Innovation through Automation

How autonomous systems are changing the automobile industry

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Over the past 100 years, automotive technology has consistently advanced to improve both vehicle safety as well as user experience. With each new model year, cars and trucks become bigger, faster, safer and more luxurious. Modern vehicles are capable of feats industry pioneers like Henry Ford and Ferdinand Porsche could not even fathom. Despite the onslaught of innovation one thing has always remained a constant: the need for a human to operate the vehicle. Illustrations of driverless cars have adorned the covers of magazines and advertisements since the 1950's, but predictions of the demise of the human driver have never come to fruition. Until now. Technology from industry titans such as General Motors, Mercedes Benz, Ford and Volkswagen are proving that software, not soft tissue, may prove to be the best drivers. Perhaps the biggest catalyst for change has been the entrance of a new player in the automotive field: Silicon Valley. Developers in the technology industry have taken their programming to the streets and are challenging the status quo from traditional manufacturers. But while the competition for automotive supremacy may be fought from research facilities in Stuttgart and Detroit, the biggest obstacles will have to be tackled in the court rooms of Washington and Brussels. Technology is outpacing regulation, and legislation is struggling to keep up. Lawmakers must take new approaches to ensure innovation in autonomous driving is not stifled. But the benefits are undisputable: these technologies will lead to safer roads while helping save our environment.

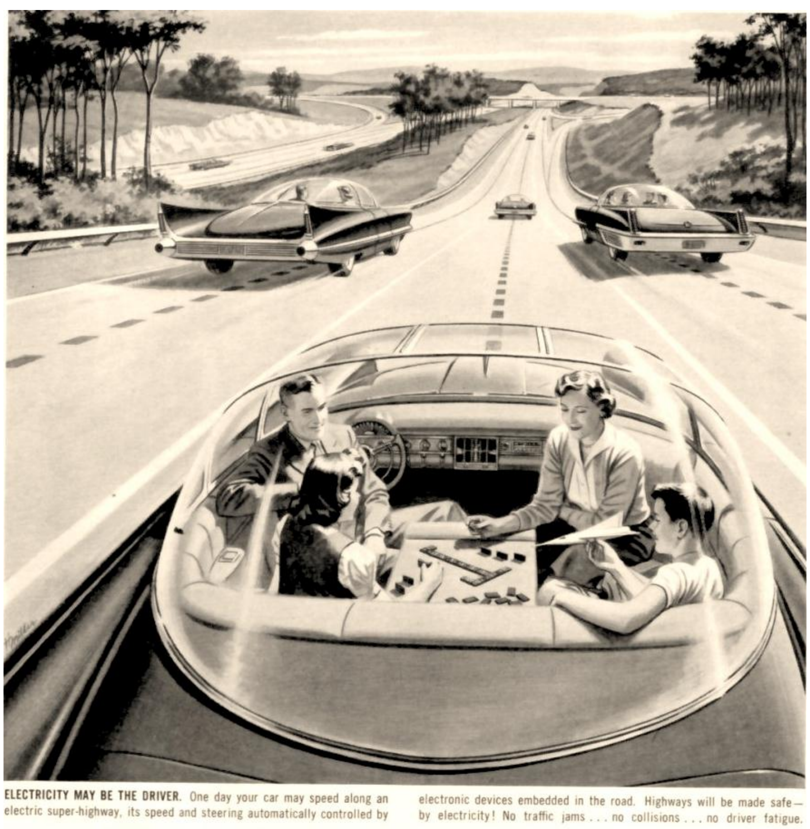

Figure 1 ***Source: Time Magazine, Dec. 17 1956***

Safety through Innovation

Auto manufacturers have made incredible progress in making our vehicles safer over the years despite the ever-increasing size and power of cars and trucks. With innovations such as air bags, anti-lock brakes and seat belts, the United States has seen the number of deaths per vehicle mile travelled decrease by more than 50% in the last 35 years (Insurance Institute for Highway Safety, 2015). Recent gains made in the European Union are even more impressive. Overall EU fatalities have decreased from 54,900 in 2001 to 31,500 in 2010 – a reduction of 43% in just 9 years (European Commission - Directorate General for Mobility and Transport, 2015). *Figure 2* illustrates that even over a short period of three years a tangible positive impact has been made in road safety.

