Transcript: Aptiv Autonomous Mobility Teach-In
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CORPORATE SPEAKERS

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- *Karl Iagnemma*; President, Aptiv Autonomous Mobility
- *Brandon Eldredge*; Chief Financial Officer, Mobility & Services Group
- *Glen De Vos*; Aptiv Senior Vice President, Chief Technology Officer and President, Mobility and Services Group

PARTICIPANTS

- *Chris McNally*; Evercore ISI; Managing Director

PRESENTATION

Operator:

Good morning. Welcome to the Aptiv Autonomous Mobility Teach-In. At this time, I'd like to turn the call over to Chris McNally from Evercore. Chris, you may begin.

Chris McNally:

Thank you so much. Good morning to everyone and all of our clients on the line. Welcome to the Evercore ISI co-hosted Aptiv Autonomous Mobility webinar, live from the Boston Tech Center at the Seaport. For those of you who don't know me, my name is Chris McNally, I cover the US autos, global suppliers, and all things future mobility and auto tech here at Evercore ISI.

That's why it's my absolute pleasure to welcome Aptiv and an all-star mobility cast for today's teach-in. Now, a quick bit of history. I've been pitching to Elena for almost a year for this event, ever since I basically saw the ADAS teach-in last year where I found the slides invaluable. Here we are today with a great line-up.

Just a quick intro of who we will hear from today: Glen De Vos, CTO and President of Mobility and Services Group, likely a familiar face for many of you in the room, but maybe it's your first time meeting some of the very busy mobility team who have joined Aptiv in the last 18 months. It's our pleasure to have Karl Iagnemma here, President of Autonomous Mobility and nuTonomy Founder, as well as Brandon Eldredge, CFO, Mobility Group. Thank you both for making the time, we know your schedules are extremely demanding. Finally, to the Aptiv IR team and the Boston Tech Center staff, thank you, again, particularly Elena and Kyle for all the hard work.

Now just a really quick high level take on Aptiv and Mobility from us before we hand it off to the team for the presentation. At the teach-in last year, Aptiv presented a BCG analysis that showed that the ADAS TAM would grow from $5 billion in 2017 to $11 to $13 billion in 2022 with 95% of that growth being level 2+ or less.

Now, Evercore's internal analysis shows that that same ADAS and level 2+ market alone will grow four to five times from today to roughly $25 billion to $30 billion of a TAM before really level 4, level 5, or AMoD takes off. While the industry and Aptiv works hard to make it commercial feasible beginning in 2021, 2022 as we saw in their slides, a quick peak shows that actually—they're discussing around $500 million of Mobility revenue by 2025 and rapidly growing from there, which is great to see.

Aptiv in our opinion, should be the leader in this largest CPV opportunity market, and we've forecast that last year's $1 billion of ADAS revenue should likely grow to $5 billion-plus by 2025. That's simply based on a 20% market share and particularly through their number one future market share provider of mobilized vision and a rapidly rising radar business. That's the baseline.

In addition, as we'll hear today, Aptiv is one of the only Tier 1 suppliers to play on both sides of the ball in both production cars and robo-taxis. In this respect, they can benefit from what is increasingly seen as the evolution of autonomous driving in the 2020s, leveraging their ADAS sensor and architecture leadership before a more disruptive revolution, 2025 to 2030 or beyond. That evolution is what we look forward to learning more about today.

With that, I hand it off to the team here at Aptiv to start the presentation.

Elena Rosman:

Wonderful, thank you, Chris. I think that was a good introduction. I'm going to kick things off today, just to bridge where we left off from our last teach-in, as Chris alluded to, in the Active Safety space, and then the focus for today is really around how we see the opportunities unfolding, specifically to the automated mobility market. Karl and Brandon are going to discuss both the technology road map but also the commercial road map and how we see the role Aptiv plays as an enabler to the automated driving technology, bringing that into a much broader mobility ecosystem, and how that's allowing us to really maximize our return on investment.

We would like to defer questions until the end of today's presentation, if that works for everyone - we'll be sure to leave plenty of time, and then following the Q&A session, Abe Ghabra, Managing Director of the Las Vegas Tech Center, is here to present our Aptiv Mobility cloud platform, so you'll see a demonstration of that as we mingle and have lunch after today's presentation.

Turning to the next slide, today's presentation does contain forward-looking statements. We ask that you review the comments on Slide 3. Our comments are based on our best view of the world as we see it today, and they're subject to risks that we outlined in our Form 10-K and other SEC filings.

Just briefly, what is Aptiv? Aptiv has really evolved into a global technology company with an industry-leading portfolio in advanced solutions that make vehicles safer, greener, and more connected, that we think are really at the forefront of enabling the future of mobility.

Turning to Slide 5, as the vehicle has increasingly become or is becoming a software-defined platform, we have really adapted our portfolio technologies to meet the demand for more complex software development and for systems integration expertise. We think that this unique portfolio composition has allowed us to be a partner of choice, really as we've optimized solutions that leverage both the brain and the nervous system of the vehicle.

As a result of our capabilities in each of those four areas - power, data, compute, and software – these are the areas underpinning what we refer to as a full vehicle solution stack, and allows us to be in a position to conceive, specify and deliver differentiated solutions to customers that many of our competitors, quite frankly, don't even know exist yet. We're applying these capabilities to solve some of what you think are mobility's toughest challenges, specifically in the areas of active safety and automated driving.

Before we get into automated driving, I wanted to take a minute to remind everyone of where we are as an industry. I think many of you are familiar with this data, but the automotive industry has been absolutely uncompromising relative to safety and the improvements that we've seen over several decades, starting with seatbelts and airbags. The challenge is that these trends have really started to reverse, though, in the last couple of years and go in the wrong direction, and when you look at the data, specifically China, China has 70% more vehicle fatalities than the U.S. with roughly half the number of miles driven on an annual basis, which is pretty staggering statistic, and I think everyone is familiar with the worldwide statistics on global fatalities - 1.25 million people were killed last year in vehicle accidents. I think one of the most shocking interpretations of that data for me is that that equates to two people dying every minute of every day around the world, so really the question is, what are we doing about it?

The reality is that passive safety is no longer enough to keep up, keeping people safe in vehicles, so we have to get to a point where the technology prevents us from absolutely hitting something. What you're seeing now is the early adoption of active safety functionality. You can see on the left-hand side of that page, features like collision warning systems and blind spot detection are really offering some basic level of information, as we define it as level zero. They're just the beginning to solving this dilemma. The real benefits come from true automation as we move further to the right of that continuum.

Our safety solutions support a broad range of our OEM customers' needs for incremental ADAS functionality from the very lowest cost systems that provide an entry point for the democratization of active safety all the way up to the premium solutions that provide more of a cutting edge performance for level 2, level 2-plus, and eventually will lead into level 3, level 4. It's our satellite architecture approach which we talked about at our active safety teach-in last year that, quite frankly, provides all of that on a cost optimized basis on the same platform for an OE, and you'll recall our CEO, Kevin Clark, mentioned the 80% to 90% win rate that we're seeing in active safety as a result of really focusing on that sweet spot for level 2 and above.

Now turning to the next slide, what's important, we think, for you to take away from today's teach-in is that the same investments that we're making today to develop advanced active safety solutions, whether that be our sensing and perception systems, the sensor fusion around the algorithm to do radar, camera, lidar, sensor fusion, policy and task planning, and eventually leading to advanced vehicle architecture, these are all the fundamental building blocks for automated driving, and as OEM vehicles continue to evolve from level 1, level 2 today to level 3 and eventually level 4 and level 5, we also see this parallel commercial path specifically for automated vehicle technology in a new group of customer, that being the mobility providers and fleet operators.

Turning to slide 9, to help accelerate our development and commercialization of these automated driving solutions, we have made a number of technology investments and acquisitions. On the software side, just to remind everyone, we acquired Ottomatika in 2015, which was the Carnegie Mellon University IP supporting automated driving, and then more recently with the acquisition of nuTonomy in 2017, their automated driving team out of MIT, both of these representing original assets that dated back to the DARPA challenges over a decade ago, looking at specifically the level 4, level 5 automated driving technology.

Along the way, we also looked at perception as being an incredibly important enabler of automated driving technology, and to ensure that we would have access to the winners in the long run for the development of solid state lidar, we have made a number of minority investments in lidar companies, so working closely with those companies now to ensure that they can industrialize and deploy their technology on the same time frame that we're looking to scale, both level 3 for traditional OEs as well as level 4 and level 5 systems in that '22 and beyond time frame.

