

## RBC Capital Markets Future of Mobility Conference

### Company Participants

- Danny Shapiro, Unknown

### Other Participants

- Mitchell Toshiro Steves, Analyst, RBC Capital Markets, LLC, Research Division
- Unidentified Participant, Analyst, Unknown

### Presentation

#### Mitchell Toshiro Steves {BIO 3255357 <GO>}

So we have Senior Director of Automotive at NVIDIA, Danny Shapiro, with us. I think what we're going to do first is he's going to go through some slides and a quick overview of the auto business. I'll then go into a few questions and then open it up for some Q&A. So take it away.

#### Danny Shapiro {BIO 20228839 <GO>}

Sounds great. Well. Good morning, everyone. And thanks for joining us. There's a clicker somewhere.

#### Mitchell Toshiro Steves {BIO 3255357 <GO>}

Yes. Here.

#### Danny Shapiro {BIO 20228839 <GO>}

Yes. So I was -- Mitch, you probably got -- we've got everything you guys got to study here. Read it quick. Fine, we'll move on.

So I just want to spend a couple minutes kind of setting the stage with respect to what we're focused on in automotive. And it's all about artificial intelligence. I think a lot of you know that. You've seen the growth of our company moving from graphics and expanding into artificial intelligence.

There's really 2 aspects of AI. And all this leads directly into the auto industry. But kind of the first phase is based on the data center and the need to be able to ingest lots of data and be able to train and iterate and build the deep neural networks that are acquired for autonomous driving as well as basically everything else that's going

on in terms of the revolution in health care and energy exploration in the finance industries. AI is transforming basically every type of industry.

Then once you've trained these models, then we sort of take them out. We have these models that we then put in the vehicle. And so the sensor data comes in. It's analyzed. We can use cameras, radars, LiDARs to perceive what's going on, running it through those deep neural networks, make decisions and actually control the vehicle. So this is the model that we apply across all the industries.

And in terms of what goes on in the vehicle, we have specific solutions then to address the problem from end to end. So in the data center, we have our DGX product, which is for training. It's also used for inferencing in web applications and other types of server-based configurations. But in the vehicle, we run the AI on our DRIVE platform. And so again, the hardware and software is a single architecture that extends from the data center to the Edge, to the vehicle, in this case. And that's where we're focused on, hardware and software for AI.

We're engaged basically with everybody. We have hundreds of developers that are building on NVIDIA DRIVE. And we're working on cars, on trucks and shuttles and buses and construction equipment and mining equipment and agricultural. So there's a lot of markets. All these different companies have unique solutions. They're working with different kinds of sensors. But they'll have the same underlying problem they need to solve. And so we're that foundational hardware or software, many, many layers of a huge software team that is building this platform, which is open for others to develop on. So that's why we've seen such great adoption. It's not just a fixed solution. It's not a black box. But it is totally customizable. And everyone is moving in kind of different ways to address these problems. They have different types of vehicles, different types of use cases. And they all want to own their IP so they're able to create custom applications based on the NVIDIA DRIVE platform.

Just an example that -- of some of the stuff we're developing, again, it's the core of the AI systems. This is what we see when we drive, right? We have our sensors, the eyes. That image data goes into our brains. And we recognize the signs, the lanes, the cars, the trucks.

And so we have to replace the human eyes and the brain with a system. And so the sensor data comes in, which is actually just a bunch of pixels and frames of video. And those pixels are just numbers, let's say, what's the red, the green and the blue value? And so there's no inherent information. So the AI is able to be trained to identify all the different types of objects in the scene, understand what's a sign, what's a lane marking, what's another car, truck, pedestrian. This requires a massive amount of computing to take place. It's not running code that's been written. But the software is written by data that's been trained to recognize patterns. And they can now do it much better than any of us in this room.

And so what we actually have is a lot of these deep neural networks that are running simultaneously in the car, detecting objects, detecting lanes, detecting free space or

the absence of objects, processing LiDAR data and point clouds, processing radar information, calculating distances, detecting pedestrians, right? So there's all these different neural nets.

