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Autonomous Vehicles: Technological Changes and Ethical Challenges

Mary Barra stood in the front of a crowded room at the 2014 Congress of the Intelligent Transportation Society (ITS). It was a Sunday in September, and the year had already been a whirlwind. In January, she had been appointed to the position of CEO of General Motors (GM), making her the first female CEO of a major automobile manufacturer. Three months later, she appeared on the cover of *Time* and was honored as one of the year's 100 most influential people, highlighted among the likes of Beyoncé, Barack Obama, and Vladmir Putin.

Barra worked her way up at GM. She began her career there in 1980 as a co-op student, later graduating with a BS in electrical engineering from Kettering University (formerly General Motors Institute) in 1985 and an MBA from Stanford in 1990. At GM, she previously served in positions ranging from engineering to human resources and product development.[1]

Barra turned her attention back to delivering the welcome address for the 21st annual gathering, which had attracted thousands of industry and government leaders to Detroit, Michigan. The theme was "Reinventing Transportation in Our Connected World," and she had exciting news to share.

After some opening remarks, she gave an abbreviated history of GM's innovation in connected technology. Then, she focused on the future: Super Cruise. Barra elaborated, "That's the working name for the GM semi-automated driving technology that allows for hands-free driving on the highway- both at speed and in stop-and-go driving."[2]

Autonomous vehicles had been a hot topic in the news. Earlier that year, the technology company, Google, revealed its prototype of a completely driverless car. There had also been murmurs across the automotive industry that several carmakers were developing autonomous driving technology. Public interest was high, and there was pressure for large automakers to keep up.

Barra continued her speech:

> *In 2013, Popular Mechanics magazine ranked Super Cruise among the year's most important innovations in technology, medicine, space exploration and automotive design. They thought it might be in production as soon as 2018. Well, we're going to better that by about two years and launch Super Cruise in the same timeframe as V2V [vehicle-to-vehicle communication technology]. And it will appear for the first time on an all-new Cadillac that's going to enter a segment where we don't compete today. With Super Cruise, when there's a congestion alert on roads like California's Santa Monica Freeway, you can let the car take over and drive hands-free and feet-free through the worst stop and go traffic around. [...] Having it done for you – that's true luxury.*[3]

Despite public anticipation, autonomous driving technology was nascent and in the early stages of testing on public roads. Only a handful of states had any laws in place related to autonomous vehicles. Many consumers and experts worried about the safety implications of releasing autonomous vehicles onto the streets.

Barra began to wrap up her monumental announcement. She made a point to mention her company's commitment to consumer safety and enjoyment, "Rest assured, Super Cruise will keep drivers alert and engaged, and when they want to take control, they're going to find a car that's really fun to drive."[4]

Road Conditions: Autonomous Vehicle Background

In the 2010s, many major automotive companies were designing autonomous vehicles, but none had been released to the public. However, in late 2015, Tesla Motors[5] ("Tesla"), the Palo Alto-based manufacturer of electric vehicles and unique energy solutions, released a software update for its cars. Named Autopilot, an homage to the autopilot feature on airplanes, the software was controlled through a touch screen, and enabled cars to automatically manage speed, steer within lanes, change lanes, and park. The software involved feedback from cameras, radar, ultrasonic sensors, and GPS to offer live data feedback. Cars that had been in driveways for years had been manufactured with all of the required hardware to later become semi- autonomous with the Autopilot software update.

Tesla was founded in 2003 with a mission to accelerate the world's transition to sustainable energy. The company was co-founded and led by the well-known futurist, Elon Musk. In 2012, Tesla released the first fully electric premium sedan. The sedan earned acclaim from *Motor Trend*, the U.S. National Highway Traffic Safety Administration (NHTSA), and many others. Tesla's release of Autopilot was in keeping with its cutting edge reputation, and its Model S sedan became colloquially known as the first autonomous car available to the public.