As we thought about where automated driving is going, I also have mentioned Control Tec here. Obviously these automated cars generate a lot of data, and so the connected service opportunity was obviously very important as it relates to the automated driving investment that we're making, so leveraging Control Tec's data acquisition, edge processing, software and data-intensive capabilities, and we're doing that, as you'll see again, in the demonstration with the Aptiv Mobility cloud, that's helping to support our Las Vegas deployment and you'll get a chance to experience some of that real time following today's presentation.

Lastly on the page, actually a new investment for us in 2019 was an investment in Affectiva. They're a real time identification software company focused on the cognitive state of vehicle occupants. This partnership from our perspective is certainly to help innovate and develop a scalable software perception capability for specifically in-cabin experience, which plays a role in both the traditional as well as the mobility-on-demand market, so an important investment again on the automated driving spectrum for Aptiv.

With that, I will briefly introduce Karl Iagnemma here, President of the Autonomous Mobility business for Aptiv, based here in Boston, and as many of you know was the co-founder of nuTonomy and ran the robotic lab at MIT prior to that.
Brandon Eldredge, CFO of our Mobility and Services Group. Now, mobility and services, I'll say broadly encompasses both the autonomous mobility piece of the business and also our connected services and smart vehicle architecture business;

All of which, by the way, is headed by Glen De Vos, who also plays a role as Aptiv's Chief Technology Officer. Glen is also here with us today to answer questions, certainly as they relate to the subject at hand, autonomous mobility, but Aptiv more broadly. We're very excited to have you.

This is our first real investor event here at the Boston Tech Center and we want today to be as informative and educational as possible. With that, I will hand it over to Karl.

Karl Iagnemma:

All right, thanks, Elena! So very nice to have a chance to talk with all of you about what's happening in my business. Elena mentioned safe, green and connected as kind of the core themes of Aptiv. One of the things I really like is that these core themes really speak directly to addressing some of the pain points that we're going to be addressing societally, and especially around transportation of course. If you look on the left side of this chart, by 2050 clearly there will be a lot more people in the world and there will be a lot more vehicle miles traveled, and along with that we're going to see significant increases in emissions, potentially significant increases in the cost of transportation and travel time - there's going to be too many cars on the road, given the capacity of our transportation networks.

What's great about the technology we're developing is that there are multiple wins that come out of this active safety and highly automated driving space. Safety, of course is the primary one - you know, potential to reduce accidents by a vast margin, almost 90%, but as you look at transport efficiency, as you look at sharing, you also have the ability to make more efficient use of the transportation network, fewer cars on the road serving more trips, as you look at the greening of the fleet, significant potential reduction in emissions, as people are consuming more mobility services, of course they're going to need less parking, and then again getting back to the efficiency point, getting from A to B much more efficiently in a shorter period of time. This is all for the good and it's all kind of natural benefits of the technology we're building.

I'm going to go back a little bit, and I would say—you know, I think you're all familiar with Aptiv, but reintroduce some of the highlights of autonomous driving within Aptiv and previously Delphi, and there have been quite a few. I sometimes feel like Aptiv is one of the best kept secrets in the space because I don't know that anybody knows about all these great things that we've done, so I'll take a couple minutes to brag about them. Some of these predate me, but I'm happy to take credit for them.

In 2015, the then Delphi team, and this is that team that Elena mentioned, Ottomatika, that came out of CMU, was in large part responsible for a 3,000-plus mile coast-to-coast trip, route illustrated here, New York to San Francisco, 99% of the way fully autonomous. This was before really you could almost argue any of the hype reached a peak in the space. They went out and did it, and encountered all of the various things that the real world throws at you when you're on the highway and actually navigating within an urban center. Again, almost the entire trip, hands off the wheel, so really a fantastic accomplishment with what was then the Ottomatika team, kind of the core group for doing automated driving within Delphi.

Then fast forward to 2016 split screen here, because nuTonomy, which was then an independent company, a start-up that I was leading, and Delphi were both independently selected by the Singaporean government to start doing pilot testing of what we call first and last mile mobility solutions, autonomous mobility services within Singapore. Singapore, I think it's fair to say, is one of the most progressive countries in the world, city-states in the world around this particular topic, and so to have that endorsement from a place like Singapore was very powerful. That was around the same time that we as nuTonomy had piloted the first in the world, open to the public autonomous mobility service, so a real landmark in Singapore and as a combined entity, as Aptiv now, we continue our activity in Singapore.

In 2017, some of you may have had the experience at CES to be in the Aptiv vehicle, where we basically did a loop at CES, where we kind of designed a loop so that we would have that ride experience a number of interesting and challenging scenarios for our AV to handle, including some areas where—a tunnel segment where it was difficult to perform mapping and localization, we had urban driving, we had highway driving, so in its fairly short—it was about a six-mile stretch, we experienced kind of the gamut of challenging scenarios for autonomous driving, so clearly state of the art at the time. That same year in 2017, there was a similar demo done at the Shanghai auto show, so not only demonstrating that we can do it in North America but we can also do it halfway around the world. It's something that actually very few competitors have even done today, so a great accomplishment at CES.

Then fast forward to today, kind of starting from CES this past year and greatly expanding since then, we have today a working commercial, revenue generating, autonomous mobility service operating in Las Vegas. We have 30 cars on the Lyft network. You can go to Vegas today, open your Lyft app and have a very good chance to get in one of our cars and take an autonomous trip, completely flexible, point to point, no predefined route anymore - you tell it where you want to go and it will take you there, between 2,000-plus destinations on the Las Vegas strip. This map looks kind of like modern art, but it's showing you pick-up and drop-off destinations where we go in Las Vegas, so nothing on rails, nothing scripted, nothing preplanned. A real commercial, working, autonomous mobility service, so we're very proud of that.

We've got 75 total vehicles in Las Vegas, autonomous vehicles, as I mentioned, 30 of those dedicated to Lyft. To date, we have given over 40,000 trips, so 40,000 paying passengers. Our star rating—when you get out of your Lyft and you've got to give one star through five, our star rating today is 4.95 stars, which to me in one kind of single number speaks to a few things: the safety of that trip obviously, the efficiency, did you get from A to B in a direct line, and the comfort, did you feel comfortable and confident in the autonomous technology. So 4.95 out of 5 tells me that people are saying yes to all those questions, nine out of 10 riders would ride again. As a fleet, we have driven over a million miles in autonomous mode, and that's roughly split between urban and highway driving.

A few points to brag about, but I think the larger point is within Aptiv, we've got this multi-year tradition of autonomous driving expertise and demonstrating it in the real world.

To follow on from Vegas, there's really a number of key points and lessons learned that have been very valuable that have come out of this investment, really, that Aptiv has made. Three I want to touch on, three real key points. The first is that we're gaining a deep understanding of what paying passengers want and expect from an autonomous mobility service. The only way to get that knowledge is to have members of the public in the car. We can't get it by having our PhDs take trips or by having internal Aptiv employees. We have to get civilians in the car, so that's what we've done. They give us their feedback and we bake that into our technology development, so that's the first point.

The second is that we are developing a playbook for going into the next city and then the next and the next after that, so a couple years ago we looked at Vegas and it was, should we do something in Vegas, if so what would it look like, how do we do it? Abe was one of our leaders that helped us stand up this operation, we did it efficiently, we got on the road. We've got cars on the road that are utilized now very effectively and at a high degree of efficiency, so we've got that playbook that's going to serve us very well both from a tactical operational perspective as we go to the next city and the next and the next, but also from a business model perspective. We know how long it's going to take and what it's going to cost to go into those next cities.

This is all within the context of a shared fleet. We've got our autonomous vehicles operating side by side with human piloted vehicles, and it's a great complement. The human piloted vehicles take trips that we can't handle, and we take trips maybe the human piloted cars don't want to take, and it fits together extremely nicely.

The last point, and this is kind of near and dear to my heart as an engineer, we improve our technology by having a significant fleet on the road. We learn about scenarios that the cars may have challenges with and we can iteratively improve. We also learn by having a fleet and not just a single car. We learn about the fleet specific technology, so we're going to talk about the command center today. The command center is our tool for managing the entire fleet, seeing where the cars are, seeing if all systems are go or if there's some indications that we need to be aware of, potentially reaching into the car through what we call tele-operation and getting a view from the car's perspective, if you will, and sending commands as needed. That command center tool is something, again, you can't develop in simulation, you have to develop by having a real fleet on the road, and that's what Vegas is allowing us to do, so three huge benefits coming out of Vegas.

