driver
- Semi autonomous fleet services allowed

**AV*: Autonomous Vehicle

**AV** Adoption Index

- **LOW**
- **HIGH**

Note: Autonomous Vehicle regulations have been verified from reports published by Department of Motor Vehicle, California and other state regulatory bodies in respective geographies. The above analysis is based on the DRAUP’s proprietary engineering database and insights from industry stakeholders, updated as on Feb, 2018

- Michigan being a traditional automotive engineering hub became the first state to approve the latest autonomous technology allowing automakers to test their autonomous prototypes on public roads even without a driver.
- **Governments of UK, Japan and Germany are cautious about the safety** of current autonomous technology. Thus they have taken proactive regulatory measures by allowing testing only in the presence of a driver.
- Governments in geographies such as Germany, UK and other European countries are not able to develop a concrete regulatory framework for testing and assessing autonomous driving because they face challenges in defining ethical laws relating to responsibility in accidents caused by fully autonomous vehicles.
- The Netherlands’ Council of Ministers recently updated its bill to allow tests without a driver. Shanghai issued its first self-driving license, allowing automakers to test their AVs on public roads.
Open-source Ecosystem created by Technology Mafia’s and new age players have created a collaborative and co-innovative environment

### Open-source driving data and frameworks

**Udacity**
Open-sourced driving data

**Github**
Various open-source autonomous projects

**PolySync Autonomous Kit**
Open-source car control project detailing conversion of a vehicle into an autonomous driving vehicle.

**Robot Operating System**
Enables automakers to quickly develop and prototype autonomous vehicles and sensor-rich vehicles using predefined ROS packages.

### Open-source Autonomous Car Platforms

**Baidu’s Apollo Project**
Provides hardware platform, software platform, vehicle platform and cloud data services

**OSVehicle - EDIT**
Open-source self-driving car platform by OSVehicle

**Lyft Open Platform Initiative**
Early partners include Waymo, nuTonomy, Jaguar, Land Rover, GM

### Patents and other supporting infrastructure open to 3rd parties

**Tesla Motors**
Open-sourced all patents on AV development

**Comma.AI**
Comma Neo: Open-source robotics platform

**Wind River Rocket**
Open-source embedded operating system

**Uptane**
Open-source Cybersecurity framework

Voyage, the self-driving car spin-out from Udacity, has open-sourced its approach under an Open Autonomous Safety initiative. It has also deployed 5 Level-4 autonomous vehicles in retirement communities in California and Florida.

StreetDrone is another UK based start-up developing open source self driving software and automotive car models on the Renault Twizy.

Note: The list above may not be exhaustive. We shortlisted major open source initiatives as of Feb, 2018 which have been accelerating growth of the autonomous vehicle ecosystem; The above analysis is based on the DRAUP’s proprietary engineering database and insights from industry stakeholders, updated as on Feb, 2018
Electric Autonomous Cars such as Hybrid, Plug-ins and Plug-in hybrids autonomous cars to cover the urban transportation landscape by the next decade

- **Level 2** integration with Cadillac CT6 hybrid
- **Level 3** integrated Cadillacs
- **Level 4** deployment with Jaguar I-Pace
- **Level 5** integrated Cadillacs
- **Level 5** capable hardware in Tesla Lineup
- **Integrated level 2** in Tesla Model S & X
- **Integrated level 5** capable hardware in Tesla Lineup
- **Activate Level 5** in all models through over-the-air updates (OTA)
- **Deploy self-driving with a fleet of Ford Fusion Hybrids**
- **Testing self-driving with a fleet of Ford Fusion Hybrids**
- **Partner with OEMs** to deploy AV technology.
- **Partner with OEMs** to deploy AV technology.
- **Test self-driving with a fleet of Volvo XC90**
- **Test Self-driving with a fleet of Volvo XC90**

➢ 58% of autonomous light-duty vehicle models are currently built over an electric powertrain while a further 21% utilize a hybrid powertrain, according to a testimony submitted at the House Energy & Commerce Committee.

