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Autonomous Vehicles: Why Drive When the Vehicle Drives You

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Published: June 2020

Executive Summary

The idea of being effortlessly chauffeured by self-driving cars or autonomous vehicles (AV), has been a dream of futurists for several decades. They envision a time where we will simply input our destination and be safely driven there while we do work, relax, watch a movie, or even take a nap. Commercially, trucks will self-drive in platoon formations 24 hours a day transporting goods from one part of the country to another.

Google was one of the first companies focusing on autonomous technology to hit a major milestone in 2009 when Google's Waymo first demonstrated a 1,000 mile drive in a prototype, self-driving Toyota Prius. Since then, major automotive companies, along with hundreds of new companies, have entered into the self-driving arena. Both Waymo and Voyage now have fully self-driving robo-taxi fleets operating in specific communities in Florida, Arizona and California. There have been highly successful self-driving trucking tests by companies such as TuSimple and the now defunct Starsky Robotics.

Firms tout new achievements in AV technology weekly, but for now, almost all operate in a test mode capacity as they develop data to further increase the safety and reliability of their AV systems. Reliable and unwavering safety of these systems remains elusive due to a high level of complexity. It will likely be upwards of three years minimum before we see a commercially viable AV platform that meets the necessary safety and reliability standards, likely a level 4 (L4). The dream of a level 5, fully autonomous vehicle is probably a decade or two away.

Market Growth

Forecasts from market research studies vary greatly and will be affected by the current economic downturn. The AV market will see growth and is projected to increase from $5.7B in 2018 to $60B in 2030.[1] This includes self-driving vehicles as well as growth from development and manufacturing of the underlying hardware sensors, computing platform and software.

History of Autonomous Vehicle Technology

One of the first autonomous vehicles was the Stanford Cart, which was developed in 1961 with a camera and rudimentary AI (artificial intelligence) system but was very slow – moving only one meter in 20 minutes. Since then some notable developments include:

- The Navlab developed by Carnegie Mellon in 1995, which steered autonomously on a 3,000 mile route but required human drivers to control braking and acceleration.
- In 2002 DARPA issued the DARPA Grand Challenge to academia and private industry with the goal of furthering the industry by developing a self-driving vehicle to navigate a 142 mile course in the Mojave Desert. In 2004, 15 competitors entered the Challenge but none finished. Most vehicles crashed, flipped or rolled over within sight of the starting gate. The most successful vehicle was Carnegie Mellon's Sandstorm, that drove seven miles in several hours before the vehicle caught fire. Technology became incrementally better and in 2005, five vehicles completed the course with Stanford's Stanley winning it.

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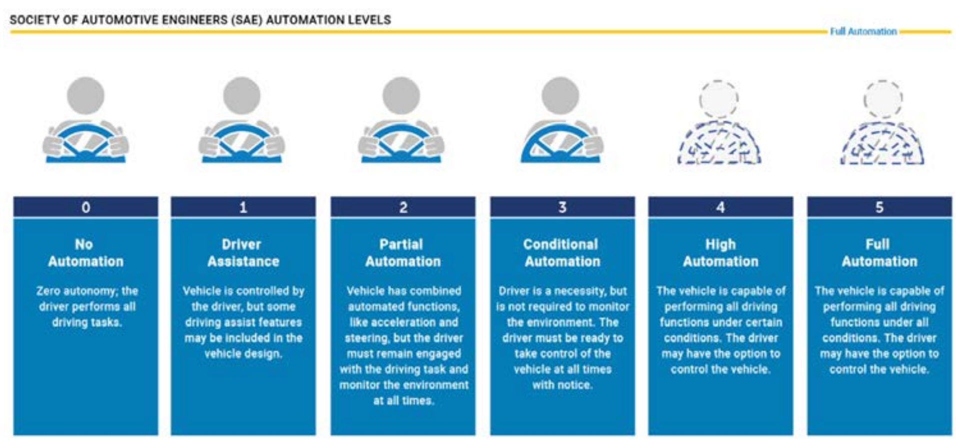
- In 2009, Google's Waymo division and its Toyota Prius self-drove 1,000 miles in California. Shortly thereafter, sensing the future of the transportation market, numerous other automotive manufacturers and private firms began work on their own AV technologies.
- As of 2020, there are hundreds of companies worldwide with viable self-driving solutions including AV platforms, software operating systems, AI software stacks, and sensor and computing hardware. Waymo has 20+ million miles of public miles driven in 25+ cities in the U.S. and another 10+ billion simulated miles driven.[2]
- Despite these significant milestones and improvements within the past decade, it is clear that more development and time is needed before we see a commercially viable and practical level 4 AV solution. Volvo believes that they will have an autonomous vehicle for highway self-driving by 2022.[3] Brian Collie, of the Boston Consulting Group, predicts that level 4 commercialization will not occur until 2025 or 2026.[4]

