Evolution of Driverless Cars

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Good afternoon. Thank you for that introduction. In a moment I will have just a bit more to add to help explain why you may find what I have to say of particular interest to your own unique viewpoint.

But first, here's a very quick overview of CATES – Center for Advanced Transportation and Energy Solutions. We are a Seattle-based not-for-profit research, development, and advocacy team working on bringing clean energy-powered, self-guided vehicles to our state. Our leadership team comes to this challenge with extensive background in the public policy, transportation research, telematics and related technologies development arenas that will enable adoption of this transportation revolution. I am CATES' Director of Development.

Now, a very quick outline of what I will set out:

1. What's happening generally in automation, which can also be called robotics
2. Progress in developing automated cars, leading to benefits now and forthcoming
3. What competition and technological development will bring in the future

Before addressing these subjects, my personal experience around the utility of roads and vehicles bears reciting. Turns out, there are quite a few links between my own youth, my family connections and the interests of the WSGRTA.

I grew up on a farm in western Iowa, a place where I personally experienced and used country roads and almost every kind of agricultural mobility device type known today, beginning with, of all things, work horses. I can still remember the early summer day of my fourth year when my dad sat me in his 4-wheel buggy seat and sent me off alone to

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town, three miles away, to the local equipment repair shop, to pick up a part he needed for the farm machine he was working on. The horses knew the way, to and from, having done it many times. All they needed was a tiny bit of guidance. So, I guess I learned about autonomous vehicles very early on.

They knew that road because it was the same road that my dad helped build, using this very same team pulling a grader, in order to have a way to get our corn and oats, and our cattle to market. I would go on, between then and my early 20s, to operate almost every kind of vehicle and machine used in rural agriculture in the 50's and early 60s – tractors, combines, heavy duty earth movers, pickups, 18 wheeler trucks and more – on all manner of roads and highways, and I came to understand how important good roads are – for commerce, personal transport, and more. So, I bring that understanding to my work now at CATES.

And there is another connection to WSGRTA that I also share. There is a branch of the extended Rosmann family that has practiced wheat farming here in Washington State where, beginning in 1893, an earlier Joseph Rosmann carved out a large wheat farm over the years, a family operation that continues today. This Joseph Rosmann probably knew Sam Hill and was likely part of the organizing of the WSGRTA way back then at the turn of the beginning of the last century when WSGRTA was formed.

So, when we at CATES say that we are here to help you, we actually do have quite a few deep connections to the historical as well as present day importance of good roads, and good personal and commercial transport vehicles – in our state's rural areas as well as our cities.

Now, on to our topic of the day – the future of automated vehicles in our state and nation, beginning with some very brief discussion regarding adoption of automation, everywhere in our economy.

Why do we automate – because smart machines can do things better and faster than humans can in guiding machines ourselves, and usually also safer, more efficiently and at less cost. The entire trick in accomplishing this automation is, and has always been, in defining the human/machine interfaces such that the technical and operational processes remain controllable by their human operators while minimizing the need for human involvement in their actual present time operational actions.

And, so we today have incredibly complex fully automated process control systems in mining, raw resource refining (steel, industrial chemicals), textile manufacture, machine assembly, airplane flight operations, computer chip fabrication and computing device assembly, and many more. These systems, now essentially all computer controlled, gathering sensor data of myriad types constantly and, guided by software controls, start, adjust, and stop operations essentially automatically. The human role is now principally one of monitoring the automation controls system itself, not the actual

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machines themselves, adjusting software parameters and assuring proper operation of the sensor mechanisms.

Automation of this type is even reaching today into the surgical suite where surgeons now guide automated tools to perform microsurgery of multiple types, and other physicians oversee complex diagnostic tools. Computer based devices are reading video images of internal organs and their functions to assist radiologists in accomplishing more accurate and much faster diagnoses of human health problems.

Even in agriculture robotics are now in full bloom. Up in Lincoln County today wheat seed is sown by autonomous guidance systems that assure proper spacing of seeds, and where wheat harvesting machines circle around the hills and fields using GPS-based guidance systems that are coordinated with measures of the density of plants being harvested, the amount of grain begin gathered from each head of wheat, and the speed of the separators being carefully adjusted to avoid damage to the individual grains of wheat.

Why has automation so quickly developed in these settings – well, it's all about the presence of business economics where the owners/operators of these businesses quickly experience the economic benefits of using automation to speed production, improve the quality of their products and services, avoid accidents and down time, reduce their unit costs, and minimize labor inputs.