On slide 17, this year is going to be a big one for my group. We've got a number of milestones that we're working towards, a couple of which I want to highlight here. One of the more exciting ones is that we've got a new vehicle platform coming online - you can see an image of it here. It's going to have an integrated software stack, so Elena mentioned the acquisitions that were made, these kind of strategic moves by Aptiv to bring in expertise from the Ottomatika perspective, heritage from Carnegie Mellon from nuTonomy, kind of a different view of the world. We're going to bring these together, and this is in process today, and end up with a net result, a new software stack that really takes the best of both worlds.

That's a massive opportunity for us and a huge advantage compared to our peers, because from experience, I can tell you that once you've designed a software architecture, you've gone on the path and you keep squeezing the rock, and it gets harder and harder to squeeze some juice out of it. A huge opportunity for us as nuTonomy, coming in and having a different view of the world, we were able to look at these two stacks and in some cases say, if we combine A and B for a specific module and put them together, we'll get a better solution, and in other cases say, well, if we choose A over B, if we've got a better solution for a specific problem on one side or the other, we'll pick that better solution, so the net result is a step change in performance that we're going to see on this integrated stack, so big opportunity for us. We're working through the integration, but those cars are on the road today and being brought on.

Now, the car itself is interesting because it's what I would call a true level 4-ready vehicle. What that means is it's got the necessary redundancy, the fallback systems if something goes wrong, and that's vehicle specific. I mean, the drive-by wire, the redundant braking system in case there's a fault with the brakes, the redundant steering gear in case there's a fault with steering. It's got the ability to actuate the doors, open and close them remotely, so this is a car that you can envision now practically putting into a driverless mobility service, so it's a key enabler for that mobility service, so we're very excited about that. That's one of the big activities that we're focused on this year.

Kind of a little bit of a teaser here, but we are planning to be expanding our footprint. We anticipate that by the end of 2019, we'll be in two additional cities for testing. We're not announcing those today, but that is the current plan and we're working toward that.

All right, so turning to slide 18, I'm going to go a little bit into the technology on the mobility cloud and explain why this is important to us. I mentioned the fact that we need tools to manage our fleet. At nuTonomy, we didn't have a lot of this technology on the mobility fleet side. We knew it was important, and I'll tell you when I joined Aptiv, we walked in and we saw what the Control Tec guys had already built, and we said, "well, this is fantastic". They built tools for fleet monitoring in Control Tec in a different context - monitoring passenger vehicles, so we have been able to build on that core technology and now we're shaping it, we're expanding it for the autonomous fleet applications. There's some unique things we've had to build on top of it and we're in the process of building, but we started on third base and it's been a fantastic advantage.

If you look on the left here, some of the technical capabilities, that tells you some of the core tech nuggets that we need to have a mobility cloud command center for an autonomous fleet. That includes things like streaming video - I mentioned tele-operation. You may, as a remote operator, want to see the car's eye view of the world. If the car gets stuck, confused, you've got to see what's going on with your own eyes, so that's where the streaming video comes in. Command and control typing gives us the capability to send commands remotely to the car, so again let's imagine the car is confused, paused. As a tele-operator you can see, you can gain what we call situational awareness, and you can say, follow this path I will remotely designate to you, and the car will go and do it.

OTA - I mean, obviously send down map information, send down new software releases, notifications, authorization, authentication, and then, of course, streaming telematics, some critical information of the car itself, some of which you see illustrated here and we're going to see a live demo of this. But some kind of low hanging fruit stuff, how fast is the car going, is it in autonomous mode, is it in manual mode, and then some more, I would say, autonomous vehicle-specific things - status of the sensors, status of certain software processes, etc., so we've got deep visibility into all of these analytics, a super powerful tool for us.

Okay, I'll tell you a little bit about my group on slide 19. We've been growing fairly rapidly, as you can see on the chart on the left, from '16 to '17 to where we are today, which is about 700 headcount. Now, I want to point out one of the things that's unique about Aptiv and was mentioned by Elena, is we have level 4 robo-taxi activity. We are also building and have been building for many years ADAS and active safety technology. We've been building, validating it and shipping it, and we know how to do all that, so again when we in the autonomous mobility group need to draw on that expertise, well, we've got 2,000 ADAS engineers in other parts of the org that we can draw on, so that's why the count is 700 here and then we've got this larger shaded area. I can tell you I draw on expertise from David Paja's team and other teams, Lee Bauer and other people in Aptiv that have thought very deeply about topics that are really critical to my business, so that's on the organizational side.

From an IP perspective, we believe that it's going to be important and, honestly, valuable to have a significant IP portfolio in this area. I think about IP from a couple of different dimensions. One is protecting our freedom to operate, making sure we've got patent coverage on the technology we're developing; and then two, making sure we stake our claims in areas that we believe will be strategically valuable going forward, so we've listed a few of the areas here. It's not exhaustive, but motion planning, perception, localization, data management - these are just some representative areas that we have been gaining patent protection over, over the last couple of years. It's about 240 patents, starting count in 2018.

All right, I'll talk about the software a little bit. One of the things we aim to do, and when we think about going to market, is to go to market through partnership. That is our strategy. You won't see Aptiv, for example, building a car, you won't see us building out a ride hailing network. We're going to focus on what we believe is our core competency, which is building software. To enable those partnerships, we're building software in a very modular way so that we can interface with our partners who may be bringing a car, who may be bringing certain modules that they want to plug in, for example, so we think about this as top of mind through our entire development process. A modular approach to software development gives a great deal of flexibility in striking partnerships.

The second item here, and I'll talk about this a little bit more in a few slides, but when we look at our stack, I'm very proud of our entire software stack and the technology approach in general, but I'll talk a little bit more in a few minutes about our approach, what we call planning and policy, basically the brain of the car, the car's ability to make decisions, how we think about that. It's really informed by a combination of nuTonomy and the Ottomatika software stack, and I've already mentioned the advantages that come from having the ability to look at both of those stacks together.

Then lastly, we are building toward a scalable platform. We want to eventually be able to offer solutions that not only provide full level 4 capability but also down the stack, level 3, level 2, etc. That's actually not obvious. You will have pure play level 4 teams out there that say, hey, I've got a level 4 solution, and let's say you wanted to sell that to an OEM. Well, the obvious expectation is if you're going to own a car that does level 4, you're going to have level 3, level 2 and these other capabilities. What's not obvious is that if you don't architect with that in mind, you could end up with a system that's level 4 and then be faced with a process of saying, I've got to add other sensors, other compute to just do the level 2 or level 3, so you'd be a massive cost disadvantage and a massive complexity disadvantage. We are very, I would say, consciously working towards this scalable approach so we can deliver all the way up the ADAS stack.

Okay, I think we've got—I'm an engineer, and we've got one slide on engineering stuff. I just want to talk briefly about our approach to policy because I would argue that what separates some of these technology solutions is how smart the car is. It's also how comfortable and how smooth and all the rest, and that's absolutely true, but how smart is the car on the road, how confident is it in its ability to make decisions. That is in part what's going to inspire confidence in passengers and inspire them to take the next trip and the next in your vehicle.

Our approach to the policy problem is based on what we call structured AI. To give you a sense of what we mean by structured AI, if you think about this policy problem of having the car make decisions, in the industry today you could argue there's kind of two polar opposite schools of thought. One approach is to say let's write down specific rules that govern every scenario the car might encounter, so if you encounter a four-way stop, there is an if-then-else set of rules for that, and if you encounter a complex intersection, there is an if-then-else set of rules for that. The problem with that approach is that there are so many scenarios the car can encounter in the world, you're going to run out of if-then-else statements and your engineers are going to get exhausted, you'll find corner cases that you never thought about, and you can't possibly cover all the scenarios you'll encounter.

Now, the other kind of end of the spectrum is to say, well, teach the car through learning and teach it through example, we'll feed it data and let the car learn how to drive. Really, the same argument applies - it means you'd have to find data, you'd have to find driving examples for all the different driving scenarios. Oh, by the way, that might work in one market to a certain degree, but when you go to the next market, when you go from Boston to Singapore, well, everything is backwards, you'd need to gather all that data again. That complexity argument really applies there.

