TRANSCRIPT

Automobiles: A transformative shift towards electric vehicles and autonomy

Garrett Nelson: Hi everyone and thanks for joining us today for what we hope will be an informative presentation. First, we're going to talk about CFRA and then I will provide an outlook of electric vehicles followed by autonomous vehicles, then hand over to Angelo who will provide a semiconductor automotive outlook.

Just quickly about CFRA, our legacy dates all the way back to the 1920s when Standard & Poor started publishing research on global equities. But CFRA was founded in 1994 as the Center for Financial Research and Analysis. And then there were various transactions over the next couple decades before CFRA acquired S&P's equity and fund research business. And then most recently we acquired First Bridge Data, which brings us to where we are today as one of the world's largest independent research firms.

CFRA blends fundamental equity research with a forensic accounting. Our research covers 11 sectors in 68 different industries. We have qualitative research of over 1,500 companies globally and quantitative research of over 25,000 companies. But most importantly, research is all that we do. We do

not manage money or make trades, unlike many other firms. We're just strictly a research firm.

So, without further ado, I'm going to switch over to our electric vehicle outlook. And I'll start with a picture of a Tesla Model 3 that's charging, which I thought was a fitting place to start because Tesla vehicles have accounted for about close to 60 percent of total electric vehicle sales in the U.S. so far in 2019. And here's a brief history of electric vehicles, which have actually been around just as long as gas powered vehicles. But gas-powered cars really start to take over the market in the early 1900s when Henry Ford invented the Model T and you had low cost manufacturing innovations such as the conveyor belt assembly line, combined with the discovery of large oil fields in Texas and elsewhere. That really made EVs nearly obsolete by 1935. But if you look back to the year 1900, actually one in every three automobiles on the road in the U.S. was an electric vehicle believe it or not.

Moving forward several decades to the 1970s, oil prices started to soar, and you had the OPEC embargo in 1973, which caused oil prices to spike. And that helped renew interest in EVs. And then some new government regulations which boosted interest in the 1990s. And by the mid- to late '90s you had the first battery EVs being produced again: General Motors' EV 1 and

the Toyota Prius Hybrid. Then in the early 2000s oil prices again started to move higher which revived interest in EVs. Tesla released their first vehicle, the Roadster, in 2008, and the Nissan Leaf and Chevy Bolt both debuted in 2010.

The most significant development this decade is the big drop in battery costs, which have brought EV costs closer to parity with gas powered vehicles. This slide shows a 50 percent drop in battery costs. This is from the Department of Energy website. But in fact, if you look at lithium ion battery costs, they fell about 85 percent between the year 2010 and the year 2018.

OK. So, let's talk numbers. In 2018 global EV sales totaled just under two million vehicles. That's just over two percent of total worldwide new vehicle sales. And the breakdown of those EVs was about two-thirds battery electric vehicles and one-third plugin hybrids. The growth of the battery EV market has largely been driven by Tesla's Model 3, which debuted in late 2017 and now accounts for over 80 percent of Tesla's total sales volume. And that's one of the reasons growth has been stronger for battery EVs. Growth in battery EVs increased 78 percent last year and the plugin hybrid market grew 50 percent. In the U.S., by the way, about 360,000 EVs were sold last year. That's

also just over two percent of total auto sales in the U.S., which accounted for about 18 percent of global EV sales.

Interestingly, a *Consumer Report* joint survey released over the summer showed that 36 percent of prospective car buyers in the U.S. said that they would either consider or would definitely buy an EV within the next two years. And if they all followed through on that, that would imply electric vehicle sales of over six million in the U.S. So many times, the 360,000 or so that were actually sold in the U.S. last year. So, we think there's a significant appetite for EVs among U.S. consumers. But the two main factors which are really holding consumers back are cost, followed closely by driving range, as you see on this slide. And we think automakers have really struggled to come up with vehicles with the right combination of price and range, particularly in the extremely popular SUV crossover and pickup truck category, but we think that will be changing here very soon.

So, I think it's important to listen to what people in the industry are saying, and have said, about electric vehicles and autonomous vehicles. And here's what they've been saying. The first quote is my favorite because I think it really sums up the mentality of many of the major automakers for many years who were essentially just making EVs because they had to in order to meet

government fuel efficiency standards or sales quotas. Many automakers really didn't want people to actually buy the vehicles because they were much more expensive to make than traditional gas-powered vehicles. But you see that first quote, back in 2014 the somewhat iconic former chairman and CEO of Fiat-Chrysler, Sergio, said that he hoped people didn't actually buy their battery powered EV, the Fiat 500E, because every one that they sold cost them 14,000 dollars. But I think more recently there's been the acknowledgement that electric vehicles are here to stay.