However, the common perception of the Tesla Model S as "autonomous" was vastly oversimplified. SAE International, a standards-making body for automotive engineers, published a taxonomy that

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defined six levels of automation. At the lowest level (Level 0 on the SAE scale), a human driver performed all aspects of driving; at the highest level (Level 5 on the SAE scale), a driving automation system performed all of the tasks associated with driving.

At the time of its release, Tesla's Autopilot technology performed at Level 2 automation—capable of steering and acceleration, but only with constant supervision by a human driver who monitored road conditions. See Exhibit 1 for a full overview of the SAE levels.

Revving the Market

The potential of vehicle autonomy reached far beyond personal cars. Ridesharing companies (such as Uber and Lyft), taxis, trucking, manufacturing logistics, and public transit were all expected to be transformed by autonomous control technology. In January 2015, Boston Consulting Group predicted that the autonomous vehicles market size could be $42 billion by the year 2025,[6] a figure which likely caught the attention of every automotive industry leader. Another staggering statistic was the NHTSA's estimate that 35,200 people died in motor vehicle accidents in 2015, a 7.7% increase from the prior year.[7] A separate NHTSA report found that 94% of vehicle crashes were a result of (human) driver error.[8] See **Exhibit 2** for more data regarding roadway injuries and deaths. Thus, companies likely viewed autonomous vehicles through a lens of not only substantial financial benefit, but also profound societal benefit.

Between its lifesaving potential and its expected impact on the economy, vehicle autonomy was a high profile topic in 2016. Many car companies wished to capitalize on this hype, but were wary of labeling their technology "autonomous" in order to avoid overstating the capabilities of their driving automation systems. Marketing efforts at the time often evoked the promise of driverless cars while opting for language such as "driver assist" rather than "autonomous."

The On-Ramp: Cadillac's Vision for the Future

General Motors (GM)'s luxury car division, Cadillac, was among the world's oldest car brands, founded in 1902. But by the mid-2010s, its brand reputation was more passé than time-honored. A reflection of this, Cadillac sales dropped 6.5% between 2013 and 2014.[9] Cadillac President Johan de Nysschen, appointed in August 2014, sought to change that. Tasked with Cadillac's global business success, including sales, product development, strategic brand development, and marketing, de Nysschen relied on his management and board history with Infiniti Motor Company Ltd., Audi of America Inc. and Audi South Africa, Volkswagen of America, Inc., and BMW South Africa.[10] The same year that de Nysschen was hired, GM announced that it would allocate $12 billion to grow the Cadillac brand, and intended to launch at least eight new vehicles by 2020.[11]

Rejuvenating the brand would not be an easy task. Automotive analyst Adam Jones stated that it had never been more difficult to do this in the premium car segment. He warned, "It's going to take tremendous time and money. I'm not saying it can't work, but there's a lot of cultural inertia behind Cadillac, and there's a huge amount of competition coming from a German auto industry that's getting even more aggressive. There's not going to be any quick win."[12]

At the 2015 New York Auto Show, de Nysschen was candid about Cadillac's brand challenges, but also spoke confidently of its aspirations for the future. "Cadillac wants to move back to the center stage of the luxury car market," he said. "We also have to appeal to a new audience. The Baby Boomer generation remains important for us, but by 2020, more than 80% of the luxury cars in the world will be bought by someone who is from Gen X or Gen Y. They bring different expectations to the market, and brands that do not evolve will be marginalized."[13] [Generation X referred to people born in the 1960s and 1970s, after the Baby Boomer generation. Generation Y, also known as Millennials, referred to people born in the 1980s and early 1990s.]

Super Cruise and Autopilot

GM's semi-autonomous technology, Super Cruise, was originally announced in 2012, with a Cadillac press release boldly titled, "Self-Driving Car in Cadillac's Future." The same spring, GM also began demonstration drives for journalists and others. John Capp, GM's director of Global Active Safety Electronics and Innovation said at the time, "The primary goal of GM's autonomous and semi-autonomous vehicle development is safety. In the coming years, autonomous driving systems paired with advanced safety systems could help eliminate the crash altogether by interceding on behalf of drivers before they're even aware of a hazardous situation. More than ever, consumers will be able to trust their car to do the right thing."[14] Like Tesla's Autopilot, Super Cruise would automatically keep it in lane, make steering adjustments, and regulate speed and braking.