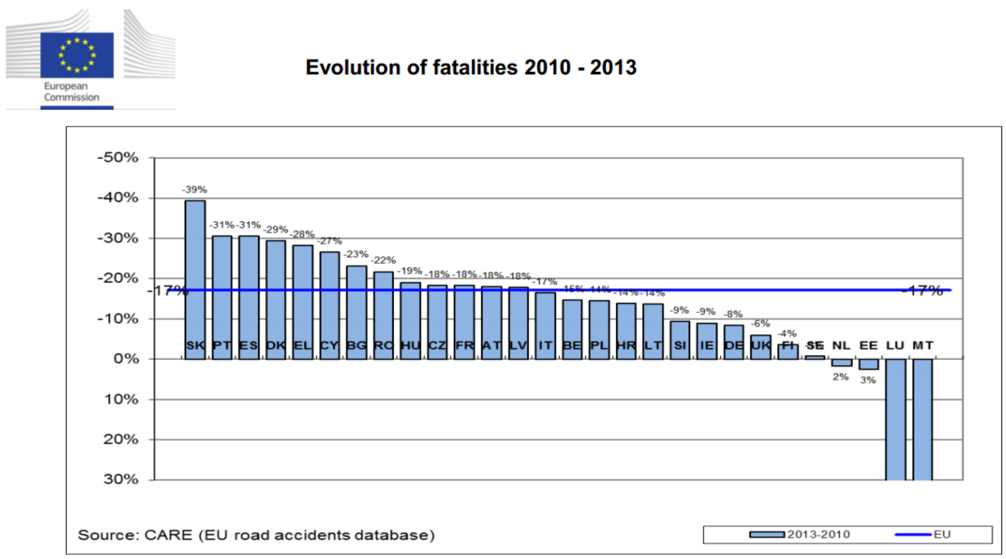

Figure 2 ***Source: EU Commission Mobility and Transport***

Despite the positive trend, there is still an urgency to push advancement of safety technology. The United States is expecting to see its population grow more than 70 million by the year 2045 which will put more cars and trucks on the road than ever before (US Department of Transportation, 2015). Vehicle ownership is sky rocketing in emerging markets as new segments of the populations in India, China and Brazil are heading to auto dealerships. New technology will be relied on more than ever to ensure drivers and passengers reach their destinations safely.

The most effective way to increase automobile safety will not be a new type of airbag or seat belt, but instead removing the human from the driving input. In a 2008 report to Congress, the U.S. National Highway Transportation Safety Administration (NHTSA), an agency within the United States Department of Transportation dedicated to highway and road safety, revealed that over 80% of all motor vehicle accidents are caused by human error (National Highway Safety Transportation Administration, July 2008). More recent studies conducted by companies such as Google put this number closer to 95%. Some of these accidents are caused by inherent driver errors such as misjudging speed or colliding with a vehicle in the blind spot. But disturbingly there has been an increase in accidents caused by distracted driving. The emergence of entertainment devices such as smart phones and vehicle "infotainment" systems tempt drivers to focus on their screens instead of the road. At a speed of 65 miles per hour it takes only 3 seconds to travel 100 yards, or the length of an American football field. At this speed reading a single text message or scrolling through a playlist could lead to a catastrophic result.

According to a 2013 NHTSA study there are approximately 660,000 drivers in the United States at any given daylight moment using cellphones or manipulating electronic devices (National Highway Traffic Safety Administration, April 2013). Especially troubling is the most inexperienced drivers, teens, are often the most likely offenders. A joint study between Toyota Motor Sales, U.S.A. and the University of Michigan Transportation Research Institute (UMTRI) found that nearly 30% of teens read a text or e-mail every time they drive, 24% of teens respond to a text while driving and roughly 22% of teens have extended text conversations while driving (Toyota Motor Sales U.S.A., University of Michigan Transportation Research Institute , 2013).

Attempts to curb distracted driving through legislation have proved ineffective. Most U.S. states have outlawed texting while driving along with talking on a cell phone. Likewise, the majority of European countries have also banned texting and other electronic device usage while operating a vehicle. Despite these efforts, studies have shown that in the United States these laws have failed to have a positive impact on the amount or severity of automobile crashes (Ehsani, 2014). The reality is that enforcing these laws is difficult, and the best chance to mitigate the use of these distracting devices is through cultural changes and driver education. In order to make the biggest reduction on injuries and deaths related to distracted driving we must rely on advancing automated vehicle technologies that would detect a probable collision and automatically maneuver the car to a safe result.

Understanding Vehicle Automation

When you mention the idea of an automated vehicle to many people they often picture cars whizzing down the Interstate or Autobahn controlled entirely by a computer while the occupants enjoy a latte or read the latest gossip on their tablet. Most do not realize we have already been enjoying the benefits of vehicle automation for many years. In fact, both the US and EU *require* some automated features in order for vehicles to be deemed legal for use on public roads. While the definition of vehicle automation differs slightly between the US and EU, the summary provided by the NHTSA is comprehensive and reflective of EU counterpart regulation:

Automated vehicles are those in which at least some aspects of a safety-critical control function (e.g., steering, throttle, or braking) occur without direct driver input. Vehicles that provide safety warnings to drivers (forward crash warning, for example) but do not perform a control function are, in this context, not considered automated, even though the technology necessary to provide that warning involves varying degrees of automation (e.g., the necessary data are received and processed, and the warning is given, without driver input) (National Highway Traffic Safety Administration).