SAE Automation Levels

The SAE (Society of Automotive Engineers) has defined six levels of driving which are used by the industry in describing self-driving technology.[5] For example, adaptive cruise control/lane control/braking are level 1 while Tesla's Autopilot is level 2. Waymo and Voyage along with numerous other companies have level 4 technology. Industry is working towards level 5 but no one has currently achieved it. Most of the AV industry is focused on level 2 or 4 and skipping level 3; there is a liability concern that Conditional Automation isn't sufficiently automated and may confuse the driver causing them to be overly reliant on the system when they should not be.



What's in a Self-Driving or AV System?

At a simplistic level, a self-driving/AV system is a plethora of sensors, computer processing hardware and a significant amount of highly sophisticated software, with a car thrown in there for good measure. To understand the sophistication of the AV software, consider that an F22 fighter jet uses 1.2 million lines of software code in its computing platform, a Boeing 787 Dreamliner has 6.5 million, while a typical level 4 AV will have 500-700 million lines of code. This is necessary in order for the AV to handle the complexity of intended and unintended interactions.[6]

The software stack consists of a computer platform with ML/AI (machine learning/artificial intelligence) algorithms. It receives and processes a significant amount of real-time data from the hardware sensors to manage four key vehicle functions – 1) where am I, 2) what is around me, 3) what will happen next and 4) what should I do?[7]

Hardware includes GPS (or GNSS – Global Navigation Satellite System), computing systems (off-the-shelf and dedicated chipsets to process the incoming data from the sensors and GPS), and a variety of sensors. For example, NVidia has designed chipsets specifically for ADAS and AV systems.

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Sensors are typically commercial-off-the-shelf devices but some of the larger AV firms develop proprietary sensor systems. These include LiDAR, radar, stereoscopic cameras, thermal imaging cameras, ultrasonic sensors, and microphones. The combination of these sensors provides the vehicle's compute system with perimeter, peripheral and short and long range situational awareness that extends 360 degrees around the vehicle.

LiDAR (Light imaging detection and ranging) can be viewed as an optical radar that uses an infrared laser to sweep an area, detect the reflected light and paint a picture of the area. LiDARs now have a range of up to 350 meters. Multiple (up to six) radar systems located on the front, rear and side of the vehicle provides a short and long range perspective that extends 360 degrees around the vehicle with a range of up to 500 meters. Camera systems with more than two dozen overlapping cameras provide imaging data with depth-of-field and stereoscopic (near 3D) vision. Ultrasonic sensors provide information on objects close to the vehicles. Some OEMs also use microphones to listen to specific sounds such as emergency vehicles which provides another important data stream to the onboard computing hardware.

There are 80+ manufactures[8] of LiDAR, including some well-known firms such as Velodyne, Luminar, Valeo, Ouster, Innoviz, and Aeva. LiDAR is more precise and better at detecting smaller objects compared to radar, works very well at night compared to camera systems, and has a longer range. However, it has a number of disadvantages. It is expensive (though getting cheaper), some of the sensors have moving components (but some are solid state now), it doesn't work well in rain and snow as these can absorb or scatter the light, and it doesn't work well when the sun is shining directly into the sensor (at dusk or dawn). Radar works better for longer distances but can create false images of smaller objects due its longer wavelength. However, in some studies, the use of radar in conjunction with stereoscopic cameras has worked as well as LiDAR for small object detection. This is one of the reasons why Tesla uses radar and not LiDAR. However, camera and radar systems do have a harder time spotting vehicles that have stopped ahead on the road.

