



- Patrick Moorhead: Raja, it is great to see you. And thank you so much for kicking off the metaverse track of the Six Five Summit 2022. You've been a busy guy, globe-trotting around launching products. I'm just tickled that you had time for us. Thank you so much.
- Raja Koduri: Oh yeah. Thank you, Pat, for this opportunity. And as you know, this is one topic that I won't miss to have a conversation with you, whether at a summit or a beer or whatever. Right. So I'm glad to be here.
- Patrick Moorhead: Yeah, it's great. I think you and I have known each other around 20 years and I think we have been talking about this notion. We didn't call it the metaverse then, but the notion of the metaverse, you and I were definitely talking about, and here we are right now, it is getting a little bit closer to reality, but I think the first question is, what's your take on this collective conversation? And is there too much focus on the hype around the experiential idea or the front end technologies and software that's being pitched a lot today?
- Raja Koduri: Yeah. As you said, we've been talking about these sort of things for a long time. It taught in our corner of the world, right. This ultimate visual immersive experience that computers can deliver. Right, in whatever form of pixels, right. Whether you're surrounded by big, nice displays or where it displays on your head and so on and so forth, all of them are about the sentiment, visual, immersive experience. What's different now is people outside our small, relatively small club are also talking about it.
- Patrick Moorhead: Right.
- Raja Koduri: That's how I would kind of position the current conversation. And I say, "Great." Right now, everyone wants to talk about it. Everyone sees the potential as this kind of the next set of experiences and all. And it's quite deep rooted on why, and I'm sure, right, we'll talk about some of those aspects as we hit on our other parts of the conversation.
- Patrick Moorhead: Yeah. It's funny. I've been around a long time, I guess my 32nd year of being in high tech. And I've seen a lot of examples where people said, "Oh, this is just hype." And then it ends up somebody figures out the building blocks of what it takes and it really makes it happen. And it really does take a village.
- Raja Koduri: Yeah.
- Patrick Moorhead: So your strategy, you have somewhat of a different, and I think unique strategy, given your place in the industry, and you're really building a technology stack to go out there. In fact, I've heard you use the term computational plumbing, which by the way, I love, but can you talk about your strategy?
- Raja Koduri: Yeah, I will Pat. And like you said, the hype, right. I mean, it's interesting, right? I mean, any big, massive initiatives, right. "Hey, we want to go to Mars." So, there is a hype that generates, I call it enough momentum and funding for various programs, right.



Patrick Moorhead: Yes.

Raja Koduri: So the people who are looking to generate that funding, generate the hype to get that scale of investment and all. But going to Mars or, forget going to Mars, right. If you see a beautiful mountain and far in the distance, and they say, "I want to go there once." Right. If there are roads to go there, you can get in a car and start driving. Right. You have a map and all that stuff, but imagine a world before there were any roads. You have to pave the roads fast. Right.

So the computational plumbing, computational infrastructure, and the rest of the infrastructure stuff that I talk about are essentially, that's the boring part. Right. I mean, it's like, once the road is there, you don't even talk about the road. Right. But before the road is there, it is everything. Right. So, that is the infrastructure. We got a good infrastructure, Web 2.1 infrastructure as they call it. Right. You got really powerful phones in your hand, right. Terraform, GPUs, PCs are amazing. The network is getting better. The data centers are there. We got a baseline Web 2.0 plumbing as they call it. But what the dream of metaverse requires is the next level of the plumbing.

Patrick Moorhead: Yeah. I love that. It's kind of like how the internet was formed. What got back in .com 1.0, what got all the buzz was the pretty stuff that you could look at and see, but on the back end was a DARPA based plumbing project that connecting DEC Alphas, and none of the pretty stuffs would've happened without that. And by the way, I love the road analogy too, or back in the Roman times, roads used to be the thing. Right. And then, we don't talk about roads much. We talk about the cars that go on them. So you're looking at a lot of these building blocks in your system, and it's more than the GPU. I mean, the GPU is a huge part of it, but there's a larger strategy in business opportunity at Intel. And I thought it would be good maybe if you could provide some examples of those building blocks.

Raja Koduri: Yeah. No, so the GPU as a visual synthesis element, right, is an important piece of the puzzle, right? And then the other computational elements in particularly AI computation, which could be done on the GPU or other engines as well, will play an important role. And I'll touch on that in a second, but most importantly, this computation, whether it's GPU, computation, CPU computation, AI computation, whatever form of computation, how is it available and accessible to anyone and everyone, right. Like again, using the road analogy, right. It's just, "Hey, I get in my car and I get on a road from in front of my home. Right. And get going to wherever I need to get there."

