RBC Capital Markets Auto Tech 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 today, we have Danny Shapiro of NVIDIA, who'll be talking about autonomous driving. Mitch Steves, research analyst for RBC. And so I guess what we'll do first is we'll give Danny a few moments to kind of go through a slide deck, kind of talk about what do you think is most -- what do you think's the most important to understand about NVIDIA and autonomous driving and autonomous cars in the future.

And so with that, I'll introduce Danny and get started.

Danny Shapiro {BIO 20228839 <GO>}

Great. Thanks so much. Good to be here. Hi, everyone. I know it's been a long day. So thank you for sticking around. And I'll go through a couple of really interesting things. I hope that it turns out to be very educational for you.

I think the most important slide here, of course, is the safe harbor, right. What we might be talking about is some forward-looking statements. So everything we're going to talk about, though, here is kind of really an in-depth look into what NVIDIA is doing in this space and how we see our technology, how we see many different industries all converging. I think, as you know, NVIDIA has been involved in a wide variety of different industries, different technologies. Everything though, it's kind of coming together with autonomous vehicles here. As a company, we started out in the gaming space. It's still a very big part of our company and the work we do and investments that we make. AI, of course, is a huge segment and an endeavor that's just -- is just taking off, multi-trillion dollar business.

And autonomous vehicles, we've been an auto company really for about 2 decades now. We first enabled carmakers from a design perspective, from an engineering perspective, the CAD systems and simulation systems. Then about 10 years ago, we

moved inside the vehicle. So we learned how to become an automotive grade company. We're supplying the infotainment systems and anywhere there's graphics, pixels on screens, NVIDIA was developing in app systems, the instrument clusters, head-up displays, rear-seat entertainment.

Our technology and the processing capabilities continue to increase. And coupled with the introduction of deep learning, our processing now has basically become the chosen methodology, the platform for autonomous vehicles. So what I want to talk about is really how all these 3 things, from graphics, from AI and automotive, are converging for us.

We believe everything is going to be autonomous, not just cars but trucks. All types of different vehicles, public transportation, delivery bots. Essentially, anything with wheels will ultimately become autonomous. Now the key thing that we believe though is this technology evolution that AI is enabling is critical here. Computer vision was kind of the original methodology, writing algorithms, hard coding algorithms to be able to accomplish tasks. And now AI is this new computing model. It's revolutionizing everything from health care to energy exploration to smart cities and now transportation. We've developed a processing architecture. And we recently introduced Xavier, which is our newest SoC. This is a AI supercomputer on a chip. It scales across all levels of autonomy. We've got multiple processors to deliver the horsepower required to process all the data coming in from sensors.

Also, we've done much more than just develop the platform for the vehicle. But we have an end-to-end solution, not only is it top to bottom from the levels but end-to-end. From the data center we start. We have to collect the data. The data's processed. (Typical) networks are trained. We do simulation. We do testing, resimulation. All this in the data center before we even deploy it in the vehicle. Then there's a cycle where data comes back from the vehicle into the cloud. So NVIDIA is focused on the whole spectrum of computing that's required for autonomous vehicles.

And again, it's not just about what we're doing. But we're engaged with over 370 different partners now just in the autonomous vehicle space; virtually every automaker that's working in this space, the truck makers, the delivery bots, the mapping companies, the sensor companies and over 125 start-up companies that are developing software. So wherever you look, presenters that were here earlier in the day, a lot of companies that we can't disclose yet. But they're using NVIDIA as the core platform in the vehicle as well as in the data center.

Important information here is we see again a huge growth potential for autonomous vehicles across wide spectrum, across different levels of autonomy and a very sizable TAM, whereas, again, both content in the vehicles and additionally, we're going to see it in the data center, too.

As I mentioned though, what's key is really a fundamental shift in how computing is done with AI. And so what our customers are seeing is they need to process a

massive amount of data. So every test vehicle that they have out on the road is out there collecting data. Some of these are autonomous vehicles. And some of these are just human-driven vehicles going out, collecting data. You see around the valley here, a lot of these cars just laden with sensors. And they're basically collecting this information, they take it back to the data center. And need to process it.