In 2014, GM announced that Super Cruise would be available in the fall of 2016. The software was intended to be a feature on the Cadillac CT6, a full-size luxury sedan which would be priced between $54,490 and $84,460. But with Tesla's release of semi-autonomous technology in 2015, GM's leadership had the opportunity to examine the public's reaction to this new technology, and to assess the views of various expert stakeholders before releasing its own technology.

In an October 2015 post on its corporate website, Tesla discussed the arrival of Autopilot. As with most Tesla announcements, media buzz soon followed. However, some consumers and experts were concerned about Tesla's semi-autonomous technology, which was capable of controlling all of the car's movements in traffic, but required constant human supervision. Tesla's CEO, Elon Musk, explained, "We tell drivers to keep their hands on the wheel just in case, to exercise caution in the beginning."[15]

Startlingly, almost as soon as Autopilot was released, videos surfaced on YouTube demonstrating drivers' over-reliance on automated features. Some drivers had even fallen asleep at the steering wheels of their Teslas. Arianna Simpson, who survived a collision in which her Tesla vehicle ran into a parked car on a highway, said that Autopilot "did absolutely nothing." Simpson went further to say, "When I have a bug on my app, it crashes. When I have a bug on my car, people die."[16] Dean Pomerleau, an expert at Carnegie Mellon University with 25 years of experience with self-driving technology, also held a critical view. He surmised, "Human nature is such that if they're not doing anything, they're going to get distracted or drowsy and incapable of taking over [a semi-autonomous car that is not properly reacting]."[17]

The mixed responses to the release of Tesla's semi-autonomous Autopilot left multiple angles for other carmakers to consider. Based on Tesla's accident logs and NHTSA data about overall traffic fatalities, it was reasonable to conclude that the availability of Autopilot saved lives by reducing the number of automobile-related deaths. Luxury cars increasingly had become defined by more than just comfort or performance, but also by innovative technology. Being among the first to release semi-autonomous vehicle technology would go a long way in attracting the younger demographic that Cadillac was actively pursuing. But research by Pomerleau and others contended that consumers may not fully understand how to properly drive semi-autonomous cars. Unlike with fully autonomous vehicles, drivers would need to embrace relinquishing control of only *some* aspects of driving, but remain fully alert and able to take back control of the car at any moment. Car manufacturers would need to figure out how to combat drivers being lulled into complacency. In addition, companies had to mitigate the liability risk with new technologies, which legal experts were only just beginning to analyze. For an established company such as GM, there was a lot at stake legally and financially, but also tremendous market opportunity if the company moved quickly.

With approximately a year until the 2016 Super Cruise release date that Barra had promised, GM's leadership team had to decide whether to proceed as planned, delay the release until it had been even more extensively tested, or forgo the release of semi-autonomous technology in favor of releasing a fully autonomous vehicle at a much later date. No analysis would have been complete without exploring legal implications and competitive behavior.

Licensed to Drive: Legal Implications

In early 2016, there were no federal statutes or regulations governing the release of automated driving systems, and only a handful of states had enacted laws to address the testing of automated vehicles. With no courtroom precedents to rely on, legal scholars and other commentators debated how liability for personal injuries caused by automated vehicles would be decided in a future legal battle. Many believed that automobile collisions involving automated vehicles would be treated as product liability cases rather than unavoidable accidents, therefore exposing car manufacturers to more lawsuits.[18]

Under general legal principles, manufacturers could be made to pay for injuries caused by their products if they were found to be "unreasonably dangerous," if the manufacturer was negligent in designing the product, or if the manufacturer failed to warn users about risks associated with the ordinary uses of the product.[19] In some cases regarding other products, manufacturers had previously been held liable for the "foreseeable misuse" of products, where a jury decided a manufacturer should have known that users would use them in dangerous ways.[20]

There were also no established standards for testing the safety of automated driving systems. Many people wondered how fault could be assigned in instances where an automated vehicle was operated by software with artificial intelligence, which they believed to be an inscrutable "black box."[21] On the other hand, even early testing appeared to demonstrate an accident-per-mile rate that was equal to, or lower than, an average human driver.[22] Even so, some feared that juries might hold automated vehicles to a higher and perhaps unachievable standard compared to human drivers.[23] From the perspective of automobile manufacturers, semi-autonomous vehicles were in a legal gray area, with the potential to expose them to great legal risk.