And the reason we do this is we want to have the redundancy and diversity that's required to ensure safety on the road. We don't want to have a single app that's running that everything's reliant on. But the fact that we're detecting objects, using one set of data and algorithms and then detecting the lack of objects, what we call OpenRoadNet or where there's free space, together those provide sort of a double check that it's safe to drive where we want to drive and we're not going to hit something. Again, when we're computing the path, we have 3 different algorithms that all come together that are then used to decide how are we going to steer the vehicle.

What this means though is there's a mass amount of computing that has to happen in the car. You can't just take traditional automotive components and piece them together with a smart camera or other controllers and deliver this kind of robust solution that is safe to put on the roads. You saw the Zoox example, right, the complexity of what's going on in numbers of things they're tracking simultaneously. They're one of our partners. And they need AI supercomputing in the vehicle to be able to deliver this kind of solution.

The other thing that we see as, obviously, a big part of this is safety. How do we ensure it's safe? And so early this year, we announced the availability of what we call DRIVE Constellation. So this is the system here. It's a data center solution. You see it's going to be -- have the skin torn away. But there's 2 servers here. One is a simulator that's using our GPUs to generate sensor data. And so basically it's emulating what the cameras on a self-driving car would see or what the radar or what the LiDAR would see.

And so it's a virtual environment. We're sensing everything that's going on in simulation. And so the output of that top server pool of GPUs is fed into the bottom server that has our NVIDIA DRIVE platform inside running the full software stack. And so essentially, we're taking the simulated input, we're trying to then process it in real time and then make driving decisions -- do we accelerate, brake, turn left or turn right -- and we feed that back into the simulator. And so this is called hardware-in-the-loop testing.

Then what we do is we basically have a rack of these. And so each one of these servers represents a virtual test vehicle. And so we can test all kinds of conditions, all different types of scenarios, different weather, different time of day and control this. So it's a way to really accelerate the testing and validation. Then we can do things that normally you wouldn't want to do in the real world because they're just too dangerous to test. So this gives us the ability to rapidly advance the testing, development and then, of course, validation of these autonomous vehicles.

So here's just a shot of us running the simulators. So there's 10 -- basically replacing 10 virtual cars. But -- and people often ask us, "Well how many miles have you driven?" And first of all, it's not so important to know about the miles you've driven but rather the scenarios, right? What are the use cases? What are the specific corner cases, the rare and dangerous events that happen?

And when you're driving a test car, usually nothing happens, which is what you want. But it's pretty boring. You're driving along and you stay in the lanes and you stop when cars come stop in front of you. But what we need to do is ensure these autonomous systems are able to handle that child running out between the parked cars or somebody running a red light or driving the wrong way or whatever it may be. And so we can just create an exhaustive list of scenarios that we want to test against and then also do it in bad weather, do it with bad lighting or the sun setting, right? And so Constellation lets us do this in virtual reality.

So we just announced that the Toyota -- at our GPU Conference a couple months ago, Toyota is now not just using us in a vehicle. But they're training with our systems in their data center. They're using Constellation to test and validate. And that exact hardware that's tested and validated then is what goes into the car.

The other thing then that's -- is unique about us is not just that it's open platform. But it's this full end-to-end solution. So again, we have DGX based on the software; CUDA and other apps; our Constellation, which is running DRIVE SIM software; and then our DRIVE AGX, which goes in the vehicle and running our full software stack that others can build applications on. So this gives us a really unique position in the marketplace that not only are we approaching it from that AI supercomputing and bringing that into the car. But we have a complete software stack that extends from the cloud to the car. And so as a result, again, virtually everybody in the industry who's building autonomous vehicles, the cars, the trucks, the shuttles as well as the mapping companies, the sensor companies, our ecosystem are all building on NVIDIA DRIVE.

So I think at that point, if you want to get into the numbers -- I don't know how much you want to talk about that. But we see that the growth potential is really large, right? We've -- in our Investor Day, we've talked about the TAM for this market being \$30 billion a little over five years from now. For us, the bulk of that is what goes inside the vehicle as those volumes ramp. But again these are all different levels of autonomy from Level 2+, which is a very advanced system where it -- basically taking the technology or putting in fully autonomous vehicles. But bringing it to market sooner, right? We're not necessarily waiting for the regulation that is not in place yet for fully autonomous. But we're taking surround sensors, we're taking the AI supercomputing and our full software stack and putting it into consumer vehicles today to make them safer. Driver still has to be in the loop. But we have full levels of autonomous capabilities to ensure that car and those passengers inside and out stay safe.