What we do at Aptiv, you could argue it's some kind of a middle ground, but it's just a little bit different. Structured AI means we start not from brittle instruction sets for each scenario or from data, we start from the rules of the road, so we write down the rules of the road which are actually fairly few in number - they talk about getting precedents, they talk about stopping at signals, etc. We organize them hierarchically, so we say what's most important to least. Most important is don't hit anything, least important is maybe some rules around comfort, for example. Then we have technology that allows us to kind of turn the crank. It's called formal method, and automatically generates software that, when faced with a situation, will decide which rules to apply and which rules to de-weigh, if you will. That's the illustration here - we start from laws, we write engineering specifications, these are formal methods to get to an implementation, and that gives rise to a behavior on the road. In many ways, it ends up being kind of similar to how humans drive. We don't have specific instructions for each intersection. We have the rules in our head, and when we face a scenario, we apply the right rules and off we go.

Now, a couple of really important things about this. One is it's scalable, so when you go to a new market, when we go from Boston to Singapore, it may mean reordering rules. It doesn't mean rewriting all the code, so that's very powerful. Then two, it's auditable or explainable, if you will, and what means is it's not a black box. We can explain to a third party why the vehicle made a particular decision that it made, and we think that's not just interesting and useful but actually necessary.

On that point, as we move into new markets, as we think about deploying at much larger scale, our position is we want to be partners with the cities, the stakeholders of the cities that we're operating in. This is the playbook that we have followed to date and we'll continue to follow.

I mentioned auditability of software. These are the type of questions that come up when you work with cities - how are we going to know what the car is going to do, and if it does something unexpected, how are we going to understand why it did what it did, how do you think about data, etc.? We engage the stakeholders among other listed here at the city, the state, in a place like Singapore it becomes the national level. We work closely with them, in part obviously to be good citizens, in part also to shape the regulation that's coming down the pipe in many cases.

To give you an example, in Singapore there was just a release of some guidance, actually an extensive document describing a potential regulatory framework for automated vehicles. We were members of the committee and had a strong voice in nearly all of the technical subjects in that document, and that's a big win for us, so we're not going to get caught flat-footed by regulation that's unexpected, unanticipated, or that we can't deal with.

Another kind of more practical and tactical aspect of this is the infrastructure dimension. We make use of infrastructure to support our AV, our actual autonomous driving, when it's available. One example would be in Las Vegas, where many of the intersections in Vegas have DSRC communication, so this vehicle infrastructure communication that tells us the state of the traffic light. Is that necessary for us? Well no, it's not. Boston, Pittsburgh, Singapore, we don't use that, but it's a nice to have. It greatly decreases the risk that we get it wrong, and you don't want to get a red light wrong and accidentally roll through an intersection. By working with the city in Vegas, we're able to facilitate the expanded deployment of DSRC, and that's not only a cost saving but obviously the engineering implications are great.

Okay, a couple more slides. Thinking about cities, I think to me this is really interesting. I think it might be a little opaque from an outside perspective as to why we might go into a particular city and not be in another city. We think very carefully and thoughtfully about how we evaluate cities. Some of the criteria are pretty obvious. Today we're going places with pretty good weather, we're going places with reasonable driving conditions, let's say, and then we quantify that. What I mean by that is the density and complexity of driving. But we really—we drill down quite deep, and what I mean by that is we have a clear understanding of what our vehicles can do today and what they'll be able to do over time. We call it our operational design domain. From map data, map information, we understand the characteristics of the road network - what are the speeds, the one-way streets, the very wide roads, etc. We can overlay those two things. We can basically align what the car can do with what the map presents to us.

Then as a third overlay, we can understand where the demand data in that city is, so where are the pick-up and drop-offs, where are people moving from and to. You put all those things together and you get a very granular, and I mean street-by-street analysis of where you can drive in a city, and it tells you how much demand you can satisfy. The models that we put together are very far from guesswork, it's a highly granular, nuanced understanding of the demand we can satisfy in a particular city, so that's why we feel confident when we think about city selection of where we're going to be able to move next and how much money we'll be able to make in a particular city, and when.

Just to summarize, my group is obviously focused on technology development but with a very clear focus on commercialization. We started from a great foundation, and this predates me but Aptiv has been developing, certifying, shipping and standing behind highly complex software systems for as long as anyone in the industry, and so we leverage that within my group. From a development and testing perspective, we've logged a lot of miles on the road, which is great; but underneath all that, we've got solid engineering both from a software perspective and from a hardware perspective, so we understand this is not a pure software game, it's not just an algorithm game. There is the industrialization dimension, there is the safety certification and validation dimension, and I think that really separates us from many of our peers.

Then lastly, as we think toward commercialization, we've got multiple bets we're putting on this space. It's not just the L4 robo-taxi, which is what I spend a lot of time thinking on, but it's technology and fusion across the stack, being able to lift the rest of that stack and ensuring that it's got cutting edge technology.

Then lastly, you know, we're not footing the bill for all this ourselves. We're partnering to take it to market, we're trying to get to market in a very capital efficient way, and we're partnering with the cities that we operate in to make sure that we're not unwelcome guests.

On that note, commercialization, I'm going to turn it over to Brandon, who is the money guy.

Brandon Eldredge:

Thanks, Karl. I'll start with what's a very simple slide to explain a very complex ecosystem. As Karl mentioned, we're very focused on enabling technology, most predominantly in the automated driving systems space, but that technology exists in a very complex ecosystem of vehicle, network providers, asset owners, managers, and it's encompassed by complex regulations, municipal objectives, and so we focus on the automated driving system. Some of our competitors have taken an approach to try to solve these complex business models across the board. We however focus on where we think we add the most value, in the technology, and then augment that through a variety of value-added partnerships.

If you look at the primary roles in the ecosystem, let's just go through each of them. On the automated driving system, you have the core software stack, you also have enabling hardware like perception and compute, that's the area that we focus, that's where we see the value and the revenue that we're ultimately going to drive. That technology gets tightly integrated into a vehicle. We have historically recently been integrated into BMWs. As Karl mentioned, we're deploying into rolling out a new platform this year. This is an area where we benefit quite a bit from the broader Aptiv organization, the deep understanding of architecture, the deep understanding of sensor performance. We're able to benefit quite a bit from that and be very efficient on that integration.

I'd point out that I think unique, probably unique relative to any of our competitors, we've actually integrated our automated driving technology into six platforms over the last four or five years, so a variety of different vehicles made by different manufacturers, different types of platforms. That vehicle then ultimately gets operated on a ride hailing network. We have a large partnership with Lyft which we've talked about, we have a variety of partnerships unannounced with other ride hailing companies, but we recognize that there is likely to be intermediaries that sit between us and them in the ultimate resulting business model - asset owners, operators. Ride hailing networks are asset-light business models, they don't want to own hundreds of millions or billions of dollars of assets on their balance sheets, which ultimately will create a variety of different business models that exist between the asset owners and managers, or the network providers. But we're focused on deploying the technology into a vehicle that then gets deployed on the ride hailing networks.

We can only be successful if our technology is allowed to be operated in cities, and we spend a lot of time working with cities, municipalities and other constituencies to educate them on technology, to get their support in the rolling out of technology into the different cities.

How does Aptiv plan to make money? We see really four key areas, kind of four key areas or buckets of where revenue can be generated from. The first is the upfront technology sale. There is ultimately an asset that has hardware, compute. We are a provider of select perception and compute technology into those vehicles, which is largely an upfront transaction, but that's really not where we focus. Where we see the vast majority of our revenue coming from are recurring revenue streams, and that's where we're focused. The software licensing represents the largest of those buckets. That's where we'll provide an annual license to our core software stack along with updates, performance expansions. That's an annual recurring model.

We also are developing and will deploy value-adding fleet monitoring and other services and technologies, so think of tele-operations, command center. Abe will take you through later this morning a demo on some of those capabilities, but we think certain of our customers will ultimately benefit and will want to benefit from those capabilities, so we're developing those alongside the core technology platform.

Then finally, it's on the data side. The cars, as you all know, generate a tremendous amount of data, and we know from conversations we have, there is a lot of opportunity, whether though data brokerages, whether through direct to cities or other constituencies, a lot of interest in that data. We see, ultimately, three of the four areas that generate revenue are recurring, all high margin in nature, and that's really where we're focused in driving our business model.

I would just add that Aptiv also generates revenue by selling some select components and services into other autonomous driving platforms, so we have yet another Aptiv avenue to generate revenue in the autonomous driving space.