State Measures

Nevada was the first state to explicitly allow autonomous vehicles, in 2011. Within the next five years, only a few states followed suit in taking action related to autonomous vehicles. State laws varied widely in their effects: Florida allowed full deployment of autonomous vehicles, but California, Michigan, and Nevada allowed autonomous vehicles to be operated only for testing purposes. North Dakota passed legislation directing research into the safety and fuel economy of autonomous vehicles. Other jurisdictions opted not to pass any new laws; some held the view that autonomous vehicles could be legally operated anywhere unless there was a law that affirmatively banned them. In most states, autonomous vehicles existed in a regulatory vacuum.

State governments and various municipalities diverged on how receptive they were to autonomous vehicle testing or deployment. While California passed regulations that restricted companies' ability to test on open roads, other jurisdictions like Arizona actively courted autonomous vehicle developers and encouraged them to set up operations there. California's position was likely influenced by the state's powerful consumer protection groups, who were reluctant to allow new autonomous technology on public roads. For example, a March 2015 letter from Consumer Watchdog to the Director of the California Department of Motor Vehicles stated, "We call on the DMV to ensure the public interest is put ahead of the self-serving agendas of the autonomous vehicle technology manufacturers."[24] Some other states likely saw this as an opportunity to promote economic development and capture some of the technology sector that had historically resided in California.

Modern Marvel, Ethical Dilemma

Under the Hood: The Technology Powering Semi-Autonomous Vehicles

The particular design of automated vehicle technology varied by developer, but the technologies all shared common features. All developers used a stock vehicle and retrofit it with a variety of sensors, including cameras, radar, and often lidar. Companies' software programs used these sensors to construct a model of the environment around the vehicle, allowing it to "see" its surroundings. Some programs, including Cadillac's Super Cruise, compared the real-time data feed to existing three-dimensional lidar-generated maps for greater accuracy and processing speed; these technologies were "geo-fenced," or designed to operate only in limited pre-mapped areas (most typically, highways).

Because the driving task was extraordinarily complex, with myriad variables and unpredictable surprises, developers found it ineffective to program logic or instructions that could anticipate every possible situation a vehicle might encounter. The success of automated driving technologies went hand-in-hand with growing successes in machine learning, and especially developments in "deep" neural networks. Rather than following predesigned rules or instructions, neural networks were "trained" to perform tasks through repeated examples and reinforcement. Many automated driving systems used a combination of rule-based logic and trained neural networks to perform object recognition, event detection and response, and other driving tasks.

Mapping the Course: Various Approaches to Semi-Autonomous Technology

Multiple companies had the capability to release some level of semi-autonomous technology. Automakers testing autonomous technology included Ford, Volvo, Nissan, and Mercedes-Benz, all of whom promised the release of some level of autonomy within the next five years (by 2020 or 2021). Ridesharing company Uber was also at the forefront of vehicle autonomy, staffing a research and development department and partnering with automakers and leaders in machine learning. Startups, such as Drive.AI, NuTonomy, and Cruise Automation, began to pop up in response to the demand for autonomous vehicles. A variety of university-based research centers were also involved in vehicle autonomy and machine learning.