Because of the complex nature of vehicle automation it is necessary to categorize these systems according to the type of automation being performed by the vehicle. The NHTSA has five different levels of vehicle automation which can be used by authoritative bodies to create policy and regulations.

Level 0 – No-Automation: *The driver is in complete and sole control of the primary vehicle controls (brake, steering, throttle, and motive power) at all times, and is solely responsible for monitoring the roadway and for safe operation of all vehicle controls. Vehicles that have certain driver support/convenience systems but do not have control authority over steering, braking, or throttle would still be considered "Level 0" vehicles.*

Many Level 0 automated features come standard on vehicles today. A typical example of this type of automation would be a lane departure warning. These driver notifications utilize a camera system that monitors the lane markers well in advance of the vehicle. If the vehicle begins to cross the driving line without activation of the turn signal, the vehicle alerts the driver either through an audio cue, visual cue or physical feedback transmitted through the driver's seat or steering wheel. The driver may receive a signal if the vehicle senses it is unexpectedly departing a lane or if the turn signal is activated and there is another vehicle in the car's blind spot. It is important to note this is considered Level 0 because although the driver will receive a notification from the vehicle, the vehicle will not assume control or intervene by applying brake power or adjusting steering. The driver is expected to take notice of this cue and adjust accordingly to prevent an incident. Additional Level 0 automation features include rain sensing headlights and automated switching between low-beam and high-beam headlight settings.

Level 1 – Function-specific Automation: *Automation at this level involves one or more specific control functions; if multiple functions are automated, they operate independently from each other. The vehicle may have multiple capabilities combining individual driver support and crash avoidance technologies, but does not replace driver vigilance and does not assume driving responsibility from the driver.*

These systems will briefly take control of a particular vehicle function to help stabilize or provide additional traction if the vehicle detects unexpected movement. This happens so quickly and so subtly the driver may not notice the system has been engaged. Level 1 automation features are readily available, or even required, on newer makes and models. Most common are forms of electronic stability control (ESC). ESC functions by detecting that the vehicle is not heading in the driver intended direction as in an understeer (where the vehicle turns less than the driver intends) or oversteer (where the vehicle turns harder than the driver intends) situation, and can apply brake pressure to an individual wheel to correct and stabilize the car, guiding the vehicle back in the expected direction. The success of ESC has led to the NHTSA requiring all new vehicles to include ESC systems since the model year 2011. In 2014, all vehicles sold in the EU also must include ESC in compliance with General Safety Regulation No 661/2009 (EC Treaty/Euratom Treaty, 2009).

In more premium cars, radar and cameras are used to monitor vehicles in front of the driver and speed is adjusted accordingly. With dynamic braking, if the vehicle determines a fontal collision is imminent the driver is notified and the brakes can automatically be applied without driver input to reduce the damage of the collision or even avoid one entirely. This technology is known as Forward Crash Avoidance and Mitigation (FCAM) Systems.

The NHTSA regards the FCAM features as critical to reducing the frequency and severity of automobile accidents. According to the NHTSA, "One-third of all police-reported crashes in 2013 involved a rear-end collision with another vehicle at the start of the crash. The agency also found that a large number of drivers involved in rear-end crashes either did not apply the brakes at all or did not apply the brakes fully prior to the crash" (NHTSA, 2015). Distracted drivers checking mobile devices are particularly susceptible to causing these types of collisions. With this in mind, the NHTSA is including FCAM as part of their *New Car Assessment Program* in order to encourage buyers to select vehicles with these safety features. Although the vehicle may assume control of a braking or throttle application, Level 1 automation requires the full attention and input of the driver at all times.

Level 2 - Combined Function Automation: *This level involves automation of at least two primary control functions designed to work in unison to relieve the driver of control of those functions. Vehicles at this level of automation can utilize shared authority when the driver cedes active primary control in certain limited driving situations. The system can relinquish control with no advance warning and the driver must be ready to control the vehicle safely. An example of combined functions enabling a Level 2 system is adaptive cruise control in combination with lane centering. The major distinction between Level 1 and Level 2 is that, at Level 2 in the specific operating conditions for which the system is designed, an automated operating mode is enabled such that the driver is disengaged from physically operating the vehicle by having his or her hands off the steering wheel AND foot off pedal at the same time.*