In a minute we'll talk about all the new electric vehicles expected to debut in the U.S. in 2020. And it's important to understand that the vast majority of them will still be eligible for the full $7,500 federal EV tax credit, which will give these vehicle models a huge competitive advantage versus the EVs sold by both Tesla and General Motors. And that's because the way the tax credit is structured, once an automaker hits 200,000 electric vehicles sold on a cumulative basis in the U.S., the credit begins phasing out over a 12-month period before going to zero. And Tesla and GM are the only two automakers so far who have hit that threshold, and therefore they're both in the phase out period.

This slide just lists just some of the failed electric vehicle startups over the past decade or two, which numbers at a dozen, on this slide, and that does include all of them. And I think the key takeaway is that the global auto industry is highly competitive, cyclical, high fixed cost, and low margin, and that the failure rate for new entrants is high. If you look at the average EBIT margin in this industry, it's only in the mid-single digits. And that's why you have a lot of stocks who are also trading at mid-single digit PE multiples.

Moving on to the next slide, there have also been numerous EV models over the past couple of decades which didn't sell particularly well and have been discontinued, including four models in 2019 alone, the most recent of which was the Chevy Volt.

And next slide, here's the list of new EVs expected to debut in the U.S. in 2020. So, there's 25 new models in total. The breakdown of those is 16 battery EVs and nine plugin hybrids. And if you look, eight of the nine plugin hybrids are expected to have a range of 40 miles or less. So, these are vehicles capable of driving to the supermarket, to work maybe, on battery power alone before switching to fuel. And it's interesting because a lot of automakers are convinced that there's a market for these suburban-oriented hybrid vehicles capable of everyday errands. But I think a lot of the vehicles on this list aren't

going to sell especially well, especially given the surge in overall electric vehicle supply we think is going to somewhat overwhelm the consumer. But generally, we think vehicles with a favorable combination of price and range will succeed, models such as the Tesla Model Y, the Ford Mustang Mach-E. Those two vehicles in particular are going to help fill a void in the extremely popular SUV and crossover category where automakers have really struggled to find a winning formula for price and range. But that's really going to start to change in 2020 and I would also point out the number of SUVs and crossovers on this list.

OK. So, let's look ahead 10 years. There are a lot of estimates out there of what the EV market looks like in 2030 and here's one. This is from the Edison Electric Institute. We included it because it seems pretty reasonable from our perspective, given how we see the market evolving today. And it shows that the market share of EVs will grow from about two to three percent of total U.S. auto sales to about 14 percent in 2030. One thing I would point out is that aside from Tesla the European automakers are forecasted to have the greatest percentage of EVs in their mix. Volvo you'll see estimated about 15 percent of their total vehicle sales will be electric vehicles, followed by Volkswagen and Mercedes both at 25 percent. BMW is there at 20 percent, while the big three U.S. automakers are forecasted to have the lowest exposure.

So, wrapping up our thoughts on electric vehicles, we think sales will surge in the coming years as prices drop closer to parity with gas powered vehicles and as charging times improve. An estimated 225 billion dollars will be spent to develop more than 200 new battery powered EVs globally through the year 2023. That's a figure that does not include hybrid vehicles. We think most vehicles will flop from a sales perspective, especially those that don't offer a compelling mix of price and range. But we think a diversified approach to EVs makes the most sense and don't expect EVs to be a major profit driver for most automakers in the near term, with the exception of Tesla, of course, which is an electric vehicle pure play. And then finally we think future oil prices and global GDP growth are the two biggest swing factors which will determine the future of the EV market.

Now I'm going to transition over to autonomous vehicles, which obviously are in a much earlier stage of their development than electric vehicles.

OK. So, what are we talking about when we discuss automated vehicles? There are five different levels of automated driving, with level five being a fully autonomous vehicle with no driver needed. And the general consensus today is that current technology is somewhere between level two and level three.

Examples of that technology include Tesla's Autopilot, GM Cruise, and some of the Waymo vehicles that have been operating in areas of the country such as Arizona. Basically, the cars can speed up, slow down, steer, and change lanes, but the driver is supposed to keep their hands on the wheel at all times. And this technology really works best on highways and on interstates, not in urban environments or in adverse weather conditions.