Despite the numerous companies interested in this area, auto analyst Thilo Koslowski contended, "GM is pushing the boundaries here. This is how the evolution to fully autonomous vehicles will occur."[25] In March 2016, GM announced its acquisition of Cruise Automation for more than $1 billion; this came only months after its $500 million investment in ridesharing company Lyft.[26]

But the decision of whether or when to release semi-autonomous driving technology came with ethical, legal, and strategic considerations. There was no standard approach for analyzing the impact of widely available semi-autonomous vehicles, so each company had to do its own calculation. Decision-making factors included a variety of areas:

- **Legal liability**: As discussed in the previous section, potential legal liability for automakers was uncertain but potentially enormous if the automated driving technology were determined to be unreasonably dangerous or negligently designed.
- **Safety benefits and risks**: Semi-autonomous and autonomous vehicles had the potential to significantly reduce the number of crashes. The CDC stated that motor vehicle accidents were the 13th leading cause of death in the United States in the prior year.[27] NHTSA reported that 2.44 million people were injured in car accidents in the United States in 2015, not counting fatalities.[28] But the release of unsafe or improperly used technology also risked injuries deaths, and car manufacturers may have greater moral and legal culpability for those injuries and deaths.

- **Financial opportunity**: The estimated $42 billion market for autonomous vehicles by 2025 was an incentive that would have been difficult for carmakers to ignore. This was particularly true because experts anticipated that autonomy was the future of automobiles; it would be beneficial to be at the cutting edge, and manufacturers that did not keep up risked becoming obsolete.
- **Brand impact**: Many believed that the release of semi-autonomous technology would boost brand image among affluent Millennials, a highly desired customer segment. Luxury brand in particular faced an increasing demand to compete on technology as well as comfort and style.

Two contemporary companies served as archetypes for GM and others to consider the different approaches and rationales for timing the release of autonomous technology.

Tesla

As of 2016, Tesla had never made a profit.[29] Although it was a public company with significant revenue and investors, it behaved more like a startup, and its CEO, Elon Musk, seemed more interested in mission and social impact than money, according to many industry observers. Musk was also a serial entrepreneur, having founded Zip2 (acquired by Compaq), X.com (which later became PayPal), SpaceX, and nonprofit research company OpenAI. Each venture was founded with advanced technology.

At Tesla, Musk had originally intended to delay release of autonomous technology until his company could deliver a fully autonomous vehicle. But he later realized that the product they currently possessed was already significantly safer than cars without any autonomous technology. Releasing the technology early would hypothetically save lives. It would also allow the company to gather further data and make continual improvements, culminating in the release of a fully autonomous vehicle.

Referring to the 2015 NHTSA data, which reported one automotive fatality for every 89 million miles, Musk said, "Autopilot miles will soon exceed twice that number and the system gets better every day. It would no more make sense to disable Tesla's Autopilot, as some have called for, than it would to disable autopilot in aircraft, after which our system is named." [30] Further, because Autopilot was significantly safer than a driver unaided by the software, Musk stated unequivocally, "it would therefore be morally reprehensible to delay release simply for fear of bad press or some mercantile calculation of legal liability."[31]

Some other companies, however, deliberately chose not to release autonomous technology until their vehicles reached Level 4 or 5 capability (full autonomy), citing safety concerns. Trent Victor, Volvo's senior technical leader of crash avoidance, remarked of Tesla's Autopilot, "It gives you the impression that it's doing more than it is. [It's] more of an unsupervised wannabe."[32] Ford's chief technical officer, Raj Nair, shared his company's similar strategy: "We abandoned the stepping-stone approach of driver-assist technologies and decided we were going to take the full leap [into Level 4-5 autonomy]."[33]

Google's Self-Driving Car Project

Google, one of the most prominent information technology companies in the world, began testing self-driving cars in 2009. According to its website, the goal of the project was, "developing technology that could transform mobility for millions of people, whether by reducing road deaths caused by human error, reclaiming the billions of hours wasted in traffic, or bringing everyday destinations within reach of those unable to drive."[34] The self-driving car project soon became housed in Google's corporate research division, X, also known as the "moonshot factory."[35]

The project's goal had always been to build a fully-autonomous car from the ground up, with no plans to release semi-autonomous technology. Over the years, the project logged several million test miles and gave various demonstration rides in its vehicles. In 2015, the self-driving car project completed the world's first fully autonomous ride on public roads in Austin, Texas, in a car with no steering wheel or pedals.[36]

In 2015, Google was restructured to create an umbrella company named Alphabet, under which X became an independent subsidiary. Alphabet budgeted more than $1 billion per year for X, much of which went to the self-driving car project.[37] As of 2016, there did not seem to be any urgency for the self-driving car project to generate its own revenue and there was no publicized release date for a commercially available autonomous vehicle.