There are pros and cons with each of these sensors, but together they complement one another and increase the overall effectiveness of detecting objects in the environment.

These sensors need to be designed to operate over the long-haul and in varying environmental conditions. They need to remain free of dirt, snow, and ice requiring OEMs to consider wipers, and heating/cooling vents/fans. These sensor packages are currently installed on vehicles as an after-market commodity by the AV firms, but over time they will be integrated into the vehicle – either designed in by the automotive manufacturer or as preconfigured package designed for a specific vehicle type.

Self-Driving Applications

While the desire is for the regular consumer to be able to purchase a L4 autonomous vehicle, the high cost of the sensor hardware systems in such vehicles will likely limit the initial application to transportation use (e.g. robo-taxis, last mile delivery and long haul trucking). Private AV use will not likely occur for several more years.

Voyage Auto, Optimus Ride and Waymo One are already operating robo-taxi systems in Florida, California and Arizona. Voyage Auto operates a fleet of AV taxis to shuttle residents in a large retirement community in Florida. TuSimple, Kodiak, Ike Robotics, Pronto.AI and number of others are developing long-haul autonomous driving system for trucks. Nuro.AI, Starship Technologies, Refraction AI and others are developing smaller, slower speed vehicle systems designed for last mile delivery (from a local warehouse to customer's home or business) of groceries and packages. Instead of leaving a package at a customer's home with the hope that porch pirates don't get to it

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before the homeowner, with last mile delivery, the homeowner can request delivery at a time of their choosing. The customer receives a code by text which allows them to access and retrieve their delivery from the secured compartment of the self-delivery vehicle.

Federal and State Regulations

The Federal government's Department of Transportation (and its NHSTA agency) has developed guidance on autonomous vehicles. In January 2020, the DOT released Ensuring American Leadership in Automotive Vehicle Technologies: Automated Vehicles 4.0. This supplements Preparing for the Future of Transportation: Automated Vehicles 3.0 released in October 2018. The Federal government is aggressively encouraging advancement with AV technology, both from an economic perspective as well as driver safety. Per the National Safety Council, in 2019, nearly 39 thousand people lost their lives and 4.4 million were injured in automotive accidents with 94% of these accidents caused by human error.[9] The DOT/NHTSA guidance is voluntary and stops short of regulating self-driving vehicles, leaving this up to individual states. There is concern with safety experts that this approach is placing AV innovation before safety.

There are more regulatory requirements at the state level, with California leading the way for self-driving passenger vehicles. The CA Department of Motor Vehicles requires AV firms to register and seek permits for testing self-driving vehicles and driving driverless vehicles on public roads, to file dis-engagement reports[10] and miles driven, maintain insurance with specific limits, have testing programs for their drivers, etc. Dis-engagement information is collated by the DMV in an annual report.[11] Although there is good intention with the annual report, the industry does not see as much value in it because each firm interprets and defines a dis-engagement differently.

Many other states have similar requirements for self-driving vehicles. Currently, there are 30 states with legislation, six have enacted executive orders, five have both, and ten states plus five territories have no legislation yet. Testing and deployment varies from simply studying the technology to full deployment/testing without a safety operator. 13 states allow firms to study AV. Eight states only allow for the deployment or testing of self-driving vehicles with a human operator. At the other end of the spectrum, two states (OH, WA) allow for testing only without a human operator, while ten states (CA, AZ, FL, GA, MI, NE, NV, NC, TN, and TX) allow for the full deployment of AV without a human operator.[12]

Five states (AL, IN, KY, MI, and SC) have regulations addressing truck platooning. Generally, for self-driving trucking applications, the states defer to the DOT and its guidelines.

Safety Standards

As there are no human drivers in an AV, the vehicle will have to self-manage all failures, and internal and external faults correctly, 100% of the time. For AV technology to become viable and commercially available, it must be designed to meet very high safety standards. This is not only for the occupants of the AV but also external factors - pedestrians, vehicles and other property around the vehicle. Safety and how an AV system will behave in the event of unusual, unintended or unforeseen event is of paramount importance.

