Rashmi Mohan: This is ACM Bytecast, a podcast series from the Association for Computing Machinery, the world's largest education and scientific computing society. We talk to researchers, practitioners, and innovators who are at the intersection of computing research and practice. They share their experiences, the lessons they've learned, and their visions for the future of computing. I am your host, Rashmi Mohan.

Every Star Trek fan worth their salt has dreamt of teleportation becoming a reality. While the world rallies around large language models and artificial intelligence, our next guest is on the frontier of the next big revolution that could perhaps make teleportation a reality someday, which is quantum computing. Travis Humble is the director of Quantum Science Center, a distinguished scientist at Oak Ridge National Laboratory, and director of the lab's quantum computing institute. Working closely with the Department of Energy's mission to further scientific discovery through quantum technologies, his lab is pushing the boundaries to unearth new materials, technologies in the quantum computing space. Additionally, Travis also leads the design, development, and benchmarking of quantum computing platforms in his role as director of the OLCF Quantum Computing User Program. He's the editor-in-chief for ACM Transactions on quantum computing and the co-chair of the IEEE Quantum Initiative. As a recipient of multiple awards, best paper recognitions and patents, he is most certainly a venerable expert in the field of quantum computing. Travis, welcome to ACM Bytecast.

Travis Humble: Thank you, Rashmi. Pleasure to be here.

Rashmi Mohan: Wonderful. So I'd like to lead with a simple question that I have asked all my guests, Travis, which is if you could please introduce yourself and talk about what you currently do, as well as give us some insight into what drew you into the field of computer science and this work.

Travis Humble: Oh, I'm happy to do this. I have been working in the field of quantum computing and other quantum technologies for almost 20 years now. I actually have a background in theoretical chemistry. I was studying how to control chemical reactions using quantum processes, and I stumbled into this field that we now call quantum information science. What caught my attention was exactly teleportation, just as you described in the opening, this idea that quantum mechanics itself gave rise to a new way of processing information that frankly had never been encountered before. By learning that methodology, the theory of quantum mechanics and its application to information theory, I became, well, I found myself in this new field that we now call quantum science and technology.

Working at the Department of Energy's Oak Ridge National Laboratory, I'm translating those ideas over into what we consider our mission of scientific discovery and energy innovation. This is all to say that quantum information science can enable new platforms for computing that are well beyond what's possible with today's current high-performance computing technology. And the crux of it is that the quantum mechanical models that we use in many of our scientific problems map intrinsically into this new paradigm of computation that we call quantum computing. So my role effectively is to try to figure that out. How do we actually take problems like chemistry and solve them on a quantum computer in a way that will enable us to discover new catalysts, perhaps better sources of energy, and then ultimately lead to new innovations that can translate out to benefit the greater of society?

Rashmi Mohan: Thank you. That's actually super helpful. I do have a follow-up question though, Travis, which is, is it a natural transition? So folks that are working in, say, theoretical chemistry as you were, is there enough of cross-pollination where they see that natural transition or did you have like a mentor or a certain opportunity that sparked that light bulb moment?

Travis Humble: Certainly in the early days of the field, there were no well-established pathways into quantum information science. A lot of people like myself were migrants from other disciplines, chemistry, material science, quantum physics, even computer science. What we have done since then is create a new community, a place where all of those different disciplines and backgrounds mixed together, and this is the foundation of quantum information science and technology. In that process and in partly in the recognition for the significance of the impact of this field, we are now establishing pipelines so that our next generation of scientists and engineers can have a more direct path into the discipline. So this includes even starting as young as primary school or high school, we do a lot of activities these days making people aware of what quantum science and technology are, demystifying the aspects of quantum computing and other things.

But of course, it's not until you get into college and post-college education that you start to dig deeper into the technology, the quantum mechanics background, the electrical engineering requirements, the computational theory that underpins it all. And of course, these days, there's many investments in the area that's created an entire new workforce and job market for experts with backgrounds in these ideas. So certainly for myself and probably a whole generation of people early in the field, it was difficult transitioning over into this new discipline. But we have now created an ecosystem that is very open and welcoming and frankly searching for eligible applicants that can participate because there's a very high demand for this skill set.

Rashmi Mohan: Great, thank you. I'll definitely want to tap into that a little bit later, but to go to one of the points that you brought up, I mean, especially when you talk about introducing the concepts of quantum information science in early years to pick the interest of young minds, I would love for it if you could maybe just give a very short introduction to what is quantum computing? How is it different from the computing that we know of in terms of software engineering or hardware engineering as we do today?