Setbacks: The First Death in a Semi-Autonomous Vehicle

In May 2016, Tesla enthusiast Joshua Brown died in a crash while driving his Tesla with Autopilot enabled. This was the first death in over 130 million miles in which Autopilot was activated. The story made headlines across the country. Just weeks prior, Tesla CEO Elon Musk shared a video that Brown had posted on Twitter of his Tesla safely dodging a collision using Autopilot, captioning his retweet, "[Tesla car] owner['s] video of Autopilot steering to avoid collision with a truck."[38]

Tesla officials consistently stated that drivers must stay alert when utilizing Autopilot. The car's manual urged that the technology was "not a collision warning or avoidance system."[39] But there were numerous videos and other accounts of drivers reading, watching movies, or otherwise not paying attention with Autopilot enabled. A portable DVD player was found in Joshua Brown's wrecked car after his death, leading some to speculate that Brown was watching a movie at the time of the collision. Autopilot's functionality had also come into question. Multiple owners of Tesla cars reported problems with Autopilot's ability to recognize stationary objects. This recognition issue is one that Brown publicly shared shortly before he was killed.

After the crash, NHTSA director Mark Rosekind stated, "No one incident will derail the Department of Transportation and NHTSA from its mission to improve safety on the roads by pursuing new lifesaving technologies...If we wait for perfect, we'll be waiting for a very, very long time. How many lives might we be losing while we wait?"[40][41]

Although no law suit was filed related to Brown's death, media coverage was extensive and it served to highlight a public debate about autonomous vehicle technology. As a relatively new company built upon a reputation of innovation and pushing the limit, Tesla's brand was largely unaffected. However, more established car manufacturers, with longstanding reputations of reliability, were likely more concerned about potential ramifications of their own semi-autonomous technology.

Months prior, in January 2016, Cadillac announced that it would not be debuting Super Cruise in that year's CT6 as originally planned. The company did not give an exact date for the new launch but alluded that it would be in 2017. Cadillac's chief engineer, Dave Leone, vaguely stated, "We're still polishing the stone here, to make sure it's ready."[42] But in the summer of 2016, shortly after Brown's Autopilot-related death, Barra (GM's CEO), said that the company was "step[ping] back" to "look at what technology is in the best interest of consumers."[43,44]

The Road Ahead

Cadillac faced a complicated analysis. GM had invested $12 billion to reinvigorate the brand, and Cadillac President Johan de Nysschen knew that he had to appeal to younger, more technology-focused consumers. The company had also made significant effort to remain at the forefront of the semi-autonomous car market, developing sophisticated technology in-house and spending $1 billion to acquire Cruise Automation.

Super Cruise had been widely discussed for the past four years. It had been rigorously tested, and had successfully taken impressed journalists on demonstration drives. Available data suggested that well-designed semi-autonomous technology would likely save lives and prevent injuries. Many other competitor companies were developing their own semi-autonomous technology, and it would be advantageous for Cadillac to be at the forefront of the market.

But some researchers were beginning to raise concern about drivers' potential misuse of semi-autonomous technology, which could have fatal consequences. The legal and regulatory environment for semi-autonomous vehicles was uncertain, and there were myriad ethical considerations. With the new model year quickly approaching, GM and Cadillac executives had to find a way to navigate the ambiguity and determine Super Cruise's future.

Exhibit 1: SAE International's J3016 Taxonomy of Vehicle Autonomy

SUMMARY OF SAE INTERNATIONAL'S LEVELS OF DRIVING AUTOMATION FOR ON-ROAD VEHICLES

Issued January 2014, **SAE international's J3016** provides a common taxonomy and definitions for automated driving in order to simplify communication and facilitate collaboration within technical and policy domains. It defines more than a **dozen key terms**, including those italicized below, and provides **full descriptions and examples** for each level.

