Patrick Moorhead: Hi, this is Pat Moorhead. And welcome back to day two of The Six Five Summit. We are here talking quantum, doing the track opener. We are super excited about this technology. And I am just amazed at how the wheel of innovation turns. And one thing I love about quantum is it's definitely the next big thing.

Daniel Newman: Yeah, Pat, it is something that the entire world is kind of watching very closely to see, "What's going to happen next? What will quantum do? How is it going to change the world?" And I think more and more, each year that's passed, we're starting to get more of that concrete idea of ways that, through entanglement, through being in partnership with classical computing-

Patrick Moorhead: Yeah, that's right.

Daniel Newman: ... that quantum is going to actually make a very big difference. And I say actually, because I think there's been skeptics over time, but companies like IBM have really been breaking through. And I'm excited about this particular session.

Patrick Moorhead: Yeah, with that, let me introduce our guest. Dario Gil, how are you?

Dario Gil: I'm wonderful.

Patrick Moorhead: Great to see you.

Dario Gil: It's great to be here.

Patrick Moorhead: Welcome back to the Six Five.

Dario Gil: Thank you. It's always good to be here.

Patrick Moorhead: Yeah.

Daniel Newman: Hey, Dario, it's great to have you. You heard me in the wind up, there has been a lot of enthusiasm and excitement and there's been some skepticism, of course, because something like quantum is so difficult, so challenging-

Dario Gil: That's right.

Daniel Newman: ... yet creates such a big opportunity. Talk a little bit about the state of quantum. Where are we at right now with quantum computing overall in the market?

Dario Gil: Yeah, no, you're absolutely right. I mean, I always like to say that the level of difficult is a 10 out of 10, and I think that that sort of has historically hindered the progress. But frankly speaking, I think from a technology maturity, obviously, it's never been more sophisticated. And I'll highlight a few points.

So first, real systems have been now running for quite a while. So we put our first system in the cloud, it was May 2016. So you fast-forward to today, we have over 20 quantum computers on the IBM Cloud, they run 24/7, around the clock. A community has been built with close to half a million people around the world. We have cumulatively run over 2 trillion circuits, meaning, think about it as the programs in a quantum computer running on actual quantum hardware. There's over 2000 scientific publications that have already been generating using IBM quantum hardware. We have six quantum computation centers now all over the world.

So what you're seeing around that is that, first, quantum is already part of the R&D environment of nations and regions. So I would say, maybe 10 years ago, maybe it wasn't even in the top 10, now it's in the top five category. So the first market that has been created is actually the one of serving the R&D community where universities, national laboratories, economic development engines within regions are saying, "I want to invest in the future. I want to create this environment." So you're actually seeing the beginning of the curve of going up because people are now calling us to say, "Hey, I saw what you did in the Basque Country, I saw what you did in Korea, I saw what you did in Japan. I want to do this here." And the same thing with companies too.

Patrick Moorhead: I took a tour, I was told I was one of the few people to take a tour of the facility where I saw at least 15 of your operational quantum computers.

Dario Gil: The first quantum data center in Poughkeepsie.

Patrick Moorhead: Exactly. And that was a real, amazing thing. I mean, it's one thing, I've crawled through multiple data centers before, but this one was just so unique. And one thing I really appreciated too, the security guard that was within 15 feet of the entire group the entire time.

Dario Gil: Trust, but verify, right?

Patrick Moorhead: No, I mean, listen, you're working on some really important stuff. And as I've said before, what amazes me, and I've been doing this longer, over 30 years, and I've never seen a research roadmap. And what's even more unique is you're actually hitting those goals and you're making multiple announcements, it's not making an announcement, "And we'll come back to you in 18 months and tell you were..." By the way, I'm seeing a lot of that right now. But can you talk about your most recent announcements and how that relates to what we're likely to see in the future?