So the kind of the moral equivalent of that from availability standpoint, no matter where I need to enter this metaverse, right, this experience that I want to get into the metaverse, how do I get in, is all the compute necessary with me in my home or in my device, or is available throughout and is just the software and the applications are just figuring out how to harness that. These are all kind of next level. I mean, they're little boring for the big, the hype folks, but for engineers that have to make it all work, very exciting and interesting conversations, right? How do we make these things available?



So at Intel, along with variety of our communication technology, 5G investments, what Nick is doing on the edge, we are looking at what is the software layer that makes it all available seamlessly? Right. And recently we demonstrated a piece of technology that we called named End Game, on which we are building this on where a computation or your GPU that's available in your neighbor's home, for example, that you may, you don't have in your home can help you run an unreal engine file quality, like visuals on any device that you own, right.

Or from a web browser for the matter. So these are the kind of things that we are working up and down the stack, right, beyond the regular Intel, Silicon roadmap, software roadmap.

Patrick Moorhead: Yeah. What's interesting to me is just how many places that Intel can play and your sandbox, your metaverse sandbox is so big. And I've talked to a lot of companies who are making pretty big investments on the data center side, big investments on the Mec side, 5G side, to really give this pervasiveness of service and what a great challenge with the latency, right. And the real time nature of it kind of similar to high performance cloud gaming in a way, or doing that from the edge. So, it's a big issue. And I'm glad to see that you're playing in multiple areas. Quite frankly, it doesn't get off the ground without Intel. So, from an investment standpoint, are you investing in unique ways into the metaverse? I mean, obviously you're investing in all the Silicon that's there and the platforms, can you provide some details around that?

Raja Koduri: Yeah. Great question. So beyond the Silicon roadmaps, the GPU roadmaps, CPU roadmaps, XPU roadmaps, the connectivity roadmaps, low latency, interconnect, and fabric roadmaps that other parts of Intel are working on. We are increasing our investment in that software layer that connects all of these limits together. Part of it, we are doing organically. And part of it we are also doing some inorganic acquisitions, right. We acquired for as example, an interesting team that's based in Poland that was doing this remoting of all applications, remote my app was their name. So that sub strategy, both organic and inorganic for the software.

The other thing that we're doing now, and this may be, I maybe going a step or two ahead here, if I really truly see the... No pun intended, End Game for an open metaverse. Right, that everybody has access to. It really got to be open every layer, right. Every layer needs to be open all the way to the instruction set architecture level.

Patrick Moorhead: Okay.

Raja Koduri: On the hardware side. So today that's not quite the case. I mean, very far from that. So when you hear Intel talk about even our participation on risk five and some of the stuff that we are doing there, they do actually connect back to this metaverse topic, right. Actually just today Pat, a day or sender, he announced our collaboration with Spain and with the Barcelona Supercomputing lab on Zeta scale, but it's surrounding risk five. I actually see that investment that we are doing there, connecting back to metaverse, right. The high performance computing and the AI computing and the GPU like things, you do, the intend to collaborate with them on a very open, large scale architecture as well.



Patrick Moorhead: Yeah. I think, one thing I think many of us agree on is that there will be open and closed metaverse ecosystems. And you did talk about the openness, I'm curious, are there some foundational standards that are essential that have to remain open and unified? Can you get specific on that?

Raja Koduri: Yeah. I think beyond the ISAS and the protocols, the way we exchange data has to be standardized. Now, in the computer graphic space, and there's a standard called USD, I think Pixar actually kind of contributed to that. And the spec universal scene description language, I think now I don't know the status of it standardization and all across Coronas and all, but that seems to be gaining some traction that we can all exchange marble textures and variety of seen information between entities in the standardized form. That I think is just essential for at least the visual immersive version of the metaverse that we all talk about.

And then there are these other layers that Pat, as they call web three, the monetization models, the role of the cryptocurrency, or blockchain type technologies and standardization of those elements as well, which, like I said, if we talk about this topic, this is a hours and hours as to each layer there is a standardization require. Maybe the simplest answer is, from the hardware, software contract layers on ISAM to the operating system layers, to the middleware layers, all the way to the application and the monetization layers, there are standards that would be required. It's almost like the TCP/IP stack, right. That each layer had a specification and you could innovate at different layers, different companies did, but if you confirmed from ethernet, it works, right. At a certain level.

Patrick Moorhead: So in the end, do you think the community or the industry will lead the way to this metaverse future?

Raja Koduri: Yeah. Looking back with the first face of web, second face of web, it's not as if we all had super clarity. Like the beginning that this is where we are going to end. Right. But now looking back, we can write the history as if it was all nicely kind of those PowerPoint things we have, web one point or web two point and all. It's a little messier than that. Right. But as humans, right. What's interesting about the exponential curves we draw on all, we have pretty damn good collectively about learning from the past and kind of applying that to the next thing and the next thing to kind of accelerate. Right. And the whole world, the amazing thing right now is it's not just one, like, "Hey, US driving it or China driving it, or Europe." The whole world is participating in this stuff.