So, here is the case for autonomous vehicles, and obviously safety is the number one talking point. Over 36,000 people died in motor vehicle crashes last year, and 94 percent of serious accidents are caused by human error. There are also significant economic, societal, and productivity benefits and the elderly and disabled could benefit greatly from a mobility perspective from fully autonomous vehicles. But let's look at recent vehicle safety trends, absent AVs, and the fact is that vehicles have never been safer than they have been in recent years. The fatality rate in the U.S. is just over one per 100 million miles travelled. And a lot of the improvement in recent decades because the invention of antilock brakes, airbags, and other innovations. And the slight uptick in both the fatality rate and the absolute number of fatalities on the right side of these charts here over the last three or four years has been attributed to an increase in texting while driving.

Now let's look at the case against AVs, and surprise, surprise, the number one talking point against AVs is also safety. And that's because statistics show that humans are extremely good drivers and the fatality rate I just cited implies a safety rate of 99.999999 percent. That's 99 followed by six nines percent. And we think autonomous vehicles won't be broadly accepted by the public until they're as safe as human drivers. But other talking points are the enormous costs associated with developing AV technology, and also cybersecurity concerns such as hacking.

Here's a picture that I took of a concept car that was featured at the North American Auto Show in Detroit earlier this year, and it was an all-electric and fully autonomous vehicle where the steering wheel disappeared into the dashboard upon command and there were no buttons or switches anywhere inside the vehicle. Everything was computerized. And this was merely a concept car, don't expect to see this on showroom floors anytime soon, but I think it provides a glimpse into where automakers are heading in future years.

Moving on, here's a snapshot of global auto sales. And I would point out that China, Europe, and the U.S. together account for about 70 percent of global auto sales volume. And the main reason sales declined last year and will decline by about five to six percent globally this year, is because China has

really hit a wall in terms of their growth. Last year China's sales declined for the first time since 1990, and it looks like their sales will be down close to 10 percent this year. We see another drop in 2020 in China auto sales but not nearly as drastic as what we've seen this year. So overall, we're forecasting a two and a half percent decline in global auto sales next year, driven by Europe and less so China.

OK. So how long will it take to get to full level five autonomy? And the truth is nobody knows exactly how long it's going to take, but here's one projection of global AV sales over the next few decades, which I personally think is pretty bullish to perhaps unrealistically bullish. But in any case, this is what LMC Automotive projects. I just think the one million vehicles by 2025 is probably not going to happen.

OK. And now let's look at what the experts are saying, and have said, about autonomous vehicles. And what I want to point out here is that there's a huge difference between what industry leaders were saying prior to this year and what they've been saying in 2019. Here you see Elon Musk saying back in 2014, "Self-driving technology is almost at a point when owners will be able to fall asleep in their cars and wake up at their destination. I think that's about two years away."

And then you had the CEO of Waymo in 2017, who said, "Fully self-driving cars are here...It's not happening in 2020, it's happening today." So, you get the point. There were some very bullish predictions being made in recent years.

And now let's look at what the various industry leaders have said about AVs this year. At the top, "Robotaxis are likely to be a fantasy until 2035," you had the CEO of Ford saying, "We overestimated the arrival of autonomous vehicles," and then Elon Musk saying, "Next year, for sure, we'll have over one million robotaxis on the road," which really it stands in contrast to what the others were saying. And then finally you had Nissan saying, "We will need at least until the late 2020s to even get to level three autonomy."

And then some more quotes from 2019, over the past year you had Waymo saying, "Over the past year, we've gone from a lot of hype that was sort of unmanageable and so mismatched to what's happening in the real world." You had the autonomous driving company called Zoox saying regarding Elon Musk's robotaxi claim, "He would need to come with four or five orders of magnitude more performance out of systems. He would need to make 50 years' more progress in order to deliver on his robotaxi claim. It's not

happening." And lastly Apple cofounder Steve Wozniak saying he's basically completely given up on level five AVs happening in his lifetime.

And then on these last few slides on autonomous driving, I'm just going to breeze over because you're going to be hearing from Angelo next, but there are significant technological, legal, regulatory, and other obstacles standing in the way of full autonomy. There are also differing views surrounding autonomous technology, much of which centers on the use of LiDAR sensors, which stands for Light Detection and Ranging, which most automakers have made a key part of their AV programs, but Tesla has been pretty outspoken against. And I think more recently there's been a growing acceptance across the industry that LiDAR is not the golden ticket in and of itself and that Elon Musk's and Tesla's out of the box approach does have some merit.