Then also this huge opportunity for us in the datacenter with our automotive customers specifically adopting our GPUs to train their neural networks and then running Constellation, our DRIVE SIM software as well. So again, great growth

opportunities. We're at the very early stages of this. I know we've been talking about self-driving cars for a long time. This industry has been making lots of promises and projections. Time lines keep slipping out. And I think the industry has recognized this is a more complex problem than originally believed.

And the key here is safety, right? We're all focused on delivering the safest possible solution. We don't want to bring something out prematurely. And the result is you need more compute, right? You need more layers of software, more redundant algorithms. And all that requires more compute. So we're not standing still. We're continuing to innovate and bring this technology to market in all different types of vehicles and all different types of use cases.

With that, I think we can jump into questions. Okay.

## Questions And Answers

### **Q - Mitchell Toshiro Steves** {BIO 3255357 <GO>}

Yes. So I guess maybe we'll just start with this slide right here. Since you guys have a \$30 billion TAM kind of out there. And that's out in 2025. So how do we think about, I guess, the ramp in terms of where you'll see the revenue uptick and driving versus training versus validation? I mean based on this, it kind of looks like training probably the first part you'd see it. But how do we kind of think about that exactly?

### **A - Danny Shapiro** {BIO 20228839 <GO>}

So our auto business has been growing for the last decade or more. And that predominantly was driven by infotainment. That was our first foray bringing our graphics technology into the car. Then five years ago, saw it as a transition as that first led to mature. And our company became an AI company. We started to bring AI into the vehicle as well. So the revenue in vehicles still dominated by infotainment. We're seeing kind of new wave of infotainment in terms of AI cockpits. But I think you're going to see growth there.

Mercedes and their MBUX, where you can talk to the car and, say, "Hi. Mercedes." With voice processing in the car, other types of sensor processing in the car as part of that UI. But to your point, yes, the data center is where we're seeing our autonomous vehicle customers having to make those investments now to train the neural networks on the development side. And this will be ongoing. I think we'll always be working to make cars safer and better and add new features.

Then Constellation, which is now available, we're seeing huge demand for that. And that'll be a great way again for the testing and validation. I think that's going to play a big role, too, working with regulators, government agencies as we need to prove the technology works in simulation. And then the results of those tests will be things that we can show the public and regulators.

### **Q - Mitchell Toshiro Steves** {BIO 3255357 <GO>}

Yes. Then interestingly, something you said earlier in the discussion here is that you said that it's not important to look at the number of miles you've driven but to look at the types of environment. So if that's the case, how would we be able to compare you guys to let's say somebody else creating their own self-driving or self-driving chips, like a Tesla or something like that? So how would we be able to do it -- prove out that you guys have tested more environments or just something like that?

**A - Danny Shapiro** {BIO 20228839 <GO>}

Yes. So I think the California DMV has their engagement or disengagement reports that are published by different companies at the end of each year. And they basically have to say the number of miles they've driven and then how many disengagements per mile, right? When did the driver have to intervene? And it's hard to compare these numbers. It's very apples and oranges kind of thing. So as a company, we're not developing vehicles. We're not developing a robotaxi service. So we have a limited number of test vehicles that we drive around the Bay Area, East Coast and Europe and in Asia. And that's really to test and validate our algorithms. Then we work with companies, whether it's a Volvo or a Toyota or a Mercedes. And they'll be the ones that are deploying it at scale and doing more validation.

But again, I think as I mentioned, the miles is less critical as opposed to what happens during those miles. And this is where the simulation part comes in. We can make every second in the simulator count, whereas when you're driving along 101, there's diminishing returns from those kinds of miles when nothing's happening. And for us, too, when -- if we want to test, well, how do the algorithms work in the fog? We have to put a couple engineers in a car, drive all the way up to the Golden Gate Bridge. And we're spending many hours getting there. And we get there, maybe the fog has lifted.