While these features allow the driver to cede primary control of the vehicle, the driver must remain alert and ready to assume primary control of the vehicle on short notice. Cadillac is one of the first automakers to market with this technology with their "Super Cruise" systems introduced in 2014. This is an advanced cruise control that, when set, will sustain the vehicle speed safely within the confines of the lane. The vehicle can adapt to bends in the road and as well as traffic. If a vehicle in front of the car were to slow down or stop, the Cadillac would slow down or stop in turn, and then accelerate automatically back to the designated speed when traffic advances – all without input from the driver. These features would prove very useful on long trips where there are limited unexpected obstacles such as construction zones, severe weather or heavy traffic. But given the limited flexibility and adaptability of these automated features, the driver must remain in a state where they are prepared to assume control to safely navigate the vehicle. If the driver did not remain attentive, they may end up in a dangerous situation where the vehicle has ceded control back to a driver who is not prepared.

Level 3 - Limited Self-Driving Automation: *Vehicles at this level of automation enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions and in those conditions to rely heavily on the vehicle to monitor for changes in those conditions requiring transition back to driver control. The driver is expected to be available for occasional control, but with sufficiently comfortable transition time.*

This level marks the tipping point where the vehicle, not the driver, is in primary control. The person behind the wheel would be able to confidently relax and enjoy long periods of time without having to interact with the vehicle. If the human driver would be required to take over primary control, the vehicle would provide ample time and notification to prepare the individual for the transition. These systems rely heavily on satellite for navigation and route planning. Complicated localized sensors on the car are used to detect and communicate with other vehicles, static objects and unexpected circumstances such as if an animal or child were to jump in front of the vehicle.

In January 2015 Mercedes-Benz unveiled a concept car that would fall into the Level 3 classification. The F 015 *Luxury in Motion* research car is designed so the driver can disengage from vehicle operation and swivel their seat to face the rear of the vehicle to interact with passengers or complete other tasks.

Figure 3 F 015 Source: ***Mercedes-Benz***

It is apparent that entertainment, and not driving experience, is the primary focus for this type of vehicle. The F 015 concept contains a plethora of screens and options for entertaining passengers that can be used as computer display devices or mimic the passing terrain. Creating a comfortable environment for the occupants is important as research shows that motion sickness is a real issue when passengers try to consume media in the confines of a moving vehicle. According to research completed by the UMTRI, 6 to 12 percent of adults riding in self-driving vehicles can expect to experience moderate to severe motion sickness at some point in time. UMTRI researcher Michael Sivak explains, “Motion sickness is expected to be more of an issue in self-driving vehicles than in conventional vehicles…the reason is that the three main factors contributing to motion sickness—conflict between vestibular (balance) and visual inputs, inability to anticipate the direction of motion and lack of control over the direction of motion—are elevated in self-driving vehicles” (UMTRI, 2015).

Level 4 - Full Self-Driving Automation: *The vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the “driver” [or person in charge of vehicle input, remotely or in-car] will provide destination or navigation input, but is not expected to be available for control at any time during the trip. This includes both* *occupied and unoccupied vehicles. By design, safe operation rests solely on the automated vehicle system.*

Level 4 is the full scale, fully automated car. This type of vehicle may not even have a steering wheel as it is designed to function without human interaction. The driver may input the destination either in the car's operating system, or remotely via computer or smart device and simply enjoy the ride. The image in *Figure 3* is of Google's autonomous car prototype introduced in 2014. The car has two seats and no steering wheel. It functions with a combination of on-board sensors and GPS. According to Google, this model, along with other Google prototypes, has logged over 1,000,000 self-driven miles in testing.