Even in transportation this is happening. Automated systems guide and fly planes today, both commercial and military because they increase fuel efficiency as well as sustain safety. Ships are being guided by navigation systems that obtain their guidance from satellites and centralized computer systems operated by shipping companies, thereby reducing on-board staff needs, increasing fuel efficiency. A German company, just now, is working to bring totally autonomous ships to market for the international shipping field, running solely on electrical power. Think of a huge ocean-going freighter with no human sailors or command staff on board, making international shipping ever more efficient and cost effective, and gaining their electrical power from natural gas-based generators and battery systems to maintain constant speeds.

In the personal transportation field, however, automation has been far slower to develop, unfortunately, in part, because it's been hard to do, and also because the direct benefits of such automation have not been well understood, or felt by car owners/drivers and their passengers.

And, the matter has also been an industry issue. Selling of cars, especially in the U.S., has long emphasized the comforts of travel (a living room on wheels), the joy of the driving experience (power, speed, exhilaration, etc.), and price, of course, over all else.

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In the face of these personal travel experience values, even safety has been a "hard sell," as Volvo and others can attest, especially when regulatory strategies in support of safety have quickly leveled the benefits playing field across all manufacturers resulting from use of limited types of automation – think air bags, ABS braking systems, and engine pollution controls.

Only now is safety about to get its first major market test in the automotive field via the introduction new driver assistance automation such as headway maintenance and automatic braking, and lane keeping and self parking systems, while increased fuel efficiency is promoted via adaptive cruise control and speed management systems to supplement existing automated engine fuel mixing controls and transmission shifting controls. Fuel efficiency also clearly sells today, but the links to automation, to accomplish all these things in cars, are not well understood by the car buying public.

All of these solutions, nevertheless, provide a superb opportunity for car drivers and passengers to learn directly how automation works in cars while they gain confidence in these technologies. Snazzy, intuitive control panels will not support consumer embrace of new automation technologies if drivers do not trust the effectiveness of such automation in meeting real needs.

The world of mobile communications, and connected car technologies are finally making possible entirely new, constructive, or entertaining travel time lifestyles. However, serious restrictions in the name of public safety have come with the very real issue of distracted driving, which is bumping up accident rates. Truly no-hands, no-feet autonomous vehicle operations will allow for in-car, in-motion time use benefit to be fully and safely realized by the car-driving public.

This is a huge issue. Traffic planners, transportation economists, and other experts may not be fully in tune with this sentiment of consumers. But all you have to do is ask any number of young people, busy and harassed mothers, and harried executives and management consultants, and almost to a person they will tell you that getting to where they need to go, by their own time spent driving, is an immense sunk cost that they can hardly wait to ditch once safe and efficient self-guided vehicles come to pass.

There are still other autonomous vehicle use benefits – both direct and indirect.

Here are some of the most important:

a. Dramatically increased safety – eliminating a major portion of the 32,000+ deaths resulting from major accidents on US roadways each year – Elon Musk, of Tesla fame, on September 18, in the Wall Street Journal claimed that autonomous vehicles would be 10 times more safe than today's safest cars
b. Tax payer savings due to:

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   i. Increased use of existing roadway capacity – 30 to 40% more vehicles moving on existing roads through closer spacing, with some claiming even greater potential for use of existing capacity
   ii. Increased safety - meaning less policing and reduced accident recovery costs

c. Shorter travel times due to smoother traffic flows, staged exits and entry to/from roadways, no need to slow for accidents
d. Dramatically higher fuel efficiency
e. Extensive participation in, and use of passenger vehicle-based ride sharing services
f. Reduced investment in vehicles by families. This is another very large incentive for vehicle automation as, if a family can reduce ownership of just one personal vehicle via use of ride sharing, etc., they can reduce their annual transportation investments as much as $6 to $10 thousand dollars per year.

These benefits are yet to be fully proven in practice, but this is what the autonomous vehicle demonstration projects now being pursued in Nevada, Florida, Michigan, Pennsylvania, California, Virginia, and soon here in Washington State are seeking to prove.

Why are these benefits possible – well, it's really very simple – machines can do repetitive motion and unwavering observation significantly better than humans in most cases, once properly designed and managed by smart systems. I said earlier the key is in the human interface design, and in the nature of the human oversight role in managing sensors, tuning system responsiveness (a software process), and preserving the requirement for human intervention when something goes wrong.

What is necessary to make autonomous vehicles happen? Where is the development process going?

We at CATES foresee a series of technical developments leading to a time when nearly all vehicles on our roadways are self driving. This goal may seem audacious. But, the beginning of the road to get there is readily visible.

Elon Musk said on September 18 that he sees the first fully autonomous vehicles operating on US limited access highways within 5 to 6 years. Demonstration and testing efforts on public roadways will begin later this year in California where Google, Audi and Mercedes were approved by the State Department of Motor Vehicles earlier this week to begin initial trial efforts.