Travis Humble: Oh, absolutely. Conventional computing or classical computing as we often refer to it, is largely based on binary representations of information. We typically refer to these as bits, zeros and ones, that make up our digital world. The information age was established by being able to control and manipulate digital information through things like microprocessors, communication systems, and a lot of that technology was actually based on semiconductor fabrication processes and ultimately semiconductors as materials. But the principles of conventional computing are entirely based on classical logic. So the types of binary decisions that we typically make or the binary programs that we typically execute, they are familiar from a classical logical representation.

Quantum computing changes that paradigm. Quantum computing says if I create technology that's based on materials and processes that are fundamentally quantum mechanical, I get an entirely new set of rules for how logic itself behaves. So I no longer talk about bits per se. Instead, I refer to qubits or quantum bits, which are actually superpositions of binary outcomes. So if you can think of something as being either up and down simultaneously, then you're starting to understand what quantum mechanics offers here. The ability to create superpositions of logical states actually represents a foundational capability that does not exist within our classical paradigm. And taking advantage of that has been for the last 40, 50, 60 years, a primary focus of the discipline.

What does superposition and other concepts like teleportation or entanglement, what do these features provide us is a computational model. It turns out that there are many different ways to use those resources, both for speeding up algorithms and a time to solution to solve very challenging calculations, as well as reducing the amount of energy or complexity that goes into representing those types of problems. So for all of these reasons, this foundational shift in the representation of logic using quantum mechanics has led rise to this revolutionary field that we now call quantum computing.

Rashmi Mohan: Got it. That was an extremely lucid description. Thank you so much, Travis. That's very helpful. So is it then that there are certain applications of quantum computing that are more natural? I mean, I've heard different theories. I did a little bit of research both on your own work as well as just the field before we got into this conversation. One that says quantum computing, especially in certain use cases, can be tens of thousands of times more efficient than say a classical computer. And then, there's another, I would say diverging thought that believes that they are actually complementary, quantum computers will never replace classical computers, but will actually work in tandem and help enhance what we can possibly do with what we know of as classical computers today. So I was just wondering how do you see these two theories and do you think both of them have some validity?

Travis Humble: I think you're exactly right. There's actually a duality right now going on in the development of this field. One I would consider to be largely on the algorithms and applications perspective, and others might refer to this as the use case. That's a nice theory that we've created around quantum computers, but what are they actually good for? And it turns out that many of the types of speed-ups that we would anticipate by using the quantum computational model directly apply to things like modeling and simulation of physical processes. So for me, having a background in chemistry, some of the most challenging problems there are understanding how atoms and molecules come together and undergo transformations, chemical reactions. They're incredibly energetic from the molecules' perspective, often very complex in terms of the physical processes that are underway.

But quantum computers are a native representation of those complex processes that make them, one, much more efficient in terms of memory and storage of the model, more efficient in terms of the execution of a program to calculate the outcome of the reaction, and then more efficient in the understanding of what's actually occurring. In some ways, you have a digital twin of a chemical reaction that you can directly probe and ask questions to, but this use case perspective isn't very separate from the technology development perspective, the other part of this dual. There, the question is how do we take a fundamentally new physical process, whether it's based on a type of material that encodes quantum mechanics or maybe individual atoms or even photons, all of these are technologies that can be considered here, how do we translate that into our existing paradigm of computation?

I don't think that as a society, we should anticipate wiping the slate clean and replacing the digital age with the quantum age. One, that's very costly and expensive and honestly probably very ineffective because a lot of the things that we are currently doing with information technology, we're doing relatively well. But there are key challenge areas where quantum computing technologies can make enormous advances so the integration of quantum technology with our conventional infrastructure is a pressing challenge. You mentioned two strategies for this. One is consider quantum in isolation. Yes, it'll have conventional control systems and interfaces for input-output relationships, but it's not really part of the gang. It's going to stand alone and it'll solve our hardest problems whenever we need it to. Conversely, you could imagine it being a full-fledged member of our entire computing ecosystem where every problem that we run, whether it's on a CPU, a GPU, or what we call a QPU, a quantum processing unit, it's all integrated together tightly.

At the moment, the first paradigm is far easier to engineer. Doing things in isolation gives experimentalists the ability to tweak and tune and optimize performance. But over the long term, I do anticipate seeing the migration of the technology from a standalone isolated component to being fully integrated into our existing ecosystem. Now, how that actually plays out is a big research question and one that I'm looking forward to seeing the answer to.