To do so, you need a supercomputer. And we're seeing, again, GPUs. And specifically now, we have our DGX-1, which is our data center AI supercomputer that's processing all this information. We're training neural nets. Basically, we're teaching the systems how to recognize lanes, how to recognize cars, trucks, bikes, motorcycles, pedestrians, how to read signs, read lights. Then also on behavior. You're able to then learn how to recognize different types of situations. And we do this with camera data, with radar data, with LiDAR data. This is a very complex process. And it's an iterative process. So it's ongoing, you're constantly collecting more data and testing and training these algorithms.

The reality is though there's no way you can generate enough data by driving a fleet of cars around. And part of the problem is that as you drive these cars around, they're not seeing everything that you want to be able to train your system to do. So simulation is playing a big, big role in terms of being able to train these systems and then also be able to test and validate them. And I'll talk about that in a second.

And finally, to drive the car, we need the supercomputer. I've actually brought one. And maybe afterwards, if people want to see it, I'll share it. But this is the DRIVE Xavier. So this, of course, is automotive grade. It's a supercomputer. And this particular configuration has a single Xavier chip on it. So this is our SoC that just got safety assessment from TÃœV SÃœD, which is a leading safety expert in Germany. Adheres to ISO 26262 standards. This is an ASIL D. So highest level of safety integration. This is ready to go into production. And so we're working with over 25 different robo-taxi companies as part of our ecosystem as well as, again, major automakers and truck makers and others alike.

I mentioned simulation. And we can talk more about this afterwards. But essentially, again, there's no way that we can drive all the miles to capture what we need to, to train these nomads. And also it's dangerous, right? The things that we need to train are for a child running out into the street or a car running a red light in front of us, somebody splitting lanes and cutting us off. And so you don't want to put real cars in those kinds of situations for training or for testing. And so what we've developed is something we call DRIVE Constellation. This is leveraging, again, multiple parts of NVIDIA together. So one of the servers in Constellation is full of GPUs. And we're essentially rendering a virtual environment. We're simulating what the sensors in a car would see at the front-facing camera, the rear camera, the side cameras. We can simulate radar. We can simulate LiDAR. And then we build a virtual world. So essentially, what we do is we create a scene, a whole road network. We can bring in maps. And we photo realistically create the environment. And then we can basically drag and drop sensors and put them on the car. So position, the types of cameras or radar, LiDAR, on the vehicle, point at wherever we need to point it, then we run the simulation. We create driving scenarios, cars driving down highways through cities,

other cars merging. What you'll see in the center then is the upper which says autosim is the visual that's generated by the simulator. Then what we do is the output of that simulator goes into our NVIDIA DRIVE computer that's also in the data center. Essentially, we're driving in this virtual world. And we're running the entire software stack in the data center to test it. So the output of the simulator goes into the NVIDIA DRIVE that processes that information as if it was driving on the road. The computer doesn't know it's in the data center. It thinks it's cruising down 101. It then sends its commands to turn left, turn right, accelerate or brake back to the simulator instead of the actual steering wheel or pedals.

And so what we can do is virtually drive billions of miles and do it in a safe way and recreate all kinds of hazardous conditions, bad weather, bad lighting conditions, blinding sun, snow, whatever it is. The benefit, of course, now is that we can create very robust neural networks that can handle blinding sun. If you have your fleet of self-driving cars that are cruising around, you can only test blinding sun for a few minutes a day. In simulation, we can do it 24 hours a day. So again, this becomes a very, very valuable tool for our customers to do both the training of the neural nets and the testing of the hardware and the systems.

Then finally, I think the strength of what we built here, this slide points to just a testament of how our open platform, our scalable platform and all the software tools that we've built are being leveraged by the industry. So we have so many partners developing so many different projects. It's really been great to build it, get a chance to work with them and to see how we're able to really help push the industry forward.

So at that point, I think I'll just pause and we can sort of dive into whatever questions you want.