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So, let's just briefly consider a four stage process, taking a period of at least 15 to 20 years, before all the technology components are in place, and a substantial portion of vehicles could be equipped to support the self-driving future.

Stage 1 – already underway, is designed to build human confidence in the ability of their car to protect they by doing things autonomously, but still under the constant intervention, if necessary. That's really what the driver assistance technologies are all about – lane keeping, refined cruise control that accelerates and decelerates the vehicle to maintain inter car distance, recognition of approaching roadway infrastructure (stop signs, stop lights, rotaries, turns) with warnings, and more. Most new vehicles will have these features in the next 3 to 5 years, and retrofit packages may also become available. So, stage 1 might be moving toward closure by the end of this decade.

Stage 2 – Individual vehicle self driving systems, what Tesla, Google, Audi, Mercedes, Nissan, GM, Ford, and others are already pursuing, and talking about. This stage builds on the car becoming "visually aware" of its surrounding environment, and incorporating that presence awareness with all of the existing stage 1 technologies. Elon Musk has said that the one key thing keeping stage 2 from fully happening is the lack of truly competent machine vision – that is, the ability of the vehicle to see around and beyond the immediate physical objects adjacent to it.

Multiple solutions are being pursued in this regard. INRIX is applying its real time video data to on-board vehicle data processing systems to provide perspective. Google is using its extensive visual mapping databases along with real-time video and other sensor data of every roadway to implement a similar capability. Still other methods build on three dimensional spatial analysis data bases; supplemented with real time radar, laser scanning called "LIDAR", and video data obtained by on-board systems and sensors. Other methods are also in development. These solutions all have potential, and combinations are most likely. Interestingly, similar sensors and guidance technology are already in use to guide combines, planters, etc. here in the agricultural fields of Washington State.

The next decade, stage 2, is also likely to see a rethinking of the very nature of the car itself. Just as robotic machines in manufacturing and other arenas have shown, moving to a fully automated technology framework requires the complete redesign of the fundamental framework of the machine. Mechanical systems must become just a subsystem of an overall high tech computer and electronics-based sensor and servo-control–based device framework.

Most cars of today, even those with extensive adoption of high tech elements, are still primarily mechanical devices onto which have been grafted a myriad of electronic and chip based subsystems. This is a problem. It's why Google has created a consortium of auto companies to work together in creating a new autonomous vehicle operating system that will guide a fully robotic vehicle that is basically a complex computer

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platform around which are aggregated a whole range of sensors and actuators. In other words, cars must become fully robots.

This reality requires a complete rethinking by the world's auto manufacturers, and massive reinvestment in their core engineering and manufacturing competence.

This is why Elon Musk, in creating the Tesla company, made a bet that, by starting anew, he could completely beat the reigning US auto manufacturers at their game. Tesla cars are fundamentally robots in their basic technology design. Computers control everything. And all the related mechanical systems and sensors serve the central Tesla operating system.

It is that reality, probably more than any concern for safety, efficiency, etc., that has motivated the world's major auto companies to get on board with self driving cars. They understood from the beginning of Tesla that Elon Musk had changed the game.

The public may view the Tesla car as primarily a different system of mobility power – all electric, but the Tesla vehicle is far more than that. Musk is hard at work in perfecting Tesla's own vehicle vision solution, so as to gain still more advantage over Detroit and Europe, and Japan in the short term.

All of this is also leading to still another competitive war that is presently shaping the future of vehicle manufacture. Who is going to have overall control of the future of autonomous transport technology – Detroit or Silicon Valley?

GM and Ford are doing all in their power to maintain control over the future of the automobile and of transportation system vehicles, as are Daimler (Mercedes) and others in Europe, and Nissan and Toyota in Japan.

Google, Apple, Nokia, and others believe otherwise. These companies are creating massive data systems, databases and server farms worldwide to support the future delivery of mapping controls and actuator technology systems that will enable fully autonomous transportation solutions. Google already has its own cars, if only to provide incentive to Detroit to join them or die.

Tesla is cooperating with at least some of these Silicon Valley companies but neither they nor their partners are talking.

And both Google and Apple have launched a full-faced attack into the automobile itself by creating Android Auto and CarPlay, backed by their millions of Android and iPhone users worldwide, as their army, to gain access to the electronic innards of every car manufacturer in the world.

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GM has already acknowledged that they have no choice but to let their iPhone and Android phone toting customers use Android Auto and CarPlay in their GM cars – connecting to the outside world via their Android and iPhone technology. This acknowledgement also came during the week of September 14.