As to timeline, I think ultimately if we start from the backwards forwards, we really see the cost curves only reaching a point where a consumer option is affordable in 2030 and beyond, and so that really—that's kind of the second leg of growth that exists in the level 4 space. But the near term opportunity really exists in this robo-taxi space. It's where the economics can—where value-based argument can be made for economics, where the cost of removing the driver and the resulting efficiency on the network can result in the ability to afford a platform and a solution that's relatively expensive in the near term. We're working now, as you know, in several smaller deployments in cities, 2018 and beyond, scaling up to true driverless commercial launches in the '21 - '22 time frame. That will then scale up over the resulting decade until the OEM opportunities present themselves, and we'll go through this in a little bit more detail.

On the deployment phases, where we are today, we have an ODD, an operating design domain, that still has some limitations and we have hardware that is still not able to fully remove the driver. Between where we are today and the commercial launches in 2021, 2022, we expand the ODD and the capabilities of the platform that allow us to deploy a meaningful commercial operating platform in geo-fenced locations across several cities. We also industrialize the technology that allows us to fully remove the driver. As Karl mentioned, a large piece of that is ramping up on a new platform that actually has the capabilities to allow the removal of the driver.

From 2022 over the next several years, we expand the ODD and continue to add incremental capabilities, we enter incremental cities, and then we advance that industrialization to its next phase, which is moving towards a fully automotive grade solution. That ultimately also allows us to really inflect the cost curve down as you move to the fully automotive grade solution, which one, allows broader adoption in the robo-taxi market but also puts you on a glide path to actually opening up the OEM market and the OEM opportunity.

Then from 2025 to 2030, you see the cost curves come down, you see more adoption in more cities, and then ultimately 2030 and beyond is where that second leg of growth in the OEM consumer option market really becomes available.

Turning to slide 30, maybe the true money slide, but we remain on track to deliver our commitments on timing and expectations on financial performance, with $500 million of Automated Mobility revenue in 2025. Important to note, the vast majority of that revenue, we expect that scale to be high-margin recurring revenue, as talked about on the earlier slides, and we're doing it in a very capital-efficient way. We've scaled investment quite a bit over the last several years, but by leveraging the broader investments that Aptiv has made, and is making, in other parts of the business, as well as the thoughtful partnership strategy where we can leverage investments that they're making, we feel that we can deliver very positive returns and be quite capital-efficient.

With that, I'll hand it back to Elena to conclude.

Elena Rosman:

Thanks, Brandon. We're going to open up to questions, but hopefully you heard today, both from Karl and from Brandon, that our technology and capabilities are developing exactly as expected, the same roadmap and certainly time commitments that we've been talking about in the last several years, and that's giving us obviously further confidence, from an Automated Mobility financial revenue track, to hit this $500 million target that we communicated in September 2017; again, specific to Automated Mobility.

You'll recall we talked about automated driving broadly in that 2025 timeframe being about $1 billion of revenue, and the other half, the other $500 million coming from traditional OE for Level 3 and above, and that's really because—I think you've seen from our Aptiv Safety Teach-In, that Level 3 system has content per vehicle in the range of $4,000 to $5,000, and while it will be very low penetrated by 2022, by 2025, you'll start to see that those deployments start ramp and, therefore, for us, $1 billion in aggregate for Automated Driving in the 2025 timeframe.

With that, I'll open it up to questions

Unidentified Participant:

You've referenced a number of patents—this may be one for Karl—you had referenced a number of patents you're putting up. I guess I was wondering have you run into situations where you had to either innovate around maybe a peer or a competitor's patents, or do you anticipate that being an issue going forward? Because, I think one of the challenges from the outside is that most of these programs seem to be running in parallel to each other and tend to be quite secretive, so it seems like if you were bumping up against somebody else, it would be hard to even know there was an issue.

Karl Iagnemma:

The answer to your question is no, we haven't had any situation yet where we felt like we were blocked by a competing patent. My feeling is we're probably at the early stages, from an IP perspective, of any conflict around that. It is still fairly early and I suspect competitors are probably ramping up their patent filings, as well. I will say that from a technical approach, we came at this problem with a fairly unique solution, at least for some of the very core technology. One of the reasons I highlighted structured AI is because it's something that, to the best of my knowledge, we're doing and no one else is, and we've been careful to protect that, from an IP perspective, as an example. Yes, nothing that I'm aware of that has us concerned, not today at least.

Glen De Vos:

Yes, I would also add that one of the things that was attractive to us with Ottomatika and NuTonomy was their roots all the way back to the DARPA challenge. If you think about MIT and CMU, there was original IP that was created there and then continued to evolve over time. We know the providence of the IP, we know where it came from, so that gives us a great deal of confidence that we're not going to be stepping on other people's IP.

Unidentified Participant:

Can you talk a little bit more about what you described as the step-change in, the combined platform with NuTonomy and Ottomatika? I mean, that struck me as pretty powerful, but you didn't really delve too much into that. I would love to know a little bit more.

Karl Iagnemma:

Yes, my main point was just that once you start down the path, from an architectural perspective, from an algorithmic perspective, it's a long path and it's hard to deviate from that significantly, that would be a big change, a big decision behind that, so you tend to get some kind of asymptotic improvement. Now, we had the opportunity, really, to bring in new ideas kind of midstream and, I mean, the cost of that was the cost of the integration, take some time to put these things together. There's a lot of software engineering involved and decision-making at a strategic level, should we do A or B, as I was kind of hinting at, put them together, should we choose module A over module B, or how do we evaluate them, but the net result is, you know, you have this opportunity to inject kind of fresh blood into the system midstream. That's where the expectation comes from.

That, coupled with the fact that, as I mentioned, a new platform, and as Brandon also pointed out, previous platforms weren't necessarily, let's say, Level 4 capable. They were fine for operating with the Safety Driver, because the Safety Driver is the backup system if something goes wrong, but there's only certain vehicles in the industry today that have the built-in capability, the vehicle platform. That would be the other kind of part of the step-change in improvement.

Unidentified Participant:

The module area, I think, makes a lot of sense. I'm curious about sort of flexibility to move across, I guess, domains. The auto domain is one. The CV domain, we haven't talked about during the course of this presentation, but does your software code or design or module area sort of easily transfer to the commercial vehicle space or other adjacencies?

Karl Iagnemma:

Yes, that's a really good question. The answer is, yes, it could. Today, we focus almost entirely on ther robo-taxi opportunity. We're obviously alert to these other possibilities for applications, and CV is one of them. A different form factor of the vehicle, right, and different use case. Highway driving as opposed to urban, generally speaking, and bigger vehicle, high speeds, you need to see longer, but same core technology, same basic core technology. There'd be an integration activity to put that software on a vehicle, and you'd have to convince yourself you could find the right sensor configuration to see as far as you need to see, etc., so I would never want to suggest that that's a turnkey switch to this other application, but our core technologies that we're building for AM could definitely find application in other use cases like that, that's a certainty.

Unidentified Participant:

In one of your slides, you talk about power. I know a lot of this technology consumes a lot of power, at least at this point. Your trials are in vehicles with internal combustion engines, others are trialing with pure electric vehicles. What's your view on sort of the ability to significantly reduce power usage of the application and how do you see the transition to pure electric vehicles? Does it just kind of match the pace of how EVs evolve, or are you agnostic about that?

Karl Iagnemma:

Today, the BMW platform is kind of our workforce, you saw a lot of pictures of it, but there was a picture or two of an Renault Zoe electric vehicle, where we're also running code on every day. We've got a small number of those platforms, probably about a dozen, but we do the play on electric vehicles.

Power today, you're right. I think, generally speaking, for the industry, and us included, you tend to throw a lot of compute at it to solve the problem and then you think about shrinking down, and some of the compute is power-intensive. I don't see this as a real showstopper going forward, for a few reasons. Obviously, as you optimize, your code per turn gets longer, so you consume, let's say, if you're on fewer GPUs. There's also a possibility to look at alternatives in compute platforms that are just much more power-efficient. For us, we're very flexible from a compute perspective. That's always been by design. We wanted to have flexibility, again, seeing through the lens of partnerships, because our partners may have specific needs or wants or requirements on the compute side. We've always been operating—to date, have been operating as kind of a hybrid compute platform, but we use some x86-type architecture, a little bit GPU thrown in, but have the ability to kind of shift balance between those various platforms, and then when dedicated kind of purpose-built compute, low-power compute is more readily available, we can shift onto that, as well. That one doesn't really worry me a lot going forward.