But Tesla is certainly taking the road less traveled from a technology standpoint, and the jury is really still out on who will get there first as far as level five, but it's going to be very fascinating to watch. And it's sort of the Space Race of our time.

So just some final concluding thoughts on AVs. Number one, level five AVs are much farther in the future than most experts thought a few years ago.

Secondly, a global recession would likely significantly affect the timeline of AV development. And then thirdly, AV programs have become a significant drag on earnings for several major automakers such as Ford and GM. And we think executives are going to be tempted to target these business decisions as a way to cut costs as many automakers are really struggling from a top and bottom-line growth perspective.

And then my final slide, just some general winners and losers on the topic of both electric vehicles and autonomous vehicles. The winners we see is Tesla, they have a pretty significant first mover advantage in both electric and autonomous vehicles and also an advantage in terms of price and range. The European automakers, and they've really been focused on -- they've invested a lot of money in developing both electric vehicles and autonomous vehicles because there's been more demand in Europe for those types of vehicles. We also think some of the winners in the near term at least will be those still eligible for the full 7,500-dollar U.S. federal tax credit for electric vehicles. And also, the SUVs and crossovers with a compelling mix of price and range because we think there's significant pent up demand for EVs in that category. That category accounts for more than seven out of 10 vehicle sales in the U.S. today.

The losers we think are the big three U.S. automakers. We just think they're behind the Europeans, and certainly behind Tesla with their EV technology in their product pipeline. And looking out a decade we think they're going to have a smaller market share in EVs versus many of the other companies, which our slide on the 2030 market showed. They're also making a big bet on LiDAR technology even though it's really the jury's still out on that technology. And then finally autonomous vehicle segments have become a significant drag on earnings. If you look at the autonomous segments for GM, GM Cruise, and Ford, which is Ford Mobility, it's been a drag on operating income of over eight percent for General Motors in the first three quarters of this year, and a 14 percent drag for General Motors. So, their earnings would have been materially higher without the impact of the losses those segments generated.

So, I will leave it there, and I'm going to turn it over to Angelo for semiconductor outlook.

Angelo Zino: All right, thanks a lot, Garrett, and hello to everybody on the call. So, I'll spend the next few minutes talking about autos really from a technology perspective, and more specifically a semiconductor perspective. It is very technical in nature, so I'll do my best to keep it high level and understandable in nature.

So, when our high-level view here at the company, at CFRA, is really that the automobile will be the next big tech device, a disruptive industry for the semiconductor industry. And essentially, we see three megatrends out there taking place to support our view. You shouldn't be surprised by the first two given Garrett just highlighted both of them, that being the shift to autonomous vehicles as well as the electrification of the car. The third one also shouldn't be much of a surprise and it's essentially the ongoing evolution towards a more connected vehicle, essentially giving a car many of the similar features that a smartphone has. And I'll go into detail here on each of these things over the next couple of slides and a new growth opportunity there for the industry.

We continue to believe auto-related semiconductor stocks will outperform in the broader semiconductor industry in terms of growth, outgrowing the industry about two times over the next three to five years. And that essentially assumes a no-growth environment for vehicles.

I laid out some of the key areas of focus here, infotainment systems, safety, power drain, battery management, autonomy, and I'll break down the five specific areas of opportunities we also see for chipmakers.

Now while fully autonomous cars, that being level five, still years away according to me as well as Garrett, many companies here have a roadmap of getting to level four here within the next several years. And we do think those initiatives will really help fuel the semiconductor content growth that we see for the industry. And before I do go into the slides here, just to be clear, just be mindful that the outlook for semiconductors here really pertains only to the actual silicon semiconductors growth that we see for the industry. So, a lot of these companies, a company like NVIDIA, they're looking to sell their hardware and software offerings to automakers out there and they're very expensive offerings. Great opportunities and opportunities I'll discuss, but it won't be in the figures in terms of the growth we see for the actual silicon content in terms of the semiconductor industry.

Going here to the next slide, this is just a representation of the exposure of autos to the semiconductor industry. We expect autos to be, again, the highest growth area among all these categories that you see here over the next several years. We think actually within the next 10 years auto could represent about 20 percent of the semiconductor industry in terms of sales. Three years ago, it was only about eight percent of sales, and as you can see today, about 12 percent of sales.