➢ Top drivers for Electric Autonomous Vehicle adoption:
  - **Regulatory restrictions** relating to gas-mileage requirements.
  - Electric cars are easier for computers to drive due to fewer moving parts and low maintenance.
  - **Wireless charging integrates** seamlessly with autonomy

➢ Self driving cars to populate urban areas first due to better availability of charging stations. The US Department of Energy lists around 36,000 such charging stations across America.

Note: The infographic above shows analysis done on specific companies. There are several other companies working towards the automation of electric vehicles. The above analysis is based on the DRAUP’s proprietary engineering database and insights from industry stakeholders, updated as on Feb, 2018.
China leapfrogging in EV sales and production (up 53% over 2016) is a key hotspot for Electric – Autonomous vehicles as more and more Chinese start-ups are focussing on developing EV-AV integrated vehicles

Key Chinese EV start-ups with Autonomous Focus

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| Capital Raised | $2.1 Billion | $2 Billion | $840 Million | $700 Million | $240 Million |
| Production Model Launch | 2017 | Q3 2018 (expected) | Q3 2018 (expected) | 2019 (expected) | 2019 (expected) |
| Self-driving Car Partners |        |        |        |        |        |
| California/China Test Permit | Yes/Yes | No/No | No/No | No/No | No/No |

China Ecosystem Insights

➢ With the Chinese government’s motive to make EVs account for 12% of overall cars sales by 2020, EV makers sold **777,000 vehicles in China in 2017** (2.7% of total car sales) vs **200,000 cars in the US** (1.2% of the total car sales)

➢ This leap in Electric Vehicles sales and production coupled with the fact that Electric cars have fewer moving parts and less maintenance overheads, has pushed Chinese Autonomous Vehicle and Electric Vehicle makers to conceptualise Autonomous Electric Vehicles.

➢ Chinese government has set up **Autonomous car demonstration zones in Shanghai, Hangzhou, Chongqing and Wuhan** and has allowed open road testing in Beijing. With this easing of regulations, Chinese Autonomous start-ups headquartered in Silicon Valley, such as **Pony.ai and JingChi have shifted their HQs back to China.**

➢ Chinese Internet firm **LeEco** also announced an autonomous EV concept project, called LeSee, backed by $1 billion in capital investments from Lenovo

Note: The above analysis is based on the Office of Beijing Municipal Public Security Bureau and DRAUP’s proprietary engineering database and insights from industry stakeholders, updated as on Feb, 2018

Source: DRAUP
New Business Models such as shared service model and fleet owned taxis for self-driving cars would replace the traditional car ownership model.

Service and public utilization based models to dominate while traditional ownership model to diminish

<table>
<thead>
<tr>
<th>Business Model</th>
<th>Description</th>
<th>Examples</th>
</tr>
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<tbody>
<tr>
<td>Individual Owned Shared Service Models</td>
<td>Privately owned vehicles provide ride hailing/sharing service when owner is not currently using it.</td>
<td>Uber, Lyft</td>
</tr>
<tr>
<td>Fleet Owned Taxis</td>
<td>Service company operates fleet of autonomous vehicles to provide mobility services</td>
<td>Waymo, NuTonomy, Lyft</td>
</tr>
<tr>
<td>Vehicle Licensing</td>
<td>Consumers pay owner for the use of vehicle in the</td>
<td>Customizable rental programs</td>
</tr>
<tr>
<td>AV–enabled software packages</td>
<td>Services and software that unlock full autonomous capabilities</td>
<td>Productive software suites</td>
</tr>
<tr>
<td>Retrofit</td>
<td>Package of Hardware and Software to retrofit fully autonomous capabilities on selected vehicles</td>
<td>Comma One</td>
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Note: The above analysis is based on the DRAUP’s proprietary engineering database and insights from industry stakeholders, updated as on Feb, 2018.
Level 5 Autonomous Vehicles have Millions of Test Miles to complete before they can be Consumer Ready; Companies are investing in Simulation platforms

Waymo and GM seem to be way ahead of the competition when it comes to real world tests but are way behind the Industry Standard.