Instead in a simulator, we can actually recreate those conditions and test all kinds of crazy stuff happening plus fog and different times of day or blinding sun. And so the benefit from simulation is enormous.

Then of course, we're not going to replace real testing. But we're going to use it to dramatically augment and improve it. Then we can iterate very quickly. We can just update the software in the simulator.

And the key thing here though is it's not like we're doing one test in the cloud and then something totally different on the real road, though. It's the exact same hardware and software that's in the server that's being tested that we put in the vehicle. So it's a true digital twin.

**Q - Mitchell Toshiro Steves** {BIO 3255357 <GO>}

Okay. Then when we think about the different types of cars you guys are involved in, we see you're doing everything from robotaxi to delivery vans, et cetera, right? So first of all, I mean, how do those ASPs differ when you're trying to put an NVIDIA box into each car, each vehicle? Then secondly, which one should actually come first? Should it be more the robotaxi side? Or should we expect, I guess, delivery vans? I mean how do we think about that in terms of the actual use case going forward?

## **A - Danny Shapiro {BIO 20228839 <GO>}**

Well so I think the way I'd characterize it as more the capabilities of the system are the differences as opposed to whether it's a car or whether it's a truck. Because the problem is, is essentially the same as you saw or heard this morning with Zoox, right, with their -- it's about the sensor configuration. They have the -- what they believe is the optimal sensor configuration. But regardless of that, you're going to put -- you're going to need 360-degree sensors. And you're going to put them in different place on a truck versus a car versus a robotaxi shuttle.

But essentially, the fundamental technology is identical, right? You have surround sensors feeding a massive amount of data and that needs to be processed. And so the different ASPs come in to play really with how much sensor processing needs to go on because of the level of autonomy. So we have our Level 2+ base system kind of at the entry level going all the way up to a Level 4, Level 5 system. So we have -- we're in the hundreds of dollars for the entry systems, up to the thousands of dollars for the fully autonomous.

In the interim, a couple of years, we're seeing Level 2+ systems coming to market. We announced with Tier 1 suppliers still take our technology, build and integrate and work with us, deliver it to the OEMs. So we have Continental, ZF in Veoneer that are all building Level 2 with us. Toyota's already announced production plans. Volvo's already announced production plans. So that's -- over the next several years.

We have a number of trucking initiatives, too, in that Level 2+ or more driver assistance but much higher levels of driver assistance that are on the road today, often includes driver monitoring. So AI plays a big part of ensuring the driver's still alert, not falling asleep, not distracted.

Then also, there is that robotaxi deployment. So we're working with a number of the robotaxi companies, some that are -- are presenting here, others whether they're in the Bay Area or elsewhere in the world are realizing the problem is solved by supercomputing. You can't put a bunch of smart cameras in. You need an AI computing platform. And NVIDIA has that, the leading technology in that front.

And so again, those are in a couple of years, too. As early as later this year, right, Mercedes, Daimler with Bosch and NVIDIA are going to be deploying robotaxis in San Jose, again, pilot programs. Just last week, 2 simple one of our partners on the trucking side completed a trial with the U.S. Postal Service, figure out autonomous runs of mail from Dallas to Phoenix. So long-haul trucking, I think, will be one of those categories though that comes up much sooner than others.

## **Q - Mitchell Toshiro Steves {BIO 3255357 <GO>}**

Got it. And since we're at a financial event, I mean, one more question. I'm sure you won't like this. But the gross margin's trajectory, right? So if I go from let's say a Level 2 car to let's say a Level 5. I realize the ASP may be up 10x, right. But is there some sort of gross margin structure that should also occur? Or...

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**A - Danny Shapiro {BIO 20228839 <GO>}**

So I think what -- what's different maybe is from the old NVIDIA, it's more software than hardware, right? They have great gross margins on software. And so we have an enormous software stack. You saw all those different neural networks. That's part of our software. We have our DRIVE OS software. We have the neural nets. We have a bunch of other libraries and tools.

And so when a customer is buying NVIDIA, they're buying a whole bunch of different things from us. And again, it could be hardware with software in the data center, our DRIVE SIM software and then software in the cars. I think that's where we're going to see a lot of additional growth for us.