There are a number of safety standards that AV firms need to consider and design their systems against to ensure that the system works correctly at all times. ISO 26262:2018 Road Vehicles-Functional Safety[13] addresses functional safety of electrical and/or electronic systems in automobiles. It ensures that there is an awareness of the hazards and has been designed to prevent people from being injured by some fault in the system's hardware and software. Emphasis is on avoiding design faults through a quality management system and mitigating the effects of the equipment failing during operation. Due to complexity with automotive systems, they need to meet

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additional controls as noted by ASIL D (Automotive Safety Integrity Level D). For example, automotive infotainment systems have to meet lower safety thresholds denoted as ASIL B.

However, in the self-driving world, there are unsafe events and unintended consequences that happen outside of the vehicle system. These are environmental faults that happen outside of the scope of the vehicle itself. ISO/PAS 21448:2019 or SOTIF (Safety of the Intended Functionality) addresses this exposure. It extends the scope of ISO 26262 to cover ADAS/self-driving functionality thereby providing for a complete safety solution for self-driving vehicle systems. The automotive industry created this "safety standard for driver assistance functions that could fail to operate even if no equipment fault is present."[14] SOTIF requires developers to design a system so external, unintended events can be safely handled. It requires that the developer design the system to handle not only the known unsafe events but also the unknown, unsafe events that could affect the AV. Some examples include: how the AV's LiDAR system handles glare from the combination of the sun and oncoming vehicle, what it will do when a rock kicked up by a truck in front of it hits its wind shield, or how it reacts to a pedestrian laying down on the road. These are all unknown, unsafe external events that could undermine the overall safety of the AV system if they are not handled appropriately.

UL (Underwriters Laboratories) released UL 4600, Standard for Safety for the Evaluation of Autonomous Products in April 2020. It encompasses autonomous systems including self-driving cars, other vehicles as well as drones. It works in conjunction with ISO 26262 and 21448 but does not require conformance to these standards. Focus is on ability of autonomous products to perform safely and as intended without human intervention. Reliability of hardware and software necessary for machine learning, sensing of operating environment and other safety aspects of autonomy is also addressed.[15] UL 4600 concentrates on ensuring that a valid safety case is created through three elements: goals (what is safe in a specific context and safety requirements), argumentation (explanation on why a goal is achieved), and evidence (data from analysis, simulation and tests that supports argument validity).[16]

Issues & Concerns

With any new technology, there will be major concerns on safety and reliability of the technology. System safety, Legal/regulatory and insurance requirements will all factor into how readily this technology becomes mainstream.

- Failure of system – As noted earlier, AV systems are highly complex mix of software, hardware sensors and computing platforms and communications systems. A failure could affect a single or entire fleet of self-driving vehicles. It could result in a vehicle simply stopping, or a vehicle going out of control, resulting in property damage and bodily injury to the passengers and others. There is also concern that sensors could be spoofed. Researchers have shown that vision and LiDAR systems can be fooled or hacked, causing the AV system to react erratically. They have used drones to fake lane markers on the road causing the AV to follow the modified path. They also projected both stop signs and modified speed limits onto existing roadside signs causing the vehicle to either stop or to speed up (vehicle saw a spoofed speed limit of 55 mph rather than the actual 35 mph)[17] respectively. LiDAR sensors may also be spoofed to see a virtual obstruction causing the vehicle to either stop or perform an emergency maneuver.[18]
- Machine Learning (ML)/Artificial Intelligence (AI) - AV software systems will use ML/AI for learning. These systems are self-learning within defined boundaries and they get better as they learn and improve the system over time. However, there is some question as to what happens when the system receives a new software update from the OEM- does that wipe out all of the learning the system has done and does it have to start over again, or has the OEM designed the update process to retain this level of learning? Additionally, does the ML system have supervised or unsupervised learning? Unsupervised learning refers to data analysis methods

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where there is no defined or measured output for a set of inputs; no specific boundary conditions. This makes it harder to quality control but also conduct root cause failure analysis in the event the system fails. In such systems, the ability to assess and correct a software defect may be more challenging.