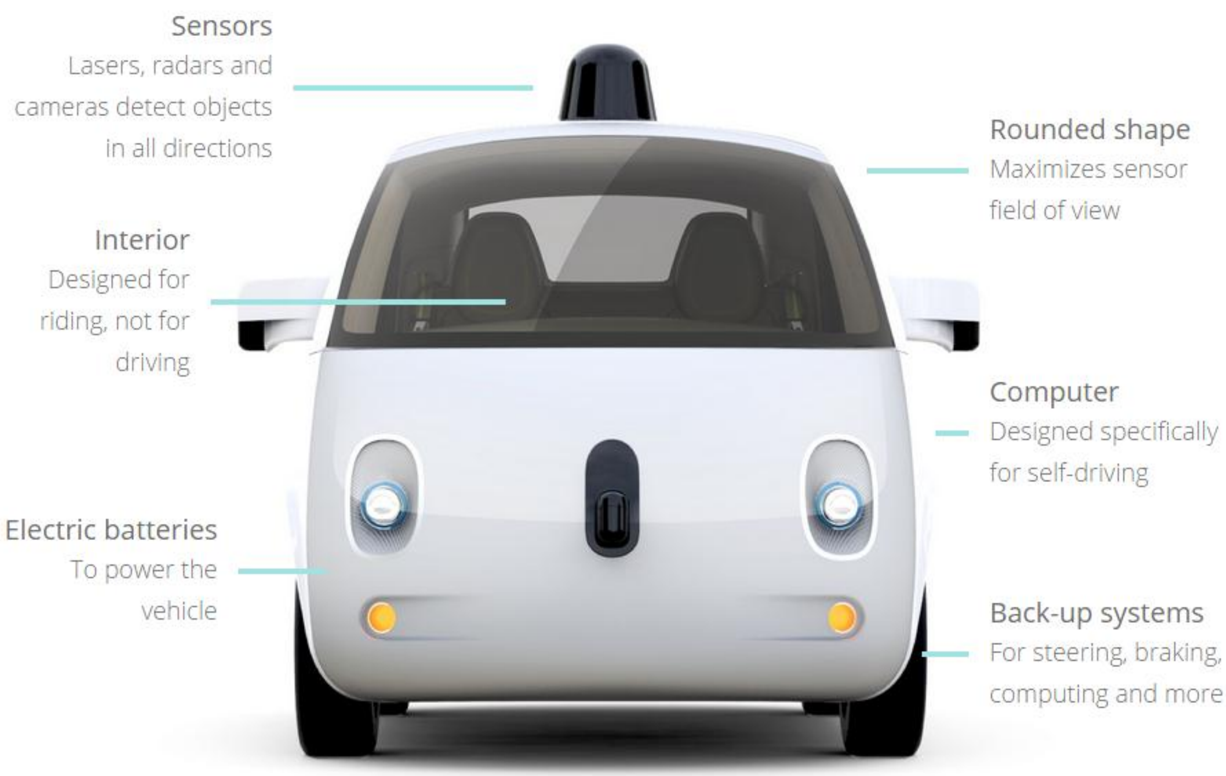

Figure 4 *Source: Google*

Operating with complex sensor arrays, fully autonomous vehicles are designed to have a complete understanding of their surroundings and the ability to handle every type of unexpected event without the need for passengers to intervene. This is especially critical because these vehicles may be operating without any humans on board as they traverse to their next pickup or back to a charging and staging lot. Level 4 vehicles would bring the freedom of movement to those who currently lack access to a vehicle or public transportation. Disabled and visually impaired individuals could become more independent by having these autonomous vehicles show up at their door and whisk them to their destination without having to rely on friends, family or shared medical transport vans.

Vehicle-to-Vehicle Communication

With humans taking a back seat to driving, vehicles will need to start communicating amongst themselves. In this situation, vehicles would broadcast critical telemetry and locational data to other vehicles (known as Vehicle-to-Vehicle, or V2V), or non-vehicles such as smart devices, sensor stations, or other stationary objects such as stoplights (known as Vehicle-to-Environment, or V2X), in order to communicate speed, direction, and any other relevant safety or route-planning information. The US Government has already reserved the 5.9 GHz bandwidth strictly for vehicle related information to ensure there is enough infrastructure to handle future communication burdens.

When vehicles broadcast and receive detailed information directly between each other there is less reliance on more passive detection systems such as cameras or radar that may be affected by weather or available light. More importantly, vehicles will be able to communicate beyond line-of-sight. An example would be two vehicles approaching an uncontrolled intersection in an urban environment from perpendicular travel routes. Human drivers may find themselves in danger of a collision if the vehicles did not slow down and yield properly due to obstruction of the drivers' views. V2V communications would alert the drivers, and if using a more autonomous system, establish a right-of-way for the cars to proceed safely and orderly.