So here we provide our full base probabilities for automotive semigrowth. The chart on the left really shows our base assumption, which we give about 60 percent probability of happening. Essentially in this scenario we're looking for semiconductor content in the car will grow about seven to nine percent ever year. And that, again, assumes no growth for vehicle sales in the automotive industry. This gets to simple math, gets you to high single digit growth here over the next three years for companies exposed to that area. Our bull case assumes that it should be given about 25 percent probability, assumes slight growth in the vehicle sales, about two to three percent. That would get you north of 10 percent growth for auto semiconductor -- the auto semi space. And then finally our bear case, 15 percent, assumes no growth in auto semis and a sharp decline in vehicle sales. And essentially you get a pushout in level four vehicle kind of investment.

And when we think about that scenario, that bear case scenario, that's essentially what's happened here in 2019 and our view of right. So, we've got a lot of these macro issues pushing down vehicle sales in 2019 while the broader semi industry is seeing sales decline 10 percent this year, whereas the auto semi guys are more flattish in that type of environment.

So, this is just a quick chart of the difference between the luxury and standard vehicle market in terms of the semiconductor content these days. So, the average car sold last year had about 400 dollars' worth of semiconductor content. You can see a big difference between the content in the luxury car versus standard vehicle. And not surprisingly these vehicles, not being on the luxury side of things, are the ones with the easy plugins. So that being said, you would imagine significant content growth. And I'll go into the slides and show the difference between the content in a plugin vehicle versus one that isn't a plugin, more your traditional IPU.

So, here's a slide, I wanted to get into a high-level discussion on where the semiconductor opportunities will come from. At the end of the day we think it's best to break down the car into five categories for the semi industry. The first is connectivity. Today about 40 percent of cars have some sort of cellular connectivity. That figure we think will rise to about 70 percent here over the next five years. Most cars being sold today already have some sort of Bluetooth and Wi-Fi capabilities, and you guys are well aware if you bought a car here in recent years. Second category is autonomy, which is where I'll probably spend most of my time talking. You can see some of the sensors believed to be needed for autonomous cars, whether it be radar, cameras, LiDAR, really the eyes of the car. Then, of course, you also need the

processors, or the brains of the car, which is really where companies like NVIDIA and Intel hope to control.

The third category out there is power trained vehicle dynamics. This is where the EV side of things really come into play, so some of the sensors included here include the power train controller, which essentially acts as the brain of the engine control system. Our view is the biggest opportunity in this area will probably be around battery management systems, which will gain steam just as EV adoption grows in nature.

Fourth category, body and comfort, just the idea of more stuff around your car becoming automated in nature: your doors, your mirrors, your sunroof, etc., and includes really sensors that control the temperature, lights, among other things within your vehicle.

And then the final category surrounds connected infotainment systems, so essentially the dashboard on your car. The market here has matured here in recent years. Most cars being sold today have some sort of touch display, especially in the U.S., but also, I've met some of the opportunities that still exist there as well.

So here we just have a table about the opportunity that EVs bring to the semiconductor industry. We believe battery electric vehicles add about 450 dollars of semiconductor content relative to your traditional internal combustion engines, your ICEs. You can see some of the table at the bottom how the opportunity incrementally grows as we move away from those ICEs towards hybrids. And the real opportunity really comes where the main charging mechanism is in the form of plugin, so the last three examples here that you see on the table, as they require more powerful batteries with greater electric traction.

Garrett talked about some of the opportunities in terms of EVs, and as these EVs grow from the two percent of the market this year towards let's say 10 percent here in the next several years, you can see how this mix alone will help a lot of these chipmakers out there. And again, battery management solutions we think will be an area of significant growth. We actually think it will grow at about a 25 to 30 percent clip, and really if you're a semiconductor company, that's one of the areas you want to be really exposed to.

So, on the autonomous side, Garrett talked about the six different levels here. This slide just essentially looks at those six levels, but on the right column you can see the additional semiconductor content increase as we need to add

more senses and capabilities around the inside of the car as we step up the levels. Clearly the jump is seen as we move to level three, four, and five. At level three you start getting that significant autonomy where the driver can disengage over time, essentially where Tesla is at the moment. So, level three we're talking about 600 dollars in semiconductor content, up from 150 at level two. And as you progress towards level five, that will double from level three levels.