Glen De Vos:

Two other things to keep in mind that will happen is, as this matures, one is—if you think about today's architectures for these systems, they're all bolt-on, which is a very inefficient approach. You're basically adding on top of the existing architecture all the compute, all the redundancies, and everything else. From both the power consumption, as well as the cost standpoint, it's a really inefficient way to do that. This is why we talk about architecture so much, because what you really want to do is shift towards more integrated architecture, where you don't have all that bolt-on redundancies basically integrating into the vehicle, and that's what we mean when we talk about smart vehicle architecture. As that comes, we'll get inherent efficiency gains with power, as well as cost.

The other piece of it is there aren't a lot of good pure EV options out there today. When we look at how do you service a market, we think you need again a F4 to 6, you know, that kind of a range in terms of passenger capacity, and so there's not a lot of real options out there. Applying a hybrid, like the vehicles shown, actually gives you kind of a dual benefit there. Now, that's changing, you're seeing more options coming out in pure EV, the pure EV vehicles. As architecture, EV vehicle supply and optimization of the system, as Karl was talking about, converge, the power issues, I think, will be mitigated.

Unidentified Participant:

Then, if I could just follow up with a second question, thank you. You showed a slide near the end where the adoption rate in mobility and then in personal vehicles with this autonomous technology, that looks like sort of a global generalization. How do you see it rolling out sort of in individual markets, the U.S. versus Europe versus China? Do you see it rolling out quicker in both those mediums anywhere or is that going to roll out sort of roughly the same across all the major markets?

Brandon Eldredge:

Yes, we certainly see the U.S. to be one of the earliest markets. Europe tends to be more challenging from a regulatory perspective, than the U.S., and not only one regulation, but many, many regulations. We tend to see the U.S. being an early market where large substantive markets are available. Singapore is another market that we see on kind of leading edge of that continuum, and then I think China is a question mark. We think there's a lot of—there's opportunity there for the government to mandate quite a bit, and that's ultimately, probably, what will drive earlier adoption versus later adoption. The economic arguments are a little bit weaker in China, but if they force the rules, it could drive it through. But, we see the U.S. market to being the large first markets specific to Automated Mobility.

Unidentified Participant:

Just on the back of that question, thinking about kind of 2021, 2022 driverless launches specific to the U.S., kind of what are the regulatory bodies that are going to be the key decision-makers and kind of green-lighting some of those projects? Is it a state and local decision, is it a federal decision? Kind of what are the key regulatory agencies that you need to work with to get clearance to sit at that milestone in 2021?

Karl Iagnemma:

Well, it depends to an extent. I mean, right now it would be a state decision, but if there's a decision at the federal level to what they call pre-empt, kind of some precedence over the state decision, then it would be a federal guideline that would come into play, and those—I mean, there's been a lot of discussion at the federal level on this topic. You guys are probably aware of some of sort of draft regulations or guidelines that have been put forward, now two iterations by two different administrations, speaking directly to automated vehicles, which is interesting and I think shows a lot of intention and foresight, but appears also at the moment to have a little bit of an uncertain future. It's a little bit hard to say when. At the moment, not a lot of momentum from my outside view of the world.

Our current plan is to operate within the rules as they stand today and to work at a state level. That also differs from state to state, the stakeholders are different. I can tell you in a place like Boston, where we are today, we work with the city, we've had engagement at the state level. We are today on a road that is actually not owned by the city, it's owned by an airport. Other parts of the city, you talk to different stakeholders, so it's somewhat local in nature. That really highlights the importance of—that's why we brought that slide up, because you don't want to have uncertainty around your ability to go to market and then stay in the market once you make a move, and so that's why we spend a lot of time working with stakeholders in the various areas we're going to be.

I mentioned a kind of city that we're—an expansion that we're planning. We've already started having conversations around that. Plans may change, but we want to be well in advance of those regulatory discussions, well in advance of any commitment of resources.

Brandon Eldredge:

Yes, I would just add to that. Our plan also isn't determinant on a specific city after another specific city. We've approached it by, I'd say, bucketing or identifying groups of cities, such that different dynamics will come into play that we don't even know today, that may shift that prioritization, and so we have groups of cities that are kind of fungible amongst themselves, that can be adjusted as we go, based on how dynamics in those specific geographies and places play out.

Unidentified Participant:

When you think about your structured AI approach, sort of taking the best of both sides of the spectrum of approaches that people have employed, what would those on either side sort of say the drawbacks are to your approach? Maybe it's Mobileye in the sort of rules base and Waymo on the pure AI side, or something like that. What would they say the drawbacks are to what you're doing?

Karl Iagnemma:

They'd probably say it's complicated and they don't understand it. I'd say that's probably the most likely conclusion. I mean, it's based on—if you kind of Google like formal methods, you'll find it's a purely analytically intensive set of tools for reasoning about—basically, making certain statements about properties of complex systems. If we want to be able to say that this system is safe and kind of provably so, you can use formal methods to do so. This has been used in semiconductor chip design. If you are old enough to remember the Intel Pentium Bug, where they were previously doing things, logic analysis by hand; after that, it was all formal methods. Space crafts, when they deploy space crafts, it's not just a good idea someone thinks it feels safe enough; they use formal methods analyzing it.

We view automated driving as on a continuum of complexity, of things like chip design, space craft design. I wish that weren't the case, but it is. You need commensurately sophisticated tools. It turns out there's not a ton of people with that expertise. I mean, we happen to have—I mean, most of them in-house here, which is great, and my former co-founder, our Chief Scientist, Emilio Frazzoli, is one of the leaders in this area. I will tell you that some of our competitors, we've seen them trying to recruit for topics like this. We feel confident in the approach, but it's not widely used, I think, because there's limited expertise in the area. That's all I can kind of guess from the outsider perspective, I don't know what they're thinking for sure.

Unidentified Participant:

Karl, could I just follow up in terms of the resources when you think about that competitive landscape. I mean, obviously, you've got a significant amount of resources over the last few years, but you have a ways to go, you want to launch two more cities. Some of the competitors are talking about spending, the top two, the numbers about $1 billion, and they're looking for partners, so it seems like it may go up. Can you talk about the limits that you—I mean, are you constrained in any way from going quicker if you had the resources available, whether it's compute, whether it's real live data? Just how do we think about that balancing act, which is obviously a big part of being part of—

Karl Iagnemma:

Yes, I can comment, and probably Glen would maybe add. Obviously, there is a trade there, to a certain degree, with time. It's not entirely a knob you turn, because some things just take time no matter how much money you throw at them, but I think some of the competitors that are spending considerably more also have accelerated timelines. When I look out there—my team will ask me, "Well, I just read that so-and-so is spending $800 million a year," and a lot of times you'll tie it back to their anticipated launch and it'll be sooner than ours. To me, that makes sense.

The other dimension is what they're actually building with that money, and, again, some of our competitors are building more than we're building, which is very much by design. We want to focus on what I feel is, one, aligns directly with our core competency, and, two, is again the most capital-efficient way to create value. That's really what it boils down to. Again, that's the reasons we're not going to set up a ride-hailing system or try to go off and build a coolest car.

I mean, beyond that, I think it's guys like you who triangulate they're spending more, how much more, is it too much or not enough, and we feel pretty good that we're calibrated well to deliver on our timeline given the outlay that we've communicated.

Glen, I don't know if you want to add anything.

Glen De Vos:

Yes, the other thing I would add to that—those are two really, really important points. The third, I would say is what we try to do is leverage both what Aptiv already is developing as part of our broader ADAS business or part of our architecture business. Wherever we can, we just leverage the work that we're already doing as part of that ongoing business, which gives us an advantage from the standpoint we're not trying to create sensors and create everything from ground up, and then we do the same with partners. One thing that's unique about our position is, when we talk about partners, we usually aren't just talking about partnering with them on AMoD. We're talking about broader partnerships with Aptiv, co-developing technologies that can be applied today. It's a lot stronger position to be in relative to technology partnerships and co-development, because that can deploy in a Level 3 system, that can deploy on other systems, as well, and that's true—so, again, that's true with software, that's true with sensors. We leverage that broader Aptiv capability and the commercial business they have to basically bring in support for us, and we're always looking at what's that right level of spend relative to timing of launch and where we want to be.

Unidentified Participant:

Is it fair to say, in that scalable approach, that the biggest expense when you enter a new city is just actually those cars, right? Because, right now the cars are still yours, right? In the future, it'll be a different model, but that 15 to 20 cars, whatever per city, whatever the five is, that's one of the largest—

Glen De Vos:

Cars, it's operations, support people driving data collection, validating that city, basically.