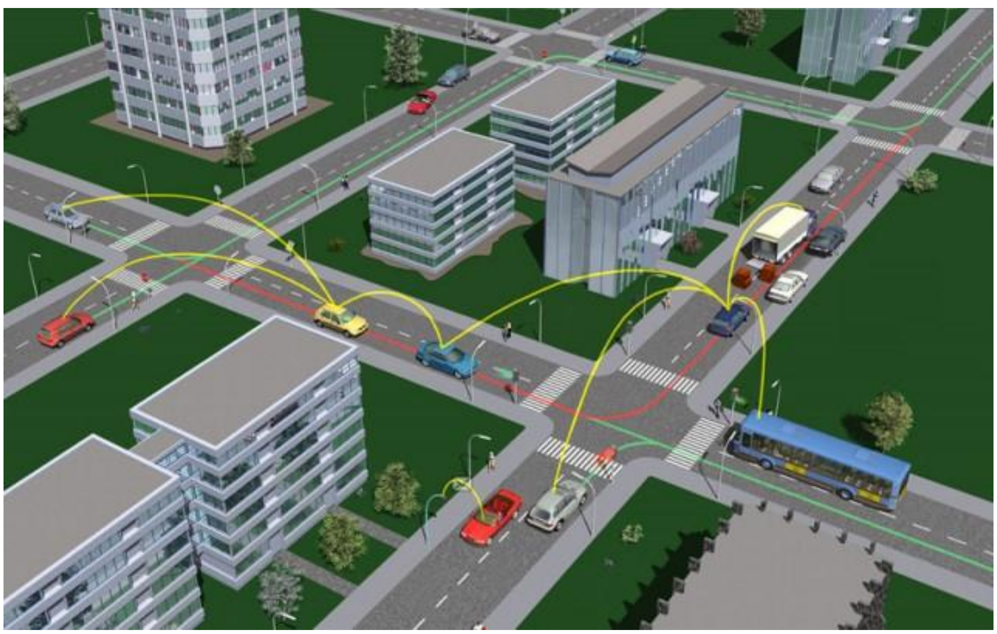

Figure 5 ***Source: Extremetech.com***

The European Commission has funded a project that would utilize V2V technology in order to positively impact both vehicle safety and emissions. Called the Safe Road Trains for the Environment [SARTRE], the project, "Will address the 3 cornerstones of transportation issues, environment, safety and congestion while at the same time encouraging driver acceptance through the increased "driver comfort" (SARTE-Consortium). Vehicles could travel at very close distances, trailing too close for humans to react under normal manned driving conditions, to reduce the aerodynamic drag and use less energy to maintain speed. The lead vehicle would establish the pace and communicate braking and accelerating in real-time. The following vehicles would operate autonomously and instantly adjust accordingly to maintain a safe and efficient distance. Meanwhile, the occupants in the vehicle would be relieved of driving responsibilities and could focus on more important tasks such as planning their upcoming ski trip in the Swiss Alps.

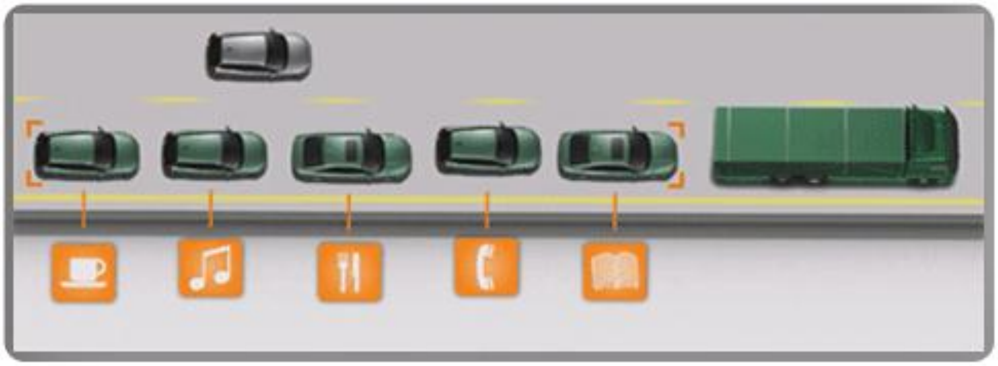

Figure 6 ***Source: EU Commission***

Utilizing aerodynamic efficiencies is nothing new to auto racing enthusiasts. Commonly known as *drafting*, the lead vehicle creates a hole in the still air while the trailing cars can slip behind the lead and enjoy reduced aerodynamic drag and increased fuel economy. Despite being in front, the lead automobile also enjoys an efficiency boost because of the lack of turbulent air pulling at the rear of the vehicle. This is illustrated by Nascar in *Figure 5*.