So just jumping here as we dig deeper on the autonomy side, much of the senses around the car can be really identified in three categories, which I alluded to: radar, LiDAR, and cameras. I think the table on the bottom right here does a really good job showing the number of sensors needed for each as we progress from level one and two to level three, and then level four and five. These three senses are essentially expected, again, to act as the eyes for the self-driving car. And for those really not familiar with the terms I'll go into a little bit deeper here over the next couple slides. Radar works through the use of radio signals that bounce off surfaces around the car. LiDAR, on the other hand, will use light sources that scan the surrounding area of the car. And then you've got cameras which have the highest resolution among all of them, great at providing closer and wide-angle views of what's around. Garrett discussed how Elon Musk has essentially said LiDAR is not necessarily and is

not utilizing it in the Tesla -- basically saying that radar and cameras are enough to do the trick.

And the last sensor I'll discuss is V2X, so that's the idea of vehicle to everything. Essentially that provides the ability for the car to communicate with everything around it, and other things to communicate with the vehicle. So, I think a good example is about a car warning another car five miles away of an accident that just happened, which would then reroute the path of that other vehicle miles away. And it's a technology that's definitely starting to gain traction with a number of the automakers out there.

So, this just gives you an idea of some of the different functions of each of these sensors. As you can see, radar and the cameras do the bulk of the work here. For instance, radar will help manage the speed of the car with physical adapters, cruise control. It's also used for capabilities like collision avoidance, obstacle avoidance. LiDAR, the strength on their end is the ability to better predict an object's behavior. So, the example I always give is LiDAR can detect if a person is facing forward or backward in the street, whereby radar can't do that very well. So, in that event LiDAR can better assume what the pedestrian or the object around the car will do before it happens. And then finally with regards to cameras, the story about cameras is that it provides the

highest resolution among the three sensors. So, it's great at reading road signs, traffic lights, anything around it. My view is when it's all said and done, for autonomous cars you really need some combination of these sensors to get it to work.

Next slide here, this goes over just comparing the eyes of the self-driving vehicle. I went through most of this stuff but what you need to know in terms of this is radar has the lowest resolution and the strength on their end is it can see hundreds of yards away and detects sizes and speeds. It's also a lot less costlier that LiDAR which is why Elon Musk has steered away from it. On the LiDAR side of things, again, I talked about the strengths there. The biggest drawback, again, cost, and the fact that hey, listen, given that it's based on light, it's just not going to work well in all weather conditions. And then same thing again with the camera. The biggest drawback there is the fact that it just doesn't work well in certain weather conditions.

So, going here, really quick on the vehicle to everything concept, again, vehicle to everything, gaining traction among some of the auto manufacturers out there. Two main components there, vehicle to vehicle, which is vehicles being able to communicate with one another, and then vehicle to infrastructure, which is vehicles communicating with external systems such as

streetlights, buildings, pedestrians. And when you start thinking about it it's essentially the concept of smart cities essentially becoming a reality. Much longer timeframe there but eventually we do thing V2X gains a lot more traction over time. 5G will help with the adoption here, and Qualcomm, with their CV2X, is a key player there. At the end of the day, V2X is essentially expected to be a complement to radar, LiDAR, and cameras out there, not the answer to autonomous vehicles.

So, we talked about the eyes of the automobile, but if you're really thinking about creating autonomous cars, it's not as simple as slapping together the sensors around the car. Otherwise we'd be there today. In fact, the most important part of an autonomous car is really the computing platform at the end of the day. The idea of an autonomous car should be thought of, in our view, as essentially a data center on wheels, or basically a concept called "computing at the edge," where it's the actual vehicle making the decision without having to reach out to that data center for input.

So now when we think about autonomous cars it's all about training your car, giving it the AI capabilities, and again that's done with the brain of the vehicle, the computing platform. Not surprisingly this can be done with four different type of options, which I highlight and compare and contrast on the table here.

And all four of these technologies, again, shouldn't be surprising given that they're very common and found in the data center. The first one is the GPU. It's a graphics processing chip but basically being dubbed as the best option out there. And video really the dominant player here and we said this, but who would have thought that the gaming space at the end of the day would have been the answer to AI in the car? But that's exactly what's happening here in this case. GPU has gained a lot of traction in the data center over the last four years or so. It's cloud giants like the Amazons, Alphabets, and Microsofts of the world has really adopted it in their ecosystems for machine learning efforts and capabilities, and we do think GPUs will eventually become the industry standard inside the car.