On-Road testing is a very lengthy process which could take years to complete. Hence companies are shifting their focus towards simulated testing which can simulate all aspects of the autonomous drive without posing any risk to pedestrians or other motorists.

OEMs are still figuring out the right balance of testing AVs in real world scenarios and simulated environments.

Companies like Tesla, Apple and BMW rely mostly on simulated testing of AVs.

Companies like NVIDIA, Electrobit, Cognata currently provide Simulation solutions for AV testing.

Testing through simulations also gives the ability to test countless variations in road conditions, scale and cost.

Research done by RAND Corporation suggests that autonomous vehicles need to drive 11 billion miles in testing before being ready for consumers while the company with the highest autonomous miles, Waymo has only completed 7 million miles in 10 years.

Note: 1-The data retrieved from the website of California DMV. The data reflects the number of test miles covered by AVs in the state of California from December 2016 to December 2017.
The current Autonomous Vehicle Technology Stack comprises of diverse technology providers across components, platforms and full stack autonomous solutions.

<table>
<thead>
<tr>
<th>Full Stack</th>
<th>Network Providers</th>
<th>Vehicle Data Platform &amp; Security</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Automakers and New age OEMs</td>
<td></td>
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<tr>
<td>Tech Mafia and auto start-ups</td>
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<tr>
<td>Niche Platform Providers</td>
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<tr>
<td>Components &amp; Hardware</td>
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<tr>
<td>Niche Equipment providers and Tier-1 suppliers</td>
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</tbody>
</table>

**Autonomous Vehicle Makers**

- Ford
- GM
- BMW
- Toyota
- Hyundai
- ZF
- Nava

**Semi-Autonomous Vehicle Makers**

- Tesla
- Harman

**ADAS Full Stack Systems**

- Waymo
- Apple
- Baidu
- Intel
- MediaTek
- drive.ai
- Argo AI

**Platforms for sensing & processing data**

- HD Maps & Navigation System
  - Here
  - TomTom
- Vision Systems
  - Civil Maps
  - DEEP VISION
  - Ironcom
  - Nauto
- AI/ Control System
  - AMotive
- Data Platforms
  - Udacity

**Processors**

- NVIDIA
- MIPS Technologies
- Qualcomm
- NXP
- Renesas
- ARM
- Velodyne's Lidar

**Components Providers**

- Embedded and wireless Sensors | Cameras
  - Bosch
  - Panasonic
  - Quanergy
- Lidar | Radar | Ultrasonic | Infrared
  - Bosch
  - Panasonic
  - Quanergy

**Design Software**

- MathWorks
- Synopsys

Note: The illustrated list of companies is not exhaustive; the above analysis is based on the DRAUP’s proprietary engineering database and insights from industry stakeholders, updated as on Feb, 2018.
Technology spending: Top 25 companies on Autonomous Vehicles

25 players

Cumulative investment in Autonomous Vehicle by top 25 players

OEMs | Tier-1s | Auto Start-ups | Software/Internet | Semi-Conductor
---|---|---|---|---
Bosch | GM | Tesla | Apple | Intel
Ford | Delphi | NVIDIA |

Autonomous Vehicle In-house¹ technology spend

~$10.5 Bn Engineering spend globally on autonomous technologies during 2017

Autonomous Vehicle External² technology spend

~$22 Bn AV – Acquisition, Corporate VC Spend and Partnership as of Feb 2018

Note: 1-AV In-house Technology spend: includes salaries and compensation along with spend on software, platforms and hardware tools required to develop In-house capability;
2-External Technology Spend: Consists of investment in Autonomous Vehicle and related technology areas through Acquisitions, Partnerships and Corporate Venture Arms;
The above analysis is based on the DRAUP’s proprietary engineering database and insights from industry stakeholders, updated as on Feb, 2018