The report's **six levels of driving automation** span from *no automation* to *full automation*. A **key distinction** is between level 2, where the *human driver* performs part of the *dynamic driving task*, and level 3, where the *automated driving system* performs the entire *dynamic driving task*.

These levels are **descriptive** rather than normative and **technical** rather than legal. They imply **no particular order** of market introduction. Elements indicate **minimum** rather than maximum system capabilities for each level. A particular vehicle may have multiple driving automation features such that it could operate at **different levels** depending upon the feature(s) that are engaged.

System refers to the driver assistance system, combination of driver assistance systems, or *automated driving system*. **Excluded** are **warning and momentary intervention systems**, which do not automate any part of the *dynamic driving task* on a sustained basis and therefore do not change the *human driver's* role in performing the *dynamic driving* task.

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
Human driver **monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
Automated driving system **("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Key definitions in J3016 include (among others):

Dynamic driving task includes the operational (steering, braking, accelerating, monitoring the vehicle and roadway) and tactical (responding to events, determining when to change lanes, turn, use signals, etc.) aspects of the driving task, but not the strategic (determining destinations and waypoints) aspect of the driving task.

Driving mode is a type of driving scenario with characteristic *dynamic driving task* requirements (e.g., expressway merging, high speed cruising, low speed traffic jam, closed-campus operations, etc.).

Request to intervene is notification by the *automated driving system* to a *human driver* that s/he should promptly begin or resume performance of the *dynamic driving task*.

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Exhibit 2: Roadway Injuries and Deaths, 2014-2015

Description	Killed			Injured		
	2014	2015	Change	2014	2015	Change
Total	32,744	35,092	+7.2%	2,338,000	2,443,000	+4.5%
Passenger Vehicles	21,050	22,441	+6.6%	2,074,000	2,181,000	+5.2%
Large Trucks	656	667	+1.7%	27,000	30,000	+11.1%
Motorcycles	4,594	4,976	+8.3%	92,000	88,000	-4.3%
Pedestrians	4,910	5,376	+9.5%	65,000	70,000	+7.7%
Pedecyclists	729	818	+12.2%	50,000	45,000	-10.0%
Other/Unknown Non-occupants	204	227	-	10,000	10,000	-

Note: Total includes occupants of buses and other/unknown occupants not shown in table.

Source: U.S. Department of Transportation National Highway Traffic Safety Administration (NHTSA) Traffic Safety Research Note, "2015 Motor Vehicle Crashes: Overview," published August 2016.

[1]Mary T. Barra's Profile on GM's website, accessed March 1, 2018. <https://www.gm.com/company/leadership/corporate-officers/mary-barra.html>

[2] GM Corporate Newsroom, "Mary Barra Addresses Intelligent Transport Society." September 7, 2014. Retrieved from: <http://media.gm.com/media/us/en/gm/news.detail.html/content/Pages/news/us/en/2014/Sep/0907-its-speech.html>

[3] GM Corporate Newsroom, "Mary Barra Addresses Intelligent Transport Society." September 7, 2014. Retrieved from: <http://media.gm.com/media/us/en/gm/news.detail.html/content/Pages/news/us/en/2014/Sep/0907-its-speech.html>

[4] GM Corporate Newsroom, "Mary Barra Addresses Intelligent Transport Society." September 7, 2014. Retrieved from: <http://media.gm.com/media/us/en/gm/news.detail.html/content/Pages/news/us/en/2014/Sep/0907-its-speech.html>

[5] Renamed Tesla in 2017.

[6] Green, Jeff, "Driverless-Car Global Market Seen Reaching $42 Billion by 2025." *Bloomberg Technology.* January 8, 2015. Retrieved from: <https://www.bloomberg.com/news/articles/2015-01-08/driverless-car-global-market-seen-reaching-42-billion-by-2025>

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