Questions And Answers

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

Okay, perfect. That was a great overview. So actually, before we go into just the NVIDIA specific questions, there was one pretty big announcement today for GM essentially getting a $2.25 billion investment from SoftBank. So maybe you could at least provide a quick overview of your thoughts on how their little team with such a large amount of money and what do you think they'll end up using it for and what they'll need to do if they want to essentially compete and create self-driving vehicles as well.

A - Danny Shapiro {BIO 20228839 <GO>}

Well I think the investment shows again how fast this industry is moving, how important these challenges are that we're trying to solve. And it's a big and complex problem that requires a lot of investment. I think they want to do it right. Hopefully, you're going to spend a lot of that money on NVIDIA GPUs for their data center, I don't know. But that would be pretty nice. But I think again, we see huge growth in this marketplace, big investment, lots of -- a lot of start-ups. Some of these

companies are acquiring start-ups. The bigger companies are acquiring start-ups. I think there will be some consolidation. So you may use some money for that. But again, I think it is capital intensive to build the vehicles and to build the data centers that are required to put safe cars on the road.

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

Yes. So I guess a quick follow-up on that. So if you were to give somebody just a large amount of money, how would you kind of structure your thinking in terms of what you would need to kind of create an environment to create a self-driving car? So obviously, NVIDIA chips would be on your list. But what else kind of products in general would you need to go down that path?

A - Danny Shapiro {BIO 20228839 <GO>}

Yes, I can't speak for GM what they're going to. But again, I think the creation and deployment of the fleets. But they need to both collect data and simulate data, I think, are the key things. And they're probably hiring people to build those teams to do all that.

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

Got it. Then turning back to an earlier slide here, you've got a $20 billion TAM for robo-taxis, $40 billion for self-driving vehicles, for self-driving cars. So how do I think about the ASPs for both of those segments. And how they would trend from now until -- well, I guess, not now but in 2020 and then kind of 2025?

A - Danny Shapiro {BIO 20228839 <GO>}

I think -- so for NVIDIA, again, we're developing a scalable platform. And the benefit for our customers is the single unified architecture. So whether they're doing a level 2 to plus 2, level 3, level 4, level 5 ultimately, or they're starting at the high end, they're going to bring it down. Either way, it's a single development effort; they're not having to deploy different teams with different types of technologies. So there's a huge benefit that they have in that space. We're in the hundreds of dollars ASPs at the lower levels of autonomy to the several thousands for the robo-taxi.

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

And I guess, what's kind of driving the large difference there in terms of the ASP content?

A - Danny Shapiro {BIO 20228839 <GO>}

Well again, our DRIVE Pegasus is our highest level platform that we've unveiled so far. And that has 2 of our Xavier processors and 2 of our next-generation high-end GPUs. We rated that at 320 trillion operations per second. So this is a hugely powerful but very energy-efficient supercomputer for the car, whereas what I held up there was a single Xavier processor rated at 30 trillion. So again, it's a scalable approach. And we work with the automakers and Tier 1s to develop the right level of compute for what it is that they're trying to accomplish.

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

All right. Then just to check all the boxes, I'll turn it back to autonomous in a second. But you guys also have a pretty big presence in infotainment. So how do we think about that in terms of what type of content we'll see from the infotainment side as we create self-driving vehicles as well?

A - Danny Shapiro {BIO 20228839 <GO>}

I think for us as a company, several years ago, we shifted our focus away from infotainment, basic infotainment, which is where we initially saw huge growth. But shifted away from that into autonomous and focusing our engineering and our R&D on deep learning and processing all the sensor data. But I think what we're going to see is over time, a transition from our personal revenue from infotainment into autonomous. That said though, I think there's going to be a next generation of infotainment that will be infused with AI. And so that's where we see ourselves playing again in that space. So doing things with gesture recognition, facial recognition, speech recognition, all those require a lot more processing than your standard graphics processor that's now going into vehicles. So I think we'll see a resurgence of new features and new capabilities. On the -- if we're talking about fully driverless vehicle, you get inside, it could be a hotel on wheels, an office on wheels, a living room on wheels. In that case, sure, I think we can see even more graphics-intensive processing where you might have -- all your windows could become sort of like a Holodeck. And now you can be transformed into a different environment or watch movies or play games or things like that.