Source: DRAUP
Two types of organisations are accelerating Autonomous Vehicle Ecosystem: In-house Innovators vs Collaborative Developers

1. In-house Innovators
- Start-ups and Tech Mafias have been investing in Autonomous Vehicle platforms and Vehicle Operating Systems, leveraging their strong software capability
- Key technology focus areas of these companies are Deep learning for vehicle control and Computer Vision for environment perception and sensing

2. Collaborative Developers
- Semiconductor giants such as Intel and OEMs such as BMW, Toyota and GM have established strong consortium to co-innovate
- These players have also acquired many companies which offer full stack Autonomous Vehicle solutions. Some of the significant acquisitions being Mobileye (by Intel) and Cruise (by GM)

Note: 1. Inorganic Growth Index: Function of investment in AV and related technology areas through Acquisitions, Partnerships and investment through Corporate Venture Arms; 2. Technology Maturity Index: Function of maturity of technology across the AV stack of components, sub-systems and full-stack autonomous systems required to develop AV capability

The above analysis is based on the DRAUP’s proprietary engineering database and insights from industry stakeholders, updated as on Feb, 2018
Tech Mafia and the Semiconductor giants are spending heavily alongside Automakers to develop strong Autonomous Vehicle capability

### AV Spend by Industry Verticals

<table>
<thead>
<tr>
<th>Industry Vertical</th>
<th>Spend Percentage</th>
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<tbody>
<tr>
<td>Traditional OEMs</td>
<td>34-36%</td>
</tr>
<tr>
<td>Tech Mafia</td>
<td>25-27%</td>
</tr>
<tr>
<td>Semiconductor</td>
<td>14-16%</td>
</tr>
<tr>
<td>Tier-1 Suppliers</td>
<td>10-12%</td>
</tr>
<tr>
<td>Automotive Start-ups</td>
<td>7-8%</td>
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<tr>
<td>Others*</td>
<td>&lt;5%</td>
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Note: The numbers above are rounded-off, so they might not add up to 100%

Others* include Telecom, Data Services, Insurance and other AV related infrastructure providers

- **OEMs** have strategic focus on developing critical **safety and driving systems** in-house. OEMs such as Daimler, BMW and Ford are establishing partnerships with technology providers to collaboratively develop software capability for vision and perception systems.
- **Semiconductor** giants such as Intel and Nvidia have developed **specialised Autonomous Vehicle SoCs** for processing and computing using ML algorithms.
- **Tech Mafia** giants are differentiating through strong AI capability leveraging **deep learning algorithms required to make advanced driving systems safe and predictable**.
- **Tier-1 suppliers** such as Bosch, Delphi and Continental are major players providing **Sensor Systems such as Lidar, Radar and Ultrasonic sensors**.
- Autonomous Vehicle **start-ups** have received nearly ~$3.5 Bn+ in VC funding as of Feb, 2018. **Full stack ADAS providers** is the most funded segment. Nauto, Argo AI and Drive.ai are the top players investing in full stack-Autonomous Vehicle solutions.

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Note: 1 Include investments on In-house R&D spend on engineering salaries and infrastructure support in AV and related technology areas; DRAUP Engineering Module – Include AV companies across major geographies such as US, Canada, Israel, Europe, China and India. Coverage may be limited in China and other south east APAC regions.
In-house R&D is focused on developing core software capabilities, leveraging deep learning for computing, vehicle control and vision-based perception.