Dario Gil: Yeah, so I'm glad you mentioned our quantum development roadmap and it's related to the question you were asking me before about when there's uncertainty and people say, "Where is the state? What is happening?" We thought one of the best things that we could do for the entire community and the industry was to provide clarity as to what was going to unfold and what could you expect.

Patrick Moorhead: Yes.

Dario Gil: But it is a moment of vulnerability too when you say, "Hey, three years ago, I'm going to go from 65 to 127 qubits to 433 to over a thousand. This is what's going to happen with the software stack about how we're going to evolve Qiskit, which is the development environment, how we're going to abstract things." And yeah, you go public saying I'm going to do it, and then, you got to do it. But you are pacing the frontier of the field.

I'll make a point. When we broke the hundred qubit barrier, which, by the way, is something that, even a few years later, no one else has done, so we've moved even from 127 to 433, why were we so proud of it? Because it is the first time that we were able to bring a lot of semiconductor packaging technology, but now adapted to the world of superconductivity and low temperature where now you could break the plane and you could have your cubics, your I/O layer, your interconnects, and multiple different layers. That was a real tour de force in being able to bring an adjacency expertise that we had and being able to develop.

So what have we announced that is exciting around all of this? I would say one of the things I'm incredibly excited is how we're shifting again to the idea of modularity. So in some ways, the chip that we will build this year with over a thousand qubits will be the limit of how big a chip we will make for how many qubits can fit in there. Let's say order of a thousand or so. So then you say, well, how are you going to scale? What's going to happen after that?

So we've been designing and we introduced relatively recently IBM Quantum System Two. So the Quantum System One is that iconic box that everybody has seen with the chandelier around that. And then, Quantum System-

Patrick Moorhead: I have many pictures with that by the way.

Dario Gil: Yeah, it's one of the most photographed machines in the world. I love that machine. But Quantum System Two, what it speaks about is much larger chambers. So first of all, the system, which we will have it and you come to see it in November, is massive. So inside the cryostat now, you can have multiple processors. So now, the future is going to be just like in classical computing, you have multiple processors connected to one another and actually, multiple systems connected to one another. So this idea of modularity at all levels is what is going to give lead to the idea of quantum-centric supercomputing, which is a hybrid classical quantum system designed for scale. And that's what's going to have tens of thousands of qubits working in concert with classical.

The other mega idea that we could not be more excited, and given where we are, everybody will hear in a few weeks, is the path to actually implement a technique called error mitigation and error suppression. Everybody knows that part of the challenge of quantum computers are errors, how you deal with them.

Patrick Moorhead: Right.

Dario Gil: So ultimately, there's full error correction, there's a way to mitigate the errors permanently. But we have come up with a methodology to characterize the error, the noise present to machine and suppress it.

So we made an announcement on something called the 100×100 Challenge. And the 100×100 Challenge basically says, "World, we will deliver by 2024 a capability where you can have a hundred qubits with depth, 100, that have been error-corrected, error-mitigated, error-suppressed." Basically, we will approach the techniques such that that depth you can actually compute and get the good errors. And that is, without a doubt, in the space of the world of utility already. So now, we have a community approach with working groups in finance, in healthcare, in high energy physics, in materials where some of the best people around the world are saying, okay, we're going to take it as a challenge, we're going to work together and design the algorithms and experiments to exploit that capability. So that I'm thrilled about.

Patrick Moorhead: A 100×100.

Dario Gil: A 100×100 Challenge.

Patrick Moorhead: Love it.

Daniel Newman: Keeping these machines the fidelity high so that they can go through these processes and really meet the promise of what we hear because that seems to be where the error correction seems to be the item that has come up as long as we've been going through, whether it's been super conducting, ion trapping, it's keeping the fidelity of these qubits high. So these money laundering, materials, these very cool applications that we know are going to work in this entanglement environment, Dario. And I'm really interested to see how these working groups start to come out. We've seen some of those papers published over the last few years, large financial institutions. And speaking of this, you have a number of these systems now deployed around the world, you have built, you said half a million, but you have a large group of members in your networking group that are building on IBM.