Brandon Eldredge:

Yes, and I think that's the gross cost. I think the piece is also, as we do this, we don't do it in isolation. There's partners that ultimately provide offsetting funding, revenue may be related to it, maybe get some government support in different cities. Ultimately cars and operating the cars is probably the largest gross cost in a city, but we obviously work through partners to try to net that down, and net that down quite a bit, and I think we've also—we've learned a lot through our operating base, operations in Vegas. That's a very large-scale operation, for a variety of different reasons, because it does a lot of things beyond just commercial deployment, there's R&D there, there's a command center there, and we've learned a lot. As we think about sizing the right footprint for an incremental city to do some small scale commercial deployment, it's orders of magnitude is cheaper than Vegas was.

Unidentified Participant:

Brandon, at one point you said—almost offhand, you said of the revenue—you were talking about the $500 million—you said when we're at scale, it'll be predominantly high margin sort of software-based revenue. At what point do you consider "at scale"? Is that the $500 million or is that some point beyond there?

Brandon Eldredge:

Yes, I'd say it's a little bit hard to specifically pin it on. I think it's probably somewhere between the 2025 and beyond of when it actually gets there. There's some transition phases as you get to automotive grade. I mean, I think, to probably answer it more pointedly, it's some point after you get to the automotive grade solution. In that 2030-plus range, 2030 plus or minus. Again, this is 10/11 years out.

Unidentified Participant:

I'm curious—I have two questions. One is, is there a certain category—in the past, there's been discussion about certain types of engineers that are kind of the hardest to hire for, most resource-constrained. I guess I'm wondering has that changed at all or what are sort of the—in terms of the talent you're trying to attract, what's the most challenging? The second thing is, I think it would be helpful, because I do think this is coming up more and more, especially with Lyft's upcoming IPO and their own autonomous program, understanding for someone like yourself, or a Lyft—and I realize you can't necessarily comment on them—for someone who's spending, let's call it, say, a couple hundred million dollars a year versus a billion dollars a year, are you able to give any color around sort of what the big buckets of spend are that maybe make sense for you to say, "Hey, we do have a viable program here and we have the resources we need, because we don't need to spend, I don't know, x hundred million dollars to equip a bunch of Bolts to run around San Francisco," just as an example?

Karl Iagnemma:

Okay, yes, certainly, I'll address the first one, and maybe you'll want to address the spend one, but I can talk about that, too. It doesn't get easier to recruit, because there's still quite a bit of competition. I would say, though, as the industry has evolved, the skill sets that we focus on, that shifts a little bit, as well. At the beginning, three/four years ago, it was all scientists. We were trying to find PhDs who could help me figure out core technologies. We still recruit in that area today and there's still a supply/demand issue there, because there's just not a lot of people with expertise in robotics and machine learning, you name it, but we've shifted a little bit more towards the industrialization, the validation part of it. As the technology gets, more and more locked in, you think about how you're going to make it safe and how you're going to ensure that you can drive for many, many miles reliably, and that is interesting, because it's partly a traditional automotive discipline, validation is something that the auto tier-ones have done for many, many years, but it's seen through quite a new lens and a step-up in complexity. Whereas before, if you wanted to validate a shock absorber, you'd say, "I'll move it back and forth a lot, make it hot, make it cold, put some sand on it." Now, kind of the dimensionality of the space, the number of variables you would have to exercise to validate an autonomous car with that same kind of mental model is just vast, right? It means you would have to drive it for a multitude of miles to be fully ramped. You can't do that, so you need people who know validation and technology industrialization, but can be flexible and creative and figure out how to solve these problems in a much more efficient way.

That is also a somewhat specialized pool. You find those people within—I mean, in-house within Aptiv. It's not everybody, but it's certain kinds of people. My VP of Industrialization, a guy named Dave Helton, came from Glen's org, from the broader Aptiv org, but he was nimble enough to say, "Hey, I know how to do all that process and formal process and be rigorous and document it and make sure if we ever need to go and explain our certification process, it's totally buttoned up, but I can adapt it to autonomous driving." That's how I say the talent pool, kind of the demand from our perspective, is shifting a bit.

Unidentified Participant:

Yes, the big buckets of spend, I think just any sort of context you're able to provide around—like, "To run this type of program, we're spending approximately x, we don't need to spend on y, and that's a multi-hundred million dollar thing, but it's not a cost for us."

Brandon Eldredge:

Yes. This will probably be insufficient to the granularity that you're looking for, but let me take a stab at it. If you look at what some of the other folks that are spending, very large dollars they are spending now, they're trying to run a financial service. We're not spending anything on running a service. We try to scope our number of cars to be, I would say, the bare minimum we need in order to deliver the objectives we have, in order to deliver our R&D objectives and our commercial objectives. We don't try to have 300 cars or 600 cars in order to have 600 cars. We don't try to be in 25 cities, because we can learn what we need to, from an R&D perspective and a commercial perspective, in four or six.

The other piece, what a lot of people have spent a lot of money on, that are spending a lot, is development of their own hardware solution, their own LIDAR, their own compute. Now, maybe that was because they thought they were going to launch in 2018, and there was not a product existent in that timeframe, because it didn't, but based on the timeline that we're driving towards, more off-the-shelf solutions, third-party developed LIDAR compute solutions that require minimal customization exists. I think there's been a lot of folks that are spending a lot of money trying to develop those homegrown built hardware solutions, that we don't need to be, because we can leverage what Aptiv is doing in areas like radar and compute, or because third-party providers, either that we've invested in or that exist in the marketplace today, maybe didn't when they did it.

Those would be a couple of the big buckets of areas where I think others are spending a lot of money, where maybe we have some more efficiency, and in the network themselves.

Unidentified Participant:

In the revenue model, how you're going to make money with this, you have the data monetization. I would think your customers probably think they own most of that or all of that. How do you work together to—

Glen De Vos:

Yes, maybe I'll speak to this. Yes, the whole data play, and this isn't just for mobility, but as it relates to commercial vehicle applications, data ownership is much more clear. You have basically the service provider and you have the tech provider, and what we've found in our discussions is it's pretty easy to bifurcate who owns what and who wants to control what. If you're a network operator, you're going to want to have access and control the data relating to your customers, network operations, things like that, but a tech provider, we want data associated with how does this system perform, detailed information about the vehicle platform, and that kind of thing. There's a natural bifurcation that occurs, that we found is pretty manageable, and then together if we can benefit from either the monetization of that data, fantastic, that's kind of an upside opportunity.

As it relates to the commercial applications, that's very sellable. As it relates to more personal vehicle things, our belief is the end consumer owns their data, and so you really kind of go from there. There's lots who say to you they own the data, or they try to control it, but the end consumer owns it. Our focus there is really on how do we provide or help our customers provide value to that end consumer in one shape or form or another, and if you're doing that, what we find is data ownership issues tend to mitigate, they tend to not come into discussions about delivering value to the end consumer, but that's a much more complex environment between privacy and other issues, we haven't navigated that, and that's part of why that whole data market is relatively slow moving. The OEMs are still kind of sorting out what are their strategies, how to get the data. Today, even though the cars are connected, there's not a lot of rich data coming off the car that's usable, but it's clearly moving, I think, in the right direction, but that'll play out much more slowly.

Unidentified Participant:

I'm just curious how you see the hardware evolving. Do you think the kind of sensors around the market today are what you need or can solutions be solved with software? I mean, how do you see that all evolving?

Karl Iagnemma:

Yes, I mean, I think the sensors out there today, generally speaking, there's a sensor set that can get you to a viable solution. I think that sensors will improve over time. Brandon mentioned one of the things we do is work with sensor developers to drive some customizations. We try to find a sweet spot between getting some of this exactly right for our needs without basically reinventing the wheel. As you guys know, there's kind of came an explosion of LIDAR, exploring the different technologies, the different wavelengths, and all the different ways you can skin that cat, and clearly pros and cons. We evaluate everything. We kind of try to evaluate every sensor that comes along and then pick what we feel will be the near-term winners and the right sensors for us. We're not building sensors outside radar, and so that's a big advantage, that we can drive requirements through our internal process. But, yes, look, I feel pretty decent from a sensor perspective.

Now, there are, let's say, operational challenges that, as an industry, we don't have great answers for today, like, for example, heavy snow. I mean, it's hard. We've done it in Boston, we can drive around to a certain degree, but the sensors aren't really that super well-designed for it. As new sensors come along, you'll be able to expand your ODD. Yes, I think that's how I would characterize it, sufficient today, but as new sensors emerge, it'll just give us better performance and expanded operation.