**Q - Mitchell Toshiro Steves {BIO 3255357 <GO>}**

Then just one more before I turn it over to the audience. I think another one that's been very topical has been Tesla's comments about -- they created a chip that's essentially going to be able to do self-driving rides. Can you maybe talk to us about what -- I guess is that a threat to you guys? Then secondly, what do you guys have that's going to be differentiated versus what Tesla will be able to do?

**A - Danny Shapiro {BIO 20228839 <GO>}**

Tesla's been a long customer of ours and partner. And they still are, right? Their data centers are full of NVIDIA. The -- and I think our strategies, our beliefs are very much aligned, I think. You have 2 companies now between us that -- we're the only ones that are framing the solution to self-driving in terms of having hundreds of trillions of operations per second inside the car topped. So hundreds of tops required. It's not just these low-energy ECUs that is -- there's dozens of them in vehicles. But this is a centralized computing architecture. And that's really the way forward.

Tesla has decided to vertically integrate and developing their own chips. Elon made a lot of claims that weren't exactly accurate. They're a little misleading in terms of their performance level. And sort of quoting some of our old numbers and they have multiple chips. The reality is, is they're now at, I think, 144 tops in their self-driving computer. We're at 320 topped. The energy efficiency is very similar. They, again, kind of mixed and matched numbers to make it seem like they had a big advantage. We all adhere to the same laws of physics and chip design. So there's no way they can come out of the blue and just create something that has dramatically more energy efficiency.

But their volume is relatively small. I mean they're growing. They make a great product. I drive one every day or it drives me every day. And we'll continue to get better.

And so I think their strategy is really aligned with ours. But now in the market, there's 2 options. There's a Tesla supercomputer for self-driving. And there's an NVIDIA one. And I don't know if anyone -- any of the industry can actually buy the Tesla one or not.



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**Q - Mitchell Toshiro Steves** {BIO 3255357 <GO>}

Right. Any questions from the audience?

**Q - Unidentified Participant**

(inaudible)

**A - Danny Shapiro** {BIO 20228839 <GO>}

So you have -- I don't know if everyone heard the question. It's who assumes the liability. What we're seeing really is the carmakers, right? They're selling the car. If it's in an autonomous mode -- like Volvo said that if you have a Volvo in autonomous mode, Volvo assumes liability. There's no way that you can certainly pass that to the occupant of the vehicle. It's like when you get in a taxi, right, you're not in control. You're not liable. Of course, NVIDIA would be responsible if there's some defect in something NVIDIA does. But at the end of the day, it's the automaker that has sort of the contract with the customer.

Now just kind of to follow up on that, again, what we see, too, is that car companies, at least this wave and for the foreseeable future, people who are leading the industry want to be in control of the user experience. They're building the application. They're not necessarily coming to us saying, give me -- here, I'll give you my car and you make it self-drive. They want to be able to control the whole user interface, the experience. They're deciding where it can drive autonomously, what kind of mode it has, how does somebody engage that, what's the app experience that might be tied together.

So again, we basically provided all the hardware and software for them to customize and build their applications. Like we have a whole perception stack. They may say, well, we have a bunch of engineers. And we're doing some of the same work. The benefit is we combine it. We have our perception AI. And they're going to maybe have some of their own algorithms that are also running on our hardware. But the whole system gets better because we have multiple algorithms all working together. And so -- and they'll create that application right on top. And ultimately, we'll decide does the car brake harsher or does it turn sharper. That's going to be that OEM, who's going to ultimately make those driving decisions.

And so the experience in autonomous Mercedes may be very different than an autonomous Honda, right? Even though they both could be using a lot of the same core technology, that application and that final decision making would sort of be up to that automaker. I think the key thing, though, is all of these cars are going to be much safer. They're not going to be taking the risks that all of us usually take behind the wheel.

**Q - Mitchell Toshiro Steves** {BIO 3255357 <GO>}

Let's go over next question. So Colette has stated a few times that her favorite game's Monopoly. But that aside, when I look at the auto business, I mean which companies you guys feel like you compete against the most? I mean Intel's got

Mobileye as well, right? And it's profitable and doing okay at this point. So you need to talk about who you guys see the most, what kind of the value proposition difference between you guys and Mobileye as well.