Dario Gil: It's over 200 institutions too that are part of it.

Daniel Newman: So number of institutions. Talk a little bit about how they're using these quantum machines, how are they using them, how they're testing them. What are they building towards right now? Where's this all going with this network that you've built?

Dario Gil: Yeah, so I'll give you a couple of examples. So when I made the point that it is also being used as an engine of R&D and economic development, so I'll give you that class. So when a nation partners with IBM to create a quantum computation center, and we've announced already six, so we've done with in Canada, in the US with partnership with the Cleveland Clinic, in Germany, which is the first one we did outside of the United States, in the Basque Country, in Spain, in South Korea, in Japan, and more to come, there are four quadrants that make that model and they are a unique infrastructure, obviously putting the quantum computer and the infrastructure around it, an R&D agenda, how we're going to advance it, a skills and a development agenda, how we are going to change curriculums, educate people, create certifications, training, et cetera, and then, an industrial partnership model, so how will the local industry benefit from this capability?

We have learned, and we've been very successful in sort of incorporating that learning into a program to say, just giving you a computer is not enough, is we have to create all of those. So we always do all of those elements, our partnership with IBM involves that. And then, what happens is all of those elements come in, you start seeing faculty engaging with us to develop the curriculum. You then see a local consortium of companies who join, including very senior people in the company, CEOs that guide the strategic direction of how this new capability will impact the industry and the region. So all of those elements are there.

Now, when we partner directly with that company, let's say we're working with Wells Fargo as an example, so in there, what has happened is firms are creating their first teams. So over the last few years, they've hired their leader in quantum. And it's fascinating to me to see it. You say, "Wow, how could that happen?" If you look under the rocks, they'll find physicists in every institution, right?

Daniel Newman: Sure.

Dario Gil: And people are like, "I did a PhD in physics around that, I'm really interested in doing this." So they become a kernel, they form a small working group and they start developing use cases with us. We have an offering called the Quantum Accelerator, which is all use case oriented. So with Boeing you say, okay, we want to do use cases around corrosion for materials that we can use to improve the wings. With Exxon it may be a bad catalyst in an industrial process. With Boge we've been doing things also for electrolytes and so on. So everybody will segment the use case that they care about. And with that local team and with us, they start developing, what algorithms are useful? How would we start proving it? So that's one element.

And then, the second offering that we give them in addition to the Quantum Accelerator is obviously the access. And you could say you can have remote access, you can have dedicated access on the cloud, and for some of them, as they get more advanced, you can have, do you want a full dedicated system around that?

So those is the mechanism to engage, but I mean, the number of cases are just hugely varied, I would say, in two core categories. One is, where are we seeing traction? I would say, first, in the industrial sector. Why? Because they rely on the physical world. So if you are building materials, life sciences, we're seeing picking up like crazy too around that. So all that kind of physical world, companies care about it. And then, the other category, because it involves around finding structure and data has been the financial services industry. So industrial sector including life sciences and then financials.

Daniel Newman: So when I said materials and anti-money laundering, I was-

Dario Gil: You were already on track.

Patrick Moorhead: You were close. You were close.

Daniel Newman: Exactly.

Patrick Moorhead: So that approach seems to be very provocative and valuable, from my point of view, for a couple of reasons. So first of all, each country gets to create their own value. And I know there's a lot of discussion of the centralization of technology right now across just a few countries, so you're spreading the wealth per se to people who want to sign it.

The second thing that strikes me is it's an ecosystem play. You're not just showing up and dropping off a bag of parts. And then, once you've broaden the horizontal piece, you're going vertical, which in the end, everybody is vertical, right? Nobody is a horizontal. So I see those as three really good pieces, and the last time I checked in the last two or three major ecosystem plays or big tech plays, whether it's mobile, whether it's AI or ML, it takes an ecosystem. So I really like that approach. We talked a little bit about your roadmap and by the way, hitting the dates, X product person, so I'm very impressed with hitting a date-

Dario Gil: The team has done a great job with that.