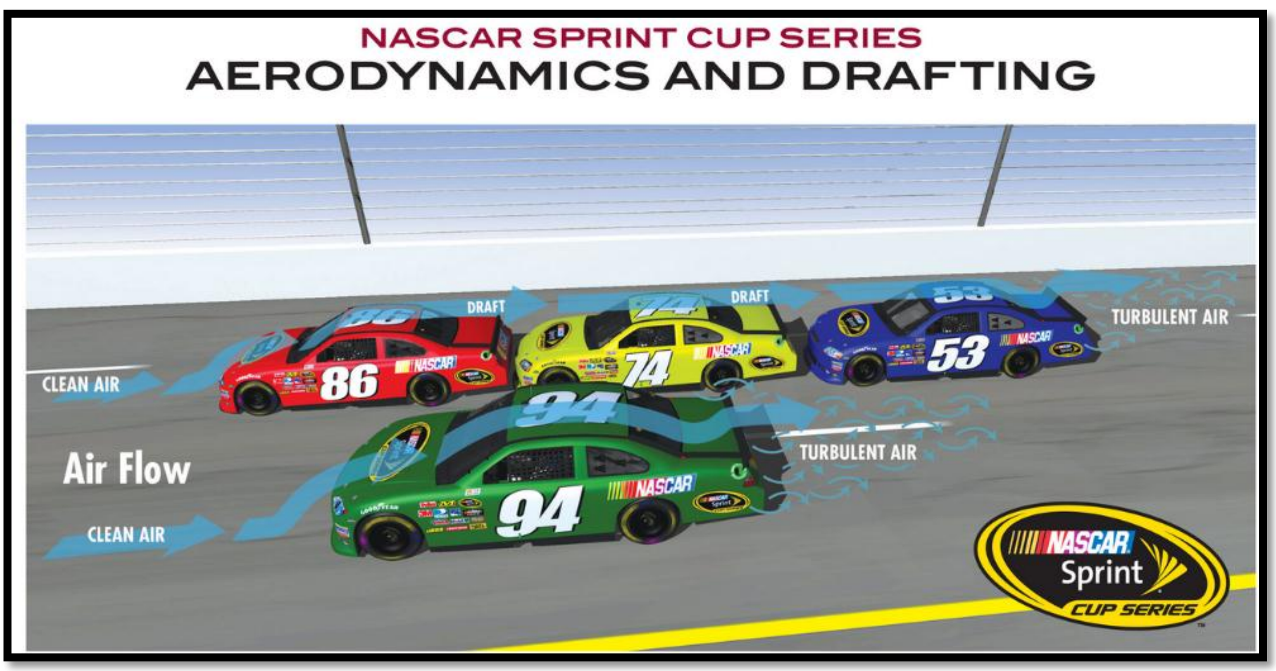

Figure 7 ***Source: Nascar.com***

The SARTRE project hopes to provide solutions that would enable fleets of cars and trucks to form road-based platoons and take advantage of efficiency gains. One of the challenges faced by the

SARTRE project is identifying how vehicles would seamlessly join and subsequently leave these platoons at different destinations through the course of a route. Effective V2V communications will allow the vehicles to control right of way and sequence, allowing drivers to join and leave the platoon as needed. The SARTRE consortium believes that emissions from platoon travelling could be reduced as much as 20% by utilizing aerodynamic benefits.

New Models of Vehicle Ownership

As autonomous vehicle technology matures, the traditional model of private vehicle ownership will be challenged. According to a study by Michael Sivak of the University of Michigan Transportation Institute, in 2011 there were 0.75 vehicles per every person in the United States and 1.1 vehicles per licensed driver in the United States. With a population of over 311 million people, this high rate of ownership translates to an incredible amount of privately owned vehicles (Sivak, 2013). Likewise in the EU, the average vehicle ownership rate ranges between 40 and 50 percent. A vehicle is often times the second most expensive item purchased by an individual after their home. Despite the large investment, typical asset utilization of personal vehicles is very poor and vehicles tend to sit unused nearly 96% of the time (Barter, 2013). In addition to the initial vehicle purchase, the cost of upkeep for fuel, maintenance, insurance and registration adds thousands of dollars annually to the cost of operation. Vehicles that are not properly maintained prove to be dangerous as bald tires prevent traction and a damaged suspension would compromise control. Older, less efficient vehicles pollute more than their modern day counterparts which utilize the latest in emission reduction technologies.

Fleets of autonomous cars that are centrally maintained could help address these problems. Instead of purchasing a vehicle, a person could simply use an app on their smartphone to request an autonomous vehicle pick them up from their house and take them to their destination. Although taxi cabs currently serve a similar purpose, driverless cars would eliminate the cost of the driver and operate at peak efficiencies without having to stop for breaks. Utilizing central servers, congestion could be monitored in real time and autonomous cars could automatically adjust the routes according to traffic volumes. Having vehicles owned in fleets would allow managed schedules with regards to maintenance and safety features such as brakes and tires. Economies of scale would ensure the per-vehicle cost of such maintenance would be lower due to commonality among components and volume of service. When rider demand is low, the vehicle could automatically return to central locations for maintenance or recharging.

Legal Hurdles

The biggest obstacle facing autonomous vehicles is not technological, but rather legal. Current legislative framework on both sides of the Atlantic does not account for incidents involving vehicles operated remotely or by systems instead of people. Responsibility and liability will have shifted from the drivers to the programmers and manufacturers. If an accident occurs involving an autonomous car – who is to blame? The car manufacturer? The software provider? The manufacturer of the sensor systems? As of 2015, there are still more questions than answers.