- Communication and Network Security – Communication channels between the vehicle and home base or amongst self-driving vehicle fleet needs to be secure or vehicle(s) could be hacked. Secure and robust communication channels are necessary to prevent the compromise of over-the-air software updates. Authentication protocols, use of strong encryption, and measures to ensure that communication channels aren't compromised will be essential.
- Connected Vehicles or Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) - The Federal Government has released guidance on Connected Vehicles – where vehicles, including AV, communicate with one another and with surrounding infrastructure to make the driving process safer and more effective. A vehicle that has broken down can communicate that fact to others around it so that they can navigate around the vehicle and avoid a collision. V2V and V2I will greatly enhance the self-driving experience but if the communications channels aren't secure and safe, they can be compromised and the integrity of the entire AV platform could be at stake. The DOT provides guidance on SCMS (Security Credential Management System)[19] which would provide real-time authentication of connected vehicles and infrastructure through the use of real-time digital certificates from trusted certificate authorities.
- Ethical Consideration – This is the classic dilemma of whether the AV system, in the event of a pending accident (e.g. head-on collision), will compromise either itself and its passenger(s), or run into a pedestrian/vehicle in the street, or in an effort to avoid the pedestrian the AV turns into an adjacent crowded shop, or it does none of these? This is a challenge that AV firms will definitely have to consider. As each scenario can vary greatly, it would be difficult to program a specific response to each scenario. More likely, AV systems will utilize ML/AI algorithms for continuous learning and improvement; starting with an initial dataset of scenarios, learning and improving over time.
- Insurance – For self-driving vehicles to succeed in the coming years, there will need to be an adequate insurance mechanism in place to address both 1st and 3rd party damage and liability. Of key concern will be who is held responsible if a self-driving vehicle fails to operate as designed resulting in an accident and causing property damage and bodily injury.
    - Is it the driver or the manufacturer of the self-driving vehicle?
    - Will this be treated as an auto liability or a products liability claim?
    - Venturing one step further, would the manufacturer pass liability onto the others such as the sensor, software, computing system or hardware manufacturers/developers?
    - Since most of the AV firms use standard vehicles from known OEMs (e.g. Ford, Toyota, GM, Honda, others) and modify these vehicles to make them into self-driving vehicles, would these OEMs have any liability? If so, how much? Or will all of the liability fall on the self-driving firm as they have modified the vehicle?
    - We would also need to consider the liability of the other driver and more importantly, take into account whether the other driver is a HV (human driven vehicle) or an AV?

  Until there is sufficient case law, there will continue to be a great deal of uncertainty on accurately assessing who will be deemed and held responsible.

  Within the industry, the belief is held that this should be covered solely under commercial automobile liability, which does have inherent benefits - it is a well-known coverage to the general public, it provides coverage for both 1st and 3rd party claims, and it can provide faster financial relief for the claimants (compared to a long drawn-out court case under products liability).

  Another school of thought is that it would be best for the AV firm to provide the 1st and 3rd party liability coverages to their customer. The AV firm would also hold its suppliers and vendors harmless. This should direct all claims directly to the AV firm and allow them to handle

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the claim. The suppliers and vendors would pay a “premium” to the AV firm for the hold harmless protection. By doing this, defense costs could be greatly limited (one defendant instead of dozens) resulting in a quicker resolution of a claim.

Conclusion

The industry will continue to experience growing pains with technology – from AV failing unexpectedly resulting in accidents including property damage, injury and/or death or network failures impairing or negatively affecting a large group of self-driving vehicles. Economically, this technology could lead to large scale job loss in the transportation sector as self-driving vehicles eliminate the need for drivers. There will also be major consolidation in the number of firms in the AV sector as they get acquired or go defunct due to lack of funding.

However, as this technology matures into the next several decades, the positives will likely outweigh the negatives. The technology can save lives as it eliminates negative elements of human-driving such as driving while impaired and sleepy or distracted driving. There would be potential increases in productivity (working while being driven), reduction of mental stress, more efficient traffic flows, and overall reduction in traffic due to more shared usage of autonomous vehicles. The economic impact in the transportation sector could be balanced by job growth that will require employees to develop a new skillset.

Though it may take years before we start to see commercially viable AV applications and uses, all the indicators point to us entering the beginning of the next golden age of technology as we work towards a self-driving culture.

Contact Us

To learn more about how OneBeacon Technology Insurance can help you manage online and other technology risks, please contact Dan Bauman, VP of Risk Control for OneBeacon Technology Insurance at dbauman@onebeacontech.com or 262-951-1455.

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