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

Or play (on the computer), right?

A - Danny Shapiro {BIO 20228839 <GO>}

You could, sure. It all comes -- all roads lead to NVIDIA, I think, is what you're trying to say.

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

Exactly. Perfect. So then turning it back a little bit to the autonomous side. So there's always a debate in terms of what type of products or need to do self-driving vehicles. So can you maybe help us understand from a technical explanation why you need NVIDIA products, why you can't use another person -- or another competitor to get to this level 5 driving?

A - Danny Shapiro {BIO 20228839 <GO>}

I think, for us, safety is the most important thing in this endeavor. And it has been discussed earlier pretty much at every confidence, right? We're going to save lives by having autonomous vehicles on the road. But to do it safely requires a massive amount of processing. We need redundancy and diversity of algorithms. And we want to be able to ensure that we're able to detect everything that's going on around us and do it with incredible precision and not only then detect what those

objects are but understand what they're doing, where they're moving and what the intent is and understand behavior. And this can all be done in AI. But every time you have new neural networks that are doing more and more, it just requires more processing. Again, I think the industry has recognized that AI is the only way to do this. Computer vision will not -- is not sustainable and very early on, the hard coded algorithms to detect objects have given away to artificial intelligence.

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

Right. I think I'll do one more before opening it up to some questions. So I think another big announcement was actually the virtual reality testing of vehicles. So maybe you can -- I'm guessing you can't name companies but describe what the adoption should look like in terms of people using the VR atmosphere to test drive cars and make them more intelligent.

A - Danny Shapiro {BIO 20228839 <GO>}

Yes, I think, I mean, we've seen in the news over the years that there are some companies that have developed their own in-house simulation. And that's really a vital part of being able to scale this up and to really be able to validate on what's been created, right? And so what we've done is really put together the system we're developing it and using it in house. And we'll be rolling that out to our customers to enable them to better scale and to -- again, the reality is you need to be able to drive many more miles than you could humanly do in your life -- in the lifetime of these test fleets. Then the flexibility we have for simulating and using the expertise of NVIDIA on the graphic side as well as then using AI to be able to generate new scenes and we can take even a scene where maybe we'd driven a car and we've recorded the data on a sunny day. You can resimulate that and create a rainstorm or fog or snowstorm. And so we can then have this multiplicative factor in terms of data we've actually obtained and data that we simulate to achieve the higher levels of reliability and essentially certify that, that the car can handle what it needs to handle.

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

I'm going to stop there real quick, see if there's any questions from the audience.

Q - Unidentified Participant

(inaudible)

A - Danny Shapiro {BIO 20228839 <GO>}

Are you all right?

Q - Unidentified Participant

Well (inaudible) I think put that back to you (inaudible).

A - Danny Shapiro {BIO 20228839 <GO>}

Yes. I don't have a good answer for it. I think what we're trying to do is develop the best products that we can and try to -- I understand that. I think it's true across all

industries, right, people want competition because they see benefits of that. I think, for us, we're developing the best products we can, the highest performing and delivering them at a very fair value. And usually, I mean, if you've seen some of Jensen's keynotes, right, what we deliver compared to our competition is a huge cost savings. And I think we're doing the same thing in the vehicle, where people sometimes say, "Oh, your chips are so expensive." Well what they don't realize is if you look at this platform that we deliver how our system's able to replace 4, 5, 6 other silver boxes in the car. And also the development cost is much less with NVIDIA because we've created all the tools, we have this long history, there are so many parts that we deliver to them and then again, they're able to scale it over all these multiple systems. So again, I think our customers recognize the value we bring to the table.