On the compute side, it's really all about cost. I mean, there are compute solutions out there. They tend to be a little expensive, can be a little power hungry, if you go back to the earlier question, and it's because the specific types of compute solutions we need just aren't being manufactured at scale, they're not being manufactured kind of auto grade today, but as demand ramps, they will be. There's a little bit of a chicken-and-the-egg situation there right now, but, again, we're at a point where, despite the fact that these compute solutions are more simple than I'd like them to be, they can fit within a BoM that's going to let us go to market in a way that is viable, and then we think—we envision—we know it will come down significantly over time.

No showstoppers there, I would say, on either side. Primarily upside and performance on sensors and upside on BoM.

Unidentified Participant:

But to the extent that there's some sort of environmental issue that the sensors can't, I guess, handle due to some operations.

Karl Iagnemma:

Yes, for ODD, for example.

Glen De Vos:

The only other comment I'd add on that is what we're always looking at, as well, is the question about how do you drive sensor costs and compute costs down, and one of the big levers is volume, how do I get volume on these things. We're always looking at how do I align our roadmaps with a Level 3 or Level 2-plus roadmap, because that adoption and that volume is going to be relatively near term. Instead of just simply the robo-taxi market, if I can leverage the Level 3 personally-owned vehicle market, that gives me tremendous volume. As we touched on earlier, that's an advantage that we can play to help drive development costs down, as well as unit costs down.

Unidentified Participant:

Karl, just because we always get the question on hardware and sensors, Vision versus LIDAR debate. You talked about the sensor set today being viable to get you there in 2022, but I think historically you use some of the sort of Gen-1 LIDAR guide, 905. Do you need to sort of breakthrough in LiDAR or some of the Gen-2 or Gen-3 sort of solutions? Is that important to get to sort of greater levels of operation of the main, or can you see a path that you can do it with existing sensors that are out there today?

Karl Iagnemma:

Depending on how you kind of bucket Gen-1 and 2 and 3, I mean, there's been step improvements along the way. When you think about our early deployments, which are fairly low-speed, you know, the current LIDARs, again, are kind of—I don't want to sing their praises too loudly, they're okay, they're pretty good, right? They allow you to see a fairly short range around the car with decent density. Obviously, if you've got a knob you can turn, you can add more, increased BoM costs, but you can add more and get more beams out there. As long as you can process them, you get more data. The performance, the resolution is okay. The reflectivity on certain objects, that's okay, too. Yes, I don't sound super-enthusiastic. I think improved performance will continue to increase. You look at, for example, going to 1550, or something, potentially, you could put more power to the system in a safe way, you can see much further. That's interesting, still pretty early in development, but that's the kind of thing we try to—

Unidentified Participant:

As it comes, it's just increasing that operational domain. It allows for higher speed.

Karl Iagnemma:

Exactly. It's always a trade space, of course, between the performance, the reliability and the cost of the system, and every system has pros and cons. I wish there was one that was cheap, could see the horizon and never fail, but that one's not here yet.

Unidentified Participant:

Then, just keying off your last comments around kind of the ability to leverage the commercial side Level 3, etc., when you think about going into an auto OEM RFP, you were able to present the roadmap of L2 to L4/5. I guess my understanding is that just far and away differentiates you versus kind of the competition. I guess I'm curious, like how important is that really. If I'm an OEM, do I just—am I content picking and choosing a Level 2 from this guy, Level 3 from that guy, Level 4/5 from somebody else, or is that comprehensive solution really a big differentiator that allows you to sort of push on economics, push on overall quantum of work, etc.?

Glen De Vos:

Yes, there's a really two dimensions to it. One is, if you think about an OEM talking to Aptiv, can we give them a roadmap for their system architecture? That means that they don't have to revalidate from ground up every time they implement a Level 2 to a Level 3, or across vehicle lineups, and that's the whole point of the satellite architecture, where there's a central controller and then distributed sensing. That gives them that scalability across vehicle platforms, as well as up and down levels. Having said that, the other thing is we don't—the idea that an OEM is going to lock everything down with one supplier on the whole system is really unreasonable, so we're very flexible in terms of how that system can be architected as it relates to the individual components. We'll work with other tier-ones' radar, we'll work with other Vision suppliers. That gives the OEM the flexibility that they always want in terms of, "Okay, how do I make sure I can take the best of what I want," and build a system up the they want to see it.

But, with the software residing on a central ECU, what that allows them to do is have that flexibility around the sensing, but then really control and manage that software and the validation of that software in those two dimensions we talked about. What we're finding is that is a very powerful argument, because the cost of validation of these systems is significant. Just like with automated driving, you invest a lot of time and money, and the OEMs want that flexibility. That's what that architecture brings them. Then, our ability to map that out to a Level 4 gives them the option of, "Hey, I have a pathway there," whether they want to do that today or tomorrow.

Unidentified Participant:

Maybe just talk about kind of the sales team. I mean, obviously, the sale is changing with your customers, from a hardware sale to a software sale, and increasingly monetizing data in the vehicle, and is it training the existing workforce to be able to make that sale, is it hiring new people, and just kind of where are you on that path?

Glen De Vos:

Yes, I'll speak to this. It's a little bit of both. If you think about—what Elena mentioned at the beginning, for connected services, smart vehicle architecture and automated mobility, we aggregated that all under the mobility and services group, so we have a commercial team that focuses just on that. That said, we leveraged the broader Aptiv Team that knows the OEM community deeply, and so understand how to work with those OEMs in terms of their sales and who to talk to, who the decision-makers are. You don't want to lose that capability, if you will. That's where the hybrid model comes in. If you're talking about commercial deployments with mobility handlers, like the Lyfts and Ubers, that's Karl and his team that have point on that. If you're talking about selling systems into a BMW or a PSA, we leverage the existing OEM teams to do that. It's really both.

Unidentified Participant:

Just a question to follow up on the sensors. I thought you were saying that there was some limitation for the sensors and over time that won't be a limiter or governor, and to make up for that, you'd kind of rein in the area, or restrict it more. I'm curious, is this a function of—is it the weather and the sensors need to overcome that, or is this a speed factor, so we're going to have to get it down to 25 miles? How much of a limiting factor is this and what is that technology, let's say, roadmap? Because, I've heard some aspects of this with your competitor set and it's just, that's a long way away, and that's why we're developing it now. I want to understand the ring-fence. If it doesn't get developed, are we talking like 10% of the TAM that's available, because it's weather and speed, or what are the limiting factors?

Karl Iagnemma:

Primarily weather. There are some long-range—I mean, Vision is a good example of a sensor mode that can see as far as the eye can see, given resolution limitations, but weather is one where LIDAR, for example, may have some challenges in heavy snow. The other thing I want to point out is that, particularly today, generally speaking, we're not super-human, in the sense that conditions that you, as a human driver, would have real trouble in, are going to pose challenges to the sensors themselves, but it's a smaller box than that, to be clear. Snow is a good example.

As I was mentioning, we do monitor, we keep track of everything that's on the horizon. The reason I think that's the right approach is because, I mean, look, we're a sensor manufacturer, we know what it takes to build sensors, we also know how expensive it is. If you're going to make a bet on a sensor, you better be right, and it's going to be expensive and take a long time. Our view is let's let the marketplace, which is very dynamic, there's billions in investment going into this space, and let's let the market fight it out. Let's keep on it really close, and make sure—we know exactly what we need, we've got all the specs, all the requirements, we've done all that homework, so we know what we're looking for, and we can quickly get on the sensor that we think is going to be the winner.

Brandon Eldredge:

I would just add, our financial projections also assume that solving those weather challenges occurs sometime after 2025. I couldn't tell you right now if it was 2027 or 2028, but the assumption of entry into the revenue generated from those markets that are burdened by snow is quite a ways out in our underlying assumptions, as well.

Glen De Vos:

Yes. This is kind of an adjacency, but some of those performance variabilities is also why we think it's important to actually launch or introduce AVs as part of a hybrid fleet, so manually, as well as automated vehicles. That gives the fleet operations the flexibility to adjust how they deploy that capacity, depending on the situation and the current weather conditions, the current conditions of the market. That variability, or that ability to manage that variability, we think is really important. We think the hybrid fleet approach really helps solve that. It gets you there much faster.

Elena Rosman:

Thank you. That does conclude our formal webcast and our formal Q&A session, so thank you Glen, Karl and Brandon. I'm going to go ahead and disconnect our line, we'll grab lunch, and maybe we can get seated again and Abe will do our demo for us. Thank you.