Patrick Moorhead: Oh, hitting dates on something that's science and you just don't know sometimes what you're going to come across.

I think you released a new roadmap called the Quantum Safe Roadmap. Can you talk a little bit about what you announced? And quite frankly, why do people need to be worrying or signing up for quantum-safe security today if the supposed bad guys might not have this capability five years? I think I know the answer, but I want to hear how you explain this.

Dario Gil: Yeah. This is the complimentary piece of the implications to quantum computing, and indeed, it has to do with the fact that, famously, we first learned about this community with Peter Shor in the 1990s is that one of the implications of large scale quantum computers are corrected will be to break asymmetric encryption. So as everybody knows, the way encryption works is we have two private keys that are made of two prime numbers, your key and my key, the product of it is the public key. The public key is in the open, everybody has it, but if you just have that number and you tell me the two prime numbers that made that large key, it turns out to be exponentially costly for a classical computer. That asymmetry, how easy it is to multiply two numbers and how hard it is to find that product is what we exploit in encryption.

Now, what Peter Shor showed is that you could actually factor that public key and find the two prime numbers exponentially faster. So now, what does that mean? It means we need to change the encryption keys. It's not the fault of quantum computers, it's just to say, okay, well, that's an implication of it. The good news is that there's an answer. There are new algorithms of which IBM research has been a huge participant in creating them. The NIST is in the final process of standardization, there's like four of them, and we've been involving creating three of the four of them. And so, now is the not small task of taking all the encryption that we have deployed all over the world, finding it and replacing it with the new protocols.

So that is the mission of IBM Quantum Safe, which is a software and technology portfolio and the skills associated with making it happen to engage with government agencies, with clients and partners all over the world to do a few things.

So first, a very important one, do you even know what your encryption is and how it's being used? So in software, there's a notion of a software bill of materials. Okay. So one of the things that technology is creating of IBM Quantum Safe is cryptographic bill of materials, scanning, understanding where cryptography is used, do you know what it is? And then, that's step one. Once you actually know what your status is, then how do we remediate it? And how can we use as much automation as possible in software to go and replace it with the right algorithm?

And also, is the idea of crypto agility. In software, there's no notion of saying, "Well, I deployed the software, we're done." And you're like, "No, it's never done." There's an idea of software agility, and how you do that. So crypto agility is the same thing. It may be that we find something, we need to change something again. So how do you instill that idea? So those are core concepts of what we have announced and being able to now say we have software and technology to make it happen, and then we also have complimentary skills to help you execute that.

Patrick Moorhead: Love it.

Daniel Newman: So Dario, leading research for IBM, you have some big tasks in front of you. It's not just quantum, you lead AI and we've hit this interesting inflection around AI where everybody's talking a lot about policy, regulation, how fast do we move? Well, in quantum, there's a similar question to be asked. And while we don't exactly know that commercialization breakthrough of the tipping point of scale.

One of the problems with AI is we had a lot of time and we had a lot of horizon to see this coming, and we didn't really come to a lot of policies, even companies like IBM had to come up with responsible frameworks because there is no global consensus on policy, there's no regulation, there's just some ideas out there.

So I'd love to get a lens of how you're thinking about this for quantum because the implications of quantum could be tremendous from a security standpoint-

Dario Gil: That's right.

Daniel Newman: ... in many aspects. And so, how are you collaborating with government and thinking about this now and maybe trying to get ahead of it with quantum in a way that maybe we weren't able to do so with AI? And is that something that you think needs to be done?

Dario Gil: Yeah, it's a great question and yes, and that is exactly how we operate. So I'll mention a couple of different vectors. So first, one is the broad implications. We just spoke about Quantum Safe, you have an implication for society of saying this is a consequence of it. How do we do everything possible to make sure that we're responsible actors and we mitigate the problem? Again, it's not quantum's fault, it's the fault we picked an algorithm in the past that needs to be changed, but be that as it may, we got to address the problem. So that's one element.