**Total In-house Technology Spend**

**USD $ 10.5 Bn**

- **3D mapping/ Localization**: 11%
- **Vision based perception**: 24%
- **HMI/ UI-UX**: 10%
- **Computing & Vehicle Control**: 30%
- **Sensors**: 20%
- **Network, Connectivity & Security**: 5%

**Technology Segments**

**In-house Innovators**

- Lidar, Radar, Odometry and Ultrasonic sensor systems for lane centering, path planning and V2V communications

**INSIGHTS**

- High resolution HD Maps enable precise lateral and longitudinal positioning for vehicle localization.
- Computer Vision systems use advanced deep learning to aggregate, classify and identify critical environment data such as obstacles, pedestrians, traffic signs etc.
- HMI is crucial to optimally support the driver in monitoring and remotely control autonomous cars and to give access to live sensor data and useful data about the car state, such as current speed, engine and gear state.
- Using Neural Networks, the vehicle brain analyses all sensor input and operates steering, accelerator and brakes for critical driving decisions such as collision warning, cruise control and advanced safety.
- Advanced vehicle connectivity infrastructure to enable communication between vehicles and environment (V2V, V2X).

**Note:** The numbers above are rounded-off, so they might not add up to 100%

**Source:** DRAUP

**Note:** 1- Technology spend includes employee compensation and related expenses along with spend on software, platforms and hardware tools required to develop In-house capability; The above analysis is based on the DRAUP’s proprietary engineering database and insights from industry stakeholders, updated as on Aug, 2017.
Technology spend by the top 5 players is largely focused on developing full stack solutions, robust sensor systems and advanced computing platforms for vehicle control.

**In-house Innovators**

$10.5$ Bn

In-house R&D Spend

**Autonomous Vehicle in-house technology spending analysis**

- R&D spend by top 5 players: $\approx 56\%$
- R&D spend by next 10 players: $\approx 31\%$
- R&D spend by next 10 players: $\approx 13\%$

**Focus Areas of top 5 Players**

<table>
<thead>
<tr>
<th>Focus Area</th>
<th>HMI / UIUX</th>
<th>Sensors &amp; Processors</th>
<th>3D Maps/Localization</th>
<th>Vision and perception</th>
<th>Computing &amp; Vehicle Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAYMO</td>
<td>15%</td>
<td>10%</td>
<td>20%</td>
<td>15%</td>
<td>40%</td>
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<tr>
<td>BOSCH</td>
<td>5%</td>
<td>50%</td>
<td>10%</td>
<td>25%</td>
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<tr>
<td>GM</td>
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<td>Intel</td>
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Note: Technology spend includes employee compensation and related expenses along with spend on software, platforms and hardware tools required to develop in-house capability. The above analysis is based on the DRAUP’s proprietary engineering database and insights from industry stakeholders, updated as on Feb, 2018.

Source: DRAUP
While the AV talent footprint is distributed across global locations, US and Europe are the hotspots with nearly 50% of talent consolidated between these two regions.

### Geographical split

- **West coast USA**: 8K
- **Central USA**: 7K
- **Western Europe**: 4.7K
- **China**: 4K
- **UK**: 2.7K
- **India**: 2K
- **Israel**: 1.9K
- **Canada**: 1.5K

#### Note: Geographical split indicates only the prime Autonomous Vehicle R&D locations. Primary locations in West Coast include California, Washington and Seattle and Central US include Michigan and Ohio; The above analysis is based on the DRAUP’s proprietary engineering database and insights from industry stakeholders, updated as on Feb, 2018.

### Global Autonomous Vehicle Engineering Headcount

38,000 – 43,000

#### In-house Innovators

- **USA- Bay Area**: is a technology hub for engineering talent in **Machine learning, Computer vision and AI**
- **Global automakers**: such as GM, VW, Toyota have opened **R&D facilities in Bay area** in the last 2 years to leverage these new age engineering skills and lead the autonomous revolution.
- **Western Europe**: is a hotspot for traditional automakers. Bosch has built a $1.1 Bn R&D facility in Dresden, Germany for developing hardware components required for autonomous vehicles.
- **UK and Israel**: are mature autonomous start-up hotbeds for autonomous innovation, with top start-ups such as FiveAI, Oxbotica, Mobileye and HERE maps. Daimler recently opened a R&D centre in Tel Aviv and Jaguar Land Rover opened a new UK R&D center highly focused on autonomous R&D.
- **China**: – Baidu is a leading player in the Chinese landscape. It has more than 50 partners for its open source Apollo Project, which has created a collaborative ecosystem for autonomous technology development.
- **India**: Top tier 1 player Bosch has its 2nd largest R&D centre in India focused on sensor system and computer vision.