Right. And I'm just this morning talking to a dude that contacted me, he has a 300 people animation team that sits in a village and he trained them on YouTube. Right. And he wants to get in this whole metaverse thing. Right. And so it's amazing. I think it is going to happen step by step, but it it won't be like, well formulated, everybody agrees on everything and every layer is clean and all that stuff, but if we are having this conversation and let's call it 2027 Pat, which I'm sure we will, we'll look back and say, "Hmm. Right."

Patrick Moorhead: Of course, that's how it played out. Right. Yeah. It is so funny how you look historically, and I think particularly younger folks who don't have this sense of history kind of they can't



necessarily appreciate because they don't have those life experiences to see how accidental some things were. I mean we talked about the internet. I mean, today's internet was created on the back of a messaging system in case of nuclear war that became the internet. I mean, that's nuts. Right. And the initial vision of the popularity of the smartphone today was not a pocket computer because previous pocket computers had failed. Right. Yeah. And people are thinking, there's no way this is going to happen. That's like, wow. Apps on a smartphone. Yeah. Let's lean into that. Right.

Raja Koduri: See, but if you go to the root of the things, Pat, right. As humans the storytelling has been part of our culture, even if you go back thousands of years. Right. And exploration is also been part of our DNA for a long, long time. It's crazy to think that people got on boats and got into the ocean, they didn't know where they were going. Right. It's just crazy. And they went to go discover stuff. So exploration is in our DNA. Storytelling is in our DNA. Right. And that, when you just think about metaverse, that the promise of what it allows, right. It's got both elements, right. Storytelling and exploring new worlds beyond what we know exists physically, which we also want to go, travel to Mars or whatever stuff. Right. So I think whether we may get the timelines wrong on realizing this technology. But so from my standpoint, it is just a matter of when it's going to happen and not if it's going to happen.

Patrick Moorhead: Yeah. I'm there with you. I am. And I like to look past, I like to look past the past, although history is most of the time, a great way to see the future. I don't think we should stare at it too much. And that's actually a positive on the metaverse in that. In fact, mathematically, and you can catch me on this. The more failures you have, the higher the probability of a success in the future in a certain area. And I think we've seen that so many times out there. So, I want to drill down a little bit into AI, something caught my ear and I think, I'm now just processing it, this relationship between the metaverse and AI. And I'm curious, first of all, what's the relationship between the two, because I don't logically put to the two together? And what does that infrastructure, that acceleration infrastructure look like in the metaverse?

Raja Koduri: Yeah. The fundamental, like if you just look at the fundamental problem of real time, photoreal computer graphics, right, that immerse you, right. You look at latest games, like an Eldon Ring or, Rise and West, amazing worlds they've created, but they are huge budgets that worked four years to create a world. Right. For you to transport team and in the gaming sense. Right. So when I look at AI, just the top level promises and what you are seeing, some of these patterns is that, "Hey, I have a vision in my head. Right. And I can describe to you computer that I need this world that looks like this at all." And what if computer just created that for me? Right.

Patrick Moorhead: Yeah.

Raja Koduri: And then I can bring my friends along to explore that world that I imagine, and that's like every storyteller's dream, is that I have an imagination and then I can kind of pull other folks in this and entertain them and thrill them and they can maybe explore and all that stuff. So the top most AI exciting thing and you're seeing that with some of the work open AI is doing, and a few startups are doing is that, "Hey, I describe something, I type something and it generates an amazing visual. That, oh my God, how did it concoct all this stuff." Right. So, that's like the ultimate stuff.



But before we get there, there are so many things, you know what we are doing practically. Right. The XeSS technology, right. "Hey, can I... Instead, I can't afford to render this photoreal quality at 4K. I don't have the computer power. Right." What if I render it at much lower resolution and use a neural network of sampling technology that makes it look magically same as if I rendered it at 4K.

Right. And that is working out super well. Right. Whether it's in video DLSS, XeSS right. And of course, there are some screen space hacks and all that we could do, but that is like almost magical when you see the output of the neural based up sampling techniques. And you can start applying those techniques for variety of algorithms in the whole computer graphics, rendering pipeline, which is what, like a whole bunch of work that's going. So, that is a very practical here and now today use of AI. In graphics, that's already, you see in action. And tomorrow, like I said, it's like, this whole notion that, I can describe my story to the computer and it gives me a visual back.

Patrick Moorhead: Oh, I'm going to list, I let, if I had a pen in front of me, I'd probably take notes, remind me in 2027 to talk to you about that. But yeah, I think I had thought about notions of super resolutions, super resolution with neural networks, but I hadn't quite thought about the, explain a world and it just auto magically appears and you can interact. I think that's really cool. So, short term, which areas of the plumbing, the infrastructure plumbing do you think will get upgraded first or needs to get upgraded first?