Because of the uncertain legal environment, automakers are hesitating to introduce some of the advanced automation features that would otherwise be ready for market. In the United States, the legality of autonomous cars is handled on a state, not federal level. As of 2015, only four states, Florida, Michigan, Nevada and California have legislation allowing some level of autonomous vehicle usage. As the legislation was developed independently in each state, there is no consistency between the legalities in the differing jurisdictions. Many other states are in various stages of passing, or in some cases striking down, new laws allowing these new technologies. This fragmentation makes implementation difficult on automakers who would prefer to have national standards thus allowing for consistent testing in different regions, terrains and weather conditions.

For Europeans, in 2014 a change was made to the 1968 Vienna Convention that originally stated, "Every driver shall at all times be able to control his vehicle or to guide his animals". The new amendment will allow vehicles to operate without the driver having primary control as long as the autonomous systems can be overridden by a human at any time. The modification to the Convention will provide a stop-gap allowing automakers to test their new technology on European roads. This allows the technology to mature and more permanent language can be implemented as lessons are learned.

Regardless of the region, implementing revolutionary technology in an fluid legal environment is incredibly challenging. As highlighted in a 2015 article in *Wired* magazine, a Google spokesperson adds, "It's really hard to try and anticipate how the technology might be used in the future and write laws for every eventuality. We think policymakers should learn about the technology and see how people want to use it first before putting a ceiling on innovation" (Davies, 2015). And what will be the first reaction when something does go wrong? Chris Nichols of the *San Diego Union-Tribune* cited a presentation given by Bryant Walker Smith of Stanford University, "What will happen is everybody will get sued… Some (defendants) will win and some will lose. And those with the deepest pockets will lose the most. Drivers, owners, operators, all the transportation actors, are potential defendants" (Nichols, 2013).

Stepping Up Security

As software becomes as critical as spark plugs, automakers will have to play catch-up regarding cyber security. Virtually every system in a vehicle can be controlled via computer which means that a compromised vehicle can literally leave the life of a driver in someone else's hands. This scary situation was brought to the forefront by an article published in *Wired* by Andy Greenberg in July 2015. As part of a demonstration, Greenberg was operating a Jeep Cherokee on the freeway when hackers sitting on a couch miles away were able to take control of the vehicle. The hackers manipulated the radio, engine, braking, transmission and other systems while Greenberg was left on the interstate helpless and unable to override the hackers' commands (Greenberg, 2015). Had this been a true hostile takeover of the vehicle, the results could have been catastrophic.

The article speaks to the seriousness of the issue – Fiat Chrysler recalled over 1.4 million vehicles less than one week after the magazines publication in order to fix the Jeep Cherokee's security flaw. Automakers are learning what software companies have been struggling with for the past three decades

– with innovation comes the opportunity for exploitation and criminals evolve in lockstep with the developers. Fiat Chrysler is not exclusive to these threats. In fact, all automakers are battling exposure to their systems. In February 2015, BMW discovered vulnerability in the code of their car operating software that allowed hackers to unlock the vehicles remotely. The company was able to fix this security flaw by issuing a patch that updated the software automatically without any action needed from the owner.

Aside from security threats, there have been new concerns regarding the privacy, and usage, of the data collected from consumers in their high-tech automobiles. GPS systems in modern cars can track every detail of your automotive habits. Information on where you drive, at what speed, duration of stays and most common routes utilized are either directly or indirectly collected by manufacturers. Incoming text messages can now be interfaced and displayed on your dash along with all your contacts. Consumers are weary this information could be collected and sold to companies for advertising purposes or worse yet, compromised by unlawful parties. Similar to the laws on operating autonomous vehicles, much effort is now focused on developing privacy laws that extend to the vehicles on the roadways.

Because of the software-driven nature of new vehicle systems, as well as the addition of Google and rumors of Apple hitting the auto scene, a shift in consumer confidence has occurred. A study conducted by KPMG indicated in autonomous vehicle applications, consumers trust technology companies *more* than traditional auto manufacturers – even more than companies like Mercedes-Benz and BMW who are traditionally on the forefront of automotive technology (KPMG, LLP).

Change is Inevitable

In 2015, we are on the cusp of change – and despite numerous obstacles, both technological and legislative, there is no avoiding that in the next 10-20 years autonomous systems will become staples in our daily lives. The cost of not innovating is too great – there is no disputing that the sooner humans take a back seat to driving the safer our roads will be. Although fully autonomous cars are still years away, implementing available automated systems, such as automatic emergency braking, will make a big impact on saving lives. Even as most of the technology related to autonomous driving is still in development, the biggest challenge will be establishing a robust legal system that enables, not suppresses, future innovation. Lost in this changing landscape may be the irony that companies who bear names of men like Porsche and Ford, men who devoted their lives to creating the most visceral driving experience imaginable, will ultimately succeed or fail based on their ability to make driving a thing of the past.

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