But then, you rightly pointed out that the technology side in itself is among the most protected technologies that, both in a company like IBM, but also governments see it as a source of national security and economic advantage as well. So we are actively engaged.

One of the things we have is active dialogues with governments on this topic. And I don't think it is a coincidence, if you look at the list of, for example, partners and countries where we have deployed quantum computation centers of who they are, it is a thoughtful process, it's not anything goes. The technology always stays in IBM controls, all of those systems are IBM technology and only IBM will service them and control them. So we're very, very thoughtful about that aspect and requires appropriate engagement.

Because while the systems right now are not capable of breaking encryption and doing things like that, in the future, they will. And obviously, as you all very well know, there's going to be a continuum of capability, that capability is already beginning to be present in terms of the technology that is being created. So you have to be engaged, you have to be responsible by your actions, and there's a lot of self-regulation, self-constraint that is also present to make sure that we get it to a good outcome. So we do take that very, very, very responsibly and very seriously.

Patrick Moorhead: So just to tie all this together, I mean, we've talked about roadmaps, we've talked about, basically, quantum security roadmaps, how you work with governments. How should we look at the progress of bringing useful quantum computing, solving real problems, and at the same time, keeping that data safe?

Dario Gil: Yeah. So I would say from a technology perspective, three vectors, one has to look at and they have to come together, quantity, quality and speed as a way to understand the progress of the system. Quantity, obviously, you need more and more qubits over time. Quality, how well they avail quantum mechanics. What's the quantum volume, the coherence and fidelity of the devices? And then, the speed, how fast can you execute these circuits? It is the blend of those three that allows you to build a system that is more capable from the previous generation. So that's one element.

The second element of it is how well is the software stack operating such that you can do deal with errors? I think it's going to be a continuum. I think the people who think about it, there is nothing, and then, there is a full tolerant million qubit quantum computer are going to be wrong on how the technology evolves. What we are seeing is, every year, we release a more capable system, the errors are better, the system is larger, it's faster, quality is better. And you keep going like that, that's the history of computing.

So as you go in there, we're going to cross a threshold that, I'm pretty sure, it's going to happen in the window of the next year or two, you are no longer talking a decade, where we're going to start in this era of utility where the combination of error mitigation, error suppression, higher quality devices, large enough with good speed are going to start doing demonstrations that when you compare to what you could do classically, you're starting to see, actually, that is starting to be better for these classes of problems. That is going to be an important inflection point.

I would say, the last six, seven years were all about, hey, a new capability, learn about it, expose to people around it, grow around it, but now the goal is... That's why the 100×100 Challenge is so important. The way I think about it is, that's a challenge to the entire community, it's not IBM solving it by itself. We all work together across different sectors and then, we put dots on the map and we say, "Hey, I think I did it. I think I did it. I think I crossed utility." There'll be a distribution. Four years later, we'll look back at the distribution and says, "Eh, 80% of those points were not true, you could do it better classically in the end," but there'll be some that will stand the test of time. And then, when we look back, we will say, that's when that began, the next phase of inflection. That's the challenge, right?

Patrick Moorhead: One to two years?

Dario Gil: Yeah.

Patrick Moorhead: Awesome.

Daniel Newman: And absolutely, you never expect it until it's there. I keep referencing the AI trend, but it was like it wasn't there, it wasn't there-

Patrick Moorhead: And then, it was there.

Daniel Newman: ... and it was everything.

Dario Gil: That's right. That's right.

Daniel Newman: I think we're going to have a similar curve. And the question mark, is it a year? Is it two? Is it three? But I think the fact is we're moving very, very quickly. Dario, thank you so much for joining us here at the Six Five Summit.

Dario Gil: Thank you. It is great to be with you and to be at the summit. Yeah.

Daniel Newman: All right, everybody, stay with us. We got more here from day two at the Six Five Summit. You just heard from Dario Gil, IBM Head of Research and Senior Vice President. More to come. See you all soon.