**A - Danny Shapiro {BIO 20228839 <GO>}**

Definitely. Again, I think we're approaching the challenge of self-driving very differently, I mentioned. And what we see is that this problem is more complicated than everyone thought it was initially. And it just requires more and more compute.

I mean already, Tesla announced they're developing their next-generation chip. So regardless of what they've built now, they feel they need more compute. We're the same. We've already made announcement that our next-generation technology continues to raise the bar, deliver more computational horsepower and lower energy consumption. So that road map is clear.

I think it's hard if you're one -- our competitor who has many different architectures. They have a smart camera architecture. They have a CPU. Now they're developing a GPU supposedly. They have a neural net processor. They have an FPGA. And so there's all these totally disparate components that they're trying to cobble together to develop a solution.

Very different from us, a single architecture from the cloud to the vehicle that makes the development much more streamlined. And it's open. I mean that's the biggest thing, too, is that others are developing. And you look at our ecosystem, it's enormous because we made it easy for them to develop on. We sort of -- we've learned this in the gaming segment, right? This is where we created all the tools and the libraries. So all the game developers can deliver unique solutions on NVIDIA. And that's kind of what fueled our original growth. That same strategy is really taking off in the auto industry. So being open, having the end to end is really unique to us.

**Q - Mitchell Toshiro Steves {BIO 3255357 <GO>}**

Then the second one is a little bit interesting, too, is on the M&A side. So you guys bought Mellanox, which obviously bolstered your data center side. I mean I see -- and I saw your presentation talking about sensors a lot. So I guess is there anything that you guys think you would be interested in at all in terms of bolstering up the automotive capability?

**A - Danny Shapiro {BIO 20228839 <GO>}**

Yes. I mean -- so I think, right now, we're obviously focused on still closing the Mellanox deal at the end of this year. We've made different investments on the automotive side usually. It could be as simple as one of them, usually a lot -- a number of different software companies.

On the sensor side, we're pretty -- we're essentially sensor-agnostic. We want to work with all the different sensor companies. We realize the diversity and redundancy of sensors is key. And so we make sure that we have support and optimize our stack for all the different sensor companies. So it makes it easy for, again, our automaker or

truckmaker customers integrate the sensors that they feel they want to use. But -- so we're not really focused on trying to -- I don't feel we need to acquire a specific sensor technology. And I think that makes it better for us if we, obviously, have a sensor, a LiDAR company that's part of NVIDIA, that's going to potentially hurt our ability to work easily with a lot of other LiDAR companies.

**Q - Mitchell Toshiro Steves** {BIO 3255357 <GO>}

Perfect. (inaudible) Just one more.

**A - Danny Shapiro** {BIO 20228839 <GO>}

(technical difficulty)

The service, it could be something that we host. We have datacenters for them. We use it in-house. I mean that's kind of the usual product path for NVIDIA is we're creating things that have never been in the market before. And so we start developing it and using it in-house first and then it gets released to the world. And in fact with Constellation, it was announced at GTC a year ago. And we had -- we spent a year using it in-house, fixing, improving, optimizing before we release it to customers.

So again, we could host it. But in many cases, they're wanting to deploy it on-site. So they'll be developing their own datacenters full of it. And it's designed, again, for them to be able to test for their vehicles. So the configuration will be specific to what they're putting in the vehicle. The whole goal is the exact same hardware and software that goes in the vehicle is what's in the data center. And it makes it very easy to iterate. But also then they know once it passes all the tests here, it's good to put on road. And so that, I think, is pretty unique. The benefits are again enormous. And they can really accelerate the development much more so than any other way. So the -- I mean that's what Toyota -- and you're going to see more announcements along that front soon in terms of others really adopting that whole pipeline.

**Q - Mitchell Toshiro Steves** {BIO 3255357 <GO>}

Okay. Perfect. Thank you for coming.

**A - Danny Shapiro** {BIO 20228839 <GO>}

Okay. Thanks a lot, everyone. I'll see you guys.

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