Raja Koduri: Yeah. The short term, I kind of put it in the three year horizon, right. That a relatively low latency access to consistent computing, like for example, what you can get on a reasonable high end PC? The top End Game consoles being more available to everybody. Right. Even people who don't think about PCs or consoles or anything. Right, in that infrastructure either through edge or through some creative home upgrade. Right. I see that happening. Just imagine that all of us have a home modern box sitting that is connected to my broadband. Right. And what if that box also has, I petaflop of compute just sitting there, helping me out on the variety of stuff that are going on around my house. And that's my first flow latency point and a petaflop of compute. Right, and if I look at my contavekiu GPU, I can hold it in my palm.

Patrick Moorhead: Right.

Raja Koduri: Right. Yeah. So, there's some more things we need to do to make it all practical and also affordable to sit in that kind of home modern box. But that is a low hanging fruit in my opinion, that needs to happen.

Patrick Moorhead: Yeah. And I think it's going to happen. I think history has shown us that you put the compute where the data is either generated or where you need responsiveness. And it seems like even though we increase the speed of the pipe going between the compute units and storage, we just find more content to shove in the pipe.

Raja Koduri: Yeah. It's interesting. Great. The biggest constraint we all work in our industry, the Silicon industry is energy. Right? So, and we have shown that the cost of computing something is lower



than the cost of moving the result of the computation, even whether it's on chip, off chip in distancing. So, it's like when I hear everybody saying that everything is going to go to cloud, I just like to say, "It's more planet. Why do you want to move all this junk all the time to cloud?" Right. It's like, so that it just doesn't match with the physics of the stuff that we are dealing with. Right. So I see we are in a very great world, digitization and all that Pat talks about and semiconductors and will be, we'll have more some air conductors in most advanced processes coming in the next five years than the last 10 years. So let's leverage it. Let's put compute closer to folks and solve these problems than trying to build pipes. And it's not practical. Right. You can-

Patrick Moorhead: Yeah. I think it's naturally going to happen, if we keep data density increasing, like it has over the last 40 years. I mean, we have these, I call it the accordion, which is we have areas of consolidation and then everything spreads out, right?

Raja Koduri: Yeah.

Patrick Moorhead: Mainframe, to mini computer, client server, PC and networks, smartphone. So, if I just, once data density starts declining or UIs can be drawn magically in the cloud, but I see the momentum is definitely, the momentum is on the edge right now.

Raja Koduri: Yeah. And the amazing thing about metaverse is that, or the formulation of it is that it really focuses it back onto the problem, right? "Hey, I need compute and I need that computer low latency." There is no other poster child case that is as dark as the metaverse use case to drive it. Right. There are many other examples we can talk about, but you can kind of squint and say, "Is it really necessary for this case, for that case?" And all that stuff. Right. "Can I get away with a little bit higher latency for the convenience of the cloud and other things?" But for this case, absolutely. You need low latency, immediate access.

Patrick Moorhead: It's been an amazing conversation and I'm sure, hope the audience is enjoying it as much as I am, but I wanted to ask you one final question. So personally Raja, what's the one thing that you're most excited about the metaverse bringing to the world, to society?

Raja Koduri: Reduction in travel.

Patrick Moorhead: I did 12 cities in two weeks. Yeah. I'm with you.

Raja Koduri: I mean, to be able to have a conversation with you, Pat and other friends and family and the stuff that, yeah. I still like the physical interactions and meeting, but being able to do that more frequently, just where I feel like we are in a three dimensional environment and having all that, the body language cues go between us will just be, we'll bring the world closer. Right. And the number of times I went to a place like China, just for one meeting, right. I need to meet that customer face to face all the way there, one hour meeting and fly all the way back is just crazy. Right. So that's one thing that, there are many things, but that's, if you want me to rate and prioritize.



- Patrick Moorhead: Listen, I love it. And what I love is your consistency, because I'm pretty sure 15 years ago, that is what you are excited about as well. You called it something different, but it's exciting too. And I think-
- Raja Koduri: Telepresence of something, the word, right that we used, but yes. Yeah.
- Patrick Moorhead: Yeah. And I think painting the vision of what that could be is super important because we can't limit it to what we are doing today. Right. It's three dimensional. I'm seeing you in very high definition. I'm seeing what you're doing with your arms, with your legs. I can see our brain is, can elicit things from even light bouncing off our bone structure as well. So a lot of work to be done in the metaverse. I am glad you are front and center, in not just because you're passionate about it, but you can actually do something about it with Intel taking this huge role in it. So I'm excited. And I want to thank you for coming and kicking off the metaverse track. Thank you.
- Raja Koduri: Thanks Pat.
- Patrick Moorhead: Yeah, let's do it again. And keep working on that telepresence. I'm in. I'm going to be your first customer.
- Raja Koduri: Thank you. Good. That's today.
- Patrick Moorhead: Great man.