Note: The numbers above are estimated R&D headcounts in respective locations updated as of 1st quarter of financial year 2018.
In Bay Area, Automakers have established AV innovation labs to collaborate with Tech Mafias and disrupters, and explore new AV enabled mobility solutions

In-house Innovators

Google’s Core R&D team of ~1,000 engineers, located in the Bay Area, is largely focused on developing deep learning software capability for advanced vehicle control and automation

Tesla is building critical ADAS systems in-house and leveraging partner network with Nvidia and Bosch for autonomous hardware capabilities.

Invested $14 M on the new expanded R&D facility in California and plans to add 1,100 workers to it’s new acquisition team at Cruise Automation

Opened a new Automated Driving Group in Silicon Valley and plans to invest $250 M on self-driving tech via its Intel Capital investment arm. Intel also has 3 other autonomous R&D labs in Arizona, Germany and Oregon.

Uber poached around 50 researchers and engineers from Carnegie Melon University’s Robotics Institute to build its autonomous capability

Followers

To invest $1 Bn in San Francisco over next five years in AI and self-driving cars R&D

Invested $1 Billion in AI startup Argo AI; Developed aDRIVE gaming environment for autonomous test driving

VW works in partnership with Stanford University for autonomous driving. Its research lab - Volkswagen Automotive Innovation Lab is located within the Stanford University campus

Acquired HERE maps for 3D mapping technology

Bosch has an autonomous driving solutions center in Palo Alto. It partnered with Daimler to launch automated valet parking system

Emerging Players

Note: Includes recent R&D initiatives and collaboration announcements/activities of the above mentioned players. List of emerging players non-exhaustive;

The above analysis is based on the DRAUP’s proprietary engineering database and insights from industry stakeholders, updated as on Feb, 2018

Source: DRAUP
Semiconductor giants and OEMs have been leveraging collaborative AV innovations...

**Total investment spend to acquire AV capability**

- **SEMICONDUCTOR**: ~$18 Bn
- **OEM**: ~$3 Bn
- **TECH MAFIA**: ~$1 Bn

Top Acquisitions:
- **SEMICONDUCTOR**: Intel, NVIDIA, Mobileye, Qualcomm
- **OEM**: GM, Ford, Argo AI
- **TECH MAFIA**: Google, Waze

Note: The above analysis is based on the DRAUP’s proprietary ecosystem database, updated as on Feb, 2018.

Source: DRAUP
...acquiring highly mature solutions to develop AV capability in emerging areas

Collaborative Developers

AV acquisitions by technology focus areas

Early Movers

Google made the inception into Autonomous Vehicle space through acquisition of mapping technology company Waze to incorporate real-time traffic data into its existing self-driving project.

Aggressive Acquirers

OEMs and Tier 1 suppliers being digitally naïve companies started acquiring mature autonomous capabilities through their Venture arms and strategic acquisitions. Some of the mature acquisitions include Cruise Automation by GM and HERE Maps co-investment by GM, BMW and Audi.

Recent Movers

Semiconductor giant Intel recently made the biggest acquisition in the AV ecosystem, investing $16 Bn to acquire core AV capabilities from Mobileye. It has also leveraged its partnership network to position itself as a full stack AV provider.

Note: List above is non-exhaustive
The above analysis is based on the DRAUP’s proprietary engineering database and insights from industry stakeholders, updated as on Dec, 2017

1- Analyzed Acquisition maturity with respect to the acquired technology maturity across the stack of components, sub-systems and full stack autonomous systems

Source: DRAUP
Incumbents have also established consortiums to co-innovate; Intel, BMW and Nvidia have the most robust partnership networks among their peers.