As a result, the fundamental direction has now been cast, I believe. Silicon Valley will have at least an equal role in shaping the future of autonomous vehicles. And how Tesla, also a Silicon Valley company, goes may even more strongly signal how much dominance Silicon Valley will have in our autonomous vehicle future.

Apple and Google have more money to throw at these issues than all the auto manufacturers combined presently. Microsoft may still also be a player, but lacks the essential mobile connectedness technology customer base that Google and Apple enjoy worldwide.

This takes us to Stage 3.

What happens when more and more cars, using these early self-guiding technologies, have to sense, track, and respond to one another to avoid collisions? Because of the problem of intersystem latency known to computer and guidance controls system designers, these vehicles also start to respond to the behavior of the other automated cars. Sensor data analysis requires time before instructions can be relayed to control systems. So, from both aeronautic guidance and rocketry guidance experience, we have learned that systems have to build in compensation for latency effects.

But, there is a significant difference between just a few planes and rockets moving around (under ten thousand airplanes over the USA in the busiest periods) and millions of vehicles staying out of each other's way around Washington State with hundreds or thousands being passed and otherwise avoided on a single freeway trip. The potential result – autonomous vehicles systems will instruct the car to slow down to avoid a collision, leading to still more slowdowns by all the other autonomous vehicles, seeking to avoid the first vehicle that slows down. Gridlock could ensue.

This potential is understood theoretically and practically, but the solutions to solving it are not yet on any horizon.

Therefore, Stage 3, for autonomous cars.

When cars start slowing down, as ever more vehicles using individual vehicle-based crash avoidance controls head down heavily traveled roads, as Stage 2 progresses, the autonomous vehicle control industry is going to face a make or break decision regarding how to deal with the communications slow-down and interference problems that come from approaching a new road environment with old technology.

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Some of the auto companies, and our Federal DOT believe that the solutions lies in a complex vehicle-to-vehicle communications solution (V2V) that will enable adjusting of software parameters dynamically in each vehicle's autonomous control system, and possibly supplemented with a government-operated system of vehicle communication to nearby infrastructure like traffic lights. (V2I). USDOT has spent millions conceptualizing a V2V and V2I solution. Unfortunately, their solution principally draws on old technology concepts from early last decade.

Meanwhile, Google, Nokia, Apple and others are already far down the road with their own mapping data and communications networking solutions that rely on state of the art technology for linking to each autonomous vehicle via cellular links using their mobile phone-based systems, and their massive cloud of data centers.

So, CATES sees a likely complicated political and technology dance ensuing. This dance will be shaped by the car companies that are going to have to choose which horse to ride – a government mandated solution, or the private sector's innovation tied in to their new fully robotic autonomous vehicle platforms.

Already the broad outline of the private sector's stage 3 solution can be framed, with solutions likely involving dynamic aggregations of platoons of vehicles, designation of platoon leaders, and guidance systems that require registration of each vehicle's intended destination and preferred travel routes. The computer technologies already in use by the Silicon Valley companies will enable these processes, linked to mobile phone mapping systems and databases.

We believe that is why Google is already marshaling a core group of automobile manufacturers to join them in fashioning a new autonomous vehicle operating system framework to be adopted by all vehicle manufacturers.

And Tesla may well also have a hidden partner too; a large majority of Tesla's software engineers all came from Apple. Read your own mind regarding what may be going on there.

Should Google and Apple both decide to vie for being the core players in defining the basic roadway automation control system to be utilized by every autonomous vehicle, their industrial might and capabilities will be immense. They have the mapping data, the communications technologies, the massive data server complexes, the super high speed data communications networks, and the thousands of man years of computer chip design and operating system development experience needed to build the complex systems that stage 3 will require. And, like no one else, they have the hundreds of billions of dollars in capital needed to develop and implement these solutions already in their banks.

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So, look for another 10 year or so battle, similar to that of stage 2, to determine whose vision will be adopted – the auto industry's and/or the governments' views, or the private high-technology sector's vision? We at CATES are inclined to bet on the private high-tech sector as it has the money and the insights necessary to build toward this future.

Regardless of how this all goes, there will still have to be a stage 4 – the time period during with the stage3 technologies get even more well defined, and during which an ever larger portion of the traveling public chooses their own vehicle platforms to ride.

I'm going to stop now, as I have already laid out more than enough for everyone to chew on. I will make just one more comment - If stages 3 and 4 develop as we at CATES think will happen, the US will once again have defined and developed a truly incredible technology platform that will be used across the world.

And, we will have once again built something as large and momentous as the personal computing revolution of the 80s and 90s, and the mobile technology revolution of the past 10 years. This is truly a very exciting time to be alive and benefiting from these incredible innovations. I welcome your questions now.

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