Q - Unidentified Participant

(inaudible)

A - Danny Shapiro {BIO 20228839 <GO>}

So I think the question was do we see specialized silicon coming in. I think the development in the tools and the infrastructure that we've put in place has been widely adopted. I think everybody recognizes that. And the reason is because this space is moving so fast. There's new algorithms weekly practically. And the need for highly -- high levels of programmability is there. So I don't really see that changing anytime soon. And again, these cars are software-defined cars now, just like your phone, right? You continue to get updates to it. And so having the broad base flexibility that we deliver lets them continue to iterate and come up with new algorithms and try new approaches. And there's going to be new sensors that get added and have different data formats. So again, I -- we pay very close attention to the competition. It pushes us. It's good. It forces us to be very alert to continue to create higher levels of performance, higher levels of integration, be as energy efficient as we possibly can. I think the key thing is if you look at our GPUs today, I mean, our new GPUs are Tensor Core GPUs. So we continue to evolve our GPU as well. There's a lot of custom silicon inside that wasn't there years ago when we were just doing graphics. But it's not like we're competing against new technology that we don't have. We continue to evolve and improve our AI capabilities as well. So essentially, we have a custom AI ASIC. It just happens to be able to play video games as well.

Q - Unidentified Participant

(inaudible)

A - Danny Shapiro {BIO 20228839 <GO>}

How do you know I'm not a robot? How do you know this isn't a simulation? No. It's not something that I worry about. We're able to deliver solutions now that are superhuman at certain levels of perception or specific tasks. But getting to rethought and original thinking is quite different.

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

I guess I had a few more. In case there's another questioner, we can turn back to that. So basically, if we think about some of the negative headlines that we've seen with Uber rides, some terrible things that have happened. So what exactly do you think is going to be the biggest hurdle between now and let's just call it 2021, to be safe, in terms of when you get to self-driving cars? And what is NVIDIA doing to essentially help solve that problem?

A - Danny Shapiro {BIO 20228839 <GO>}

Well again, I think the simulation piece will play a big role there. We want to be able to show that this technology is safe. We need to be able to prove that it's reliable. It does what it says it's going to do. And again, being able to simulate will let us achieve higher levels of the number of scenarios that we can invalidate. And so I think the legislation is moving forward to enable it. I think there'll be different types of rules in different regions of the world. But again, we'll be ready for that.

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

Then in terms of the spending, since we're going to get closer and closer to self-driving cars, within about 3 to four years here, is the message that the people who are investing and spending like the robo-taxi companies going to essentially have an edge because already they have the best technology. And they're going to be able to start deploying cars faster? Or how do you think it's going to evolve in terms of which automotive companies will eventually, probably be obsolete and some will become larger and larger monopolies effectively, right? So how do we think about the spending relative to, I guess, the time frame? What kind of lag do you need in order to have a self-driving car that will still be production ready?

A - Danny Shapiro {BIO 20228839 <GO>}

Yes. That's a -- I don't know if I have a really good answer for that. I mean, I think you can spend a lot of money and not make progress. So I think the investment is in, again, having good development engineers to bring the right technology in to be able to deploy their fleets, to be able to have your back-end infrastructure. And again, I think there's different business models that different players are having. And I think it goes both directions. I think you can deploy a Level 5 solution. And it's much easier, of course, to dial it back then into a Level 4 and then Level 3 in that case. But then, we have customers that are starting at the lower levels of autonomy and slowly building up. So I think it's going to work both ways. So I don't see necessarily one camp winning over the other.

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

All right. Then I guess one of the high-level ones. So you've given out a TAM number. How do we think about the units in terms of how that will ramp? So I think it's a little bit difficult. So if we have 1,000 ASP and you only have a few cars, seeing the unit ramp, I think, would be pretty helpful. So if I look out from 2020 to 2025, what's like a rough cadence?

A - Danny Shapiro {BIO 20228839 <GO>}

I don't think we -- I would refer you to some of the market analysts. I mean we sort of have some numbers. But we really haven't disclosed that. I think the numbers we put out there was like 20 million in 2035 for robo-taxi numbers. But exactly how that ramp goes is something that's not totally known at this point.

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

Okay, perfect. Are there any last questions from anyone in the audience?

A - Danny Shapiro {BIO 20228839 <GO>}

Everyone's exhausted. You need to get into your robo-taxi and go home.

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

Perfect. Thank you, again. Thank you.

A - Danny Shapiro {BIO 20228839 <GO>}

All right. Thanks so much, everyone.