Note: The above analysis is based on the DRAUP's proprietary ecosystem database and insights from industry stakeholders, updated as on Aug, 2017.
Automakers are thinking ahead and collaborating with Technology providers and disrupters to move beyond their traditional business segments.

Components (Sensors)

ADAS Systems

AI/Computer Vision

Mapping

OS, UI, HMI Software

Connectivity (Infrastructure)

Collaborative Developers

Automakers

Tier-1s

Technology Suppliers

Software

Platforms

Hardware/Processors

Services/Operators

Mobility Services

Network, Security and cloud

Bosch is co-innovating with Nvidia for the AI based software systems for its sensor technology.

Delphi

CRUISE

Intel

Mobileye will provide computing platform, sensing & localization expertise.

Provides data processing, and computing SoCs along with Sensors and connectivity.

Provides full stack ADAS system.

Customized algorithms of computer vision, machine learning

Provides full stack ADAS system.

Cloud based open location platform; provides mapping and traffic data.

Connected car application to connect mobile to car dashboard.

Connected car application to connect mobile to car dashboard.

BMW and Ford have collaborated with ride sharing giants such as Lyft and Uber respectively largely to mine vehicle driving data.

Microsoft, Valeo & Renault

Nissan group partnered to leverage Azure cloud platform customization for data security, connectivity and privacy.

Ericsson and Toyota have partnered for developing 5G infrastructure for enabling V2V, V2X communications.

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Connectivity (Infrastructure)
Tier-2 suppliers are disrupting the traditional supplier relationship model to position themselves as a direct Full-stack supplier of AV solutions; **CASE STUDY-Intel**

**Traditional Industry Structure**

**New Age Industry Structure**

Intel can now offer **full stack solutions** related to autonomous vehicles - cameras, in-car networking, sensor-chips, roadway mapping, cloud software, machine learning and data management.

**Collaborative Developers**

**Tier-2**

- Intel
- Mobileye

**Tier-1**

- Continental
- Bosch
- Velodyne

**Tier-2**

- Velodyne
- Mobileye
- Harman

**Tier-n**

- Here
- HARMAN
- KARMA

**OEM**

- Ford
- GM
- Volkswagen
- Toyota

**Network**

- Intel along with Ericsson and GE has launched an open industry platform - 5G Innovators Initiative (5GI2)

**Full Stack systems**

- Mobileye provides full stack Autonomous solution based on vision systems, sensor technology and computing platform

**Connectivity/Data management**

- Intel partnered with Harman for leveraging its connectivity platform to enable V2V and V2X communications

**Sensors**

- Velodyne provides LIDAR technology for vehicle safety systems, 3D mobile mapping and security.

**Mapping**

- Here provides cloud-based open location platform; provides mapping, traffic data.

**Note**: The above analysis is based on the DRAUP’s proprietary ecosystem database and insights from industry stakeholders, updated as on Feb, 2018.

**Source**: DRAUP
Going ahead, we believe companies are committed to drive future growth in the autonomous space.

The overall Ecosystem looks populated, but through our structured research and deep dive analysis of the current capability and investment of the 25 players, we have arrived at the league of 5 for 2020 Autonomous Vehicle launch.

The league of 5 are well positioned and future-ready, basis their current R&D investment or via virtue of their acquisitions and/or partnerships.

Ford and Waymo have committed to attain Level 5 automation capabilities whereas Intel, Tesla and Bosch have envisioned Level 4 automation by 2020.

These players have been exploring a diverse set of GTM strategies such as partnerships with mobility providers, fleet management and personal ownership model to launch their first commercial Autonomous Vehicles by 2020.


The above analysis is based on the DRAUP’s proprietary engineering database and insights from industry stakeholders, updated as on Feb, 2018.
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