Now ASICs are another option. This is the path that Tesla has taken. They recently dumped NVIDIA in terms of their GPUs. The positives here is that if you can build one the right way -- and ASIC essentially stands for an Application Specific Integrated Chip. Essentially, it's a chip that you're manufacturing in-house and these chips, they're extremely difficult to build and the upfront costs are extremely high, but once in mass production, the cost aspect of it is much more affordable. In fact, a company like Tesla is essentially getting 80 cents on the dollar in terms of relative to using an

NVIDIA chip. And it could potentially become much more powerful than, let's say, using a GPU.

The other two options out there, FPGAs, we think are unlikely to be the option. The negative is that they're a lot less powerful and more costly than ASICs, but the positive is they're great for prototyping and they're flexible in nature. So, there are some benefits, but we don't think it's going to actually be the answer there. And then CPUs also we just don't think on a standalone basis is going to be the answer for autonomous cars. You're probably going to have to link that with another technology out there, similar to what you're seeing in the data center these days.

So, we look here, just really quick, this just sums up the three-step function of how autonomous cars work once it's in the real world. Really just provides a high-level view of how these sensors and computing capabilities come together to work in a real live situation. So, the first step is essentially map building, where you've got all these sensors, the LiDARs, the cameras essentially scanning the surrounding, and then essentially building that map in real life situation. Then you've got the path planning, which is essentially the vehicle just planning out the safest possible route to get that individual from location A to B. And then clearly step three is probably the most difficult to

achieve is the perception obstacle avoidance, and that's making sure that that vehicle gets from point A to point B essentially unscathed in nature.

So, this is just a comparison of some of the leading providers of autonomous capabilities. So, when we speak to a lot of investors out there, these are the three names I get asked the most about, so I figured I'd throw them on a slide here. It makes sense, too, given that these companies are currently viewed as having the first mover advantages but in different ways. But that being said, when you look at companies with first mover advantages, those capabilities and advantages rapidly waste away. They're great to have but when we look at how these companies operate, Tesla being the most advanced at least in the real world today, again, from a technology perspective they utilize only cameras and radar, no LiDAR. The brain of their cars essentially something called the ASIC, which we highlighted. As far as getting to level four, which we think they get there by the end of the next year, they're on the right path. I think the question remains from a lot of people out there is do they have the right approach to eventually get to full autonomous capabilities, that being a level five, and I think that remains to be seen.

Waymo has taken a little bit of a different approach. They use the GPUs out there that are made by the likes of NVIDIA. They are big believers in LiDAR

technology, but when you look at most of the work they've done today it's actually been in terms of simulators, whereas the benefit Tesla has is they've got tons of cars that are out there and using real world data.

And then finally in terms of NVIDIA, they're we think the wild card out there. They've got the potential to really lower the barriers to entry for the auto industry being able to commercially sell their GPU hardware, software. As they bring those prices down, it becomes more of an actual situation for many of these auto companies to strive and survive.

So just one slide here in terms of shifting away from AVs towards a connected infotainment system, again, infotainment systems maturing, we think still a good market here growing about five percent a year, so below our actual forecast for auto semiconductor growth. We think you'll still see growth, just driven by greater penetration in China and the idea of making infotainment systems more of an entertainment device, something Elon Musk has said on numerous occasions. We also see increasing displays just in general being sold both in the front and back seat of cars.

So, here is just a slide of the top 20 chipmakers on the planet in 2018 and their exposure by segment. So, auto exposure essentially being the red bar there.

The most exposure are actually overseas companies, based companies like NXP Semiconductors, Infineon, STMicro, along with Japan-based Renesas. U.S.-based companies like Analog Devices, On Semiconductors, and Texas Instruments are the most exposed here in the U.S. And we continue to believe that long term, again, auto growth will outgrow these combined industries by a factor of two, so naturally you would think those most exposed should outgrow the industry long term.

Now this is just a quick overview of our U.S. coverage and some of the chip names most exposed to the auto space. I tried to break down where these companies have the greatest exposure of their offerings by category. By no means is it expected to be exclusive but do believe that just having exposure to the area is not good enough. You need to have the right offerings in the right space and if you look at where the greatest percentage of content growth will come from, we think it's actually those first three categories, connectivity, autonomy, and vehicle dynamics. And our view again is a company like NXP Semiconductors, Analog Devices, On Semiconductors, some of those with the best offerings in those areas.

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