Rashmi Mohan: Wonderful. Thank you so much. That actually clarified so much to me as well. So as your lab right now, Travis, what are your main goals? Are you in that first paradigm where you're still working within the realm of quantum computing and as you mentioned, isolation and trying to say, "Hey, what kind of problems can I solve using this technology?" Or are you also looking at what does this mean for me to actually go towards that vision of being this integrated environment with both classical computing and quantum computing?

Travis Humble: Rashmi, it's absolutely a mixture of the two because there are benefits in both paradigms, the former providing this singular focused attention on the problem of quantum computing itself. It's essential for us to understand what are the best methods, the tools, the technology, the use cases that are going to be impactful in the long term. Here within the United States, we have a national quantum initiative specifically focused on this, developing the research, the fundamental research that's necessary to make strides in our understanding of those capabilities. But at the same time as those capabilities are coming into focus, we don't want to wait to transition them into being useful.

And so, again, as part of the research that we are doing, both at Oak Ridge National Laboratory and at many places around the country, the transition of fundamental science in quantum computing into real-world applications is a priority. Now, I should say that we don't do this in isolation here at Oak Ridge. We actually work with many partners all around the country. Some of these are industry partners, people who are building quantum computing hardware and are trying to scale it up to the sizes that will be necessary for solving real-world problems, as well as other people developing use cases and applications. Here, they are actually coming to Oak Ridge to work with us, partner with us on testing those applications on these quantum computers today.

One of the unique features about the laboratory where I work is that we also have one of the world's fastest supercomputers. It's actually called the Frontier System, and it is a largely GPU-based accelerated computing platform. So when I think about integration, what I'm actually thinking about is how do I take high-performance computing, which is the best-in-class resources we have available today, and use its unique features in tandem with these new capabilities we see are coming from quantum computers. And that's the integration paradigm that we're pursuing, the connection between the novelty of quantum computing, especially for modeling and simulation, optimization, numerical analysis, as well as just the raw computational power that you get from HPC. Putting those two pieces together are actually the best of both worlds and immediately focus on this transition of the technology.

Rashmi Mohan: I think that's wonderful. I mean, I think the idea of both you working with industry partners to say, "Hey, as new hardware is being developed, how do you incorporate that? How do you almost test and benchmark that in your laboratory?" But also encouraging external researchers to actually participate or work with you to say, "Hey, what are the possibilities of working in this domain?" How does one engage with your lab, Travis? I'm just curious, is there a call for participation or what is the process saying, "Hey, I'm interested in this field. I think I may have a possible theory that I want to experiment with, but I don't have the resources to be able to do it?"

Travis Humble: Oh, absolutely. Within Oak Ridge, we have the Oak Ridge Leadership Computing facility. This is actually a facility that is sponsored by the Department of Energy and its purpose is to provide access to users from around the world to the greatest computational resources that are available. And as we were talking earlier, a lot of this mission has focused around high performance computing, the Frontier System, and there is a robust user program through which people can request access. Over the last, I guess, seven to eight years, at Oak Ridge, we have included in that now something we call the Quantum Computing User Program. People lovingly refer to this as QCUP, but it is a program in which people can request access to some of the quantum computing resources that we have available for testing and evaluation of their ideas.

I will mention that it is a merit-based program. We are looking for the highest quality research that can possibly be done on these systems entirely because we want to provide feedback both to the people making the systems as well as the broader public on what's the potential of quantum computing, where is it at today, and where do we think that it's headed in the near term. So if they go to olcf.gov, they'll find the website for the facility and navigating through those web pages, you can find the Quantum Computing User Program in the application process.

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Wonderful, and we'll definitely provide the details of that in our notes as well. Have you found that through this program, one is how long has this been around, but have you found that through that, you've gotten leads of unique applications or use cases as we may call them, that are showing promise?

Travis Humble: Oh, absolutely. I mean, in fact, this is one of the most exciting things about the program. After seven to eight years of operations, we can actually see a trend in the types of problems and even the sizes of problems that people are able to solve on quantum computers. And what I'll say is that when things first started out, everybody was a little unsure about what they were doing. The qubits we were talking about earlier actually can be a measure of complexity of these problems, and frankly, people were working on maybe four or five qubits maximum. The hardware itself was at a stage where that was a good match. There were few hardware systems going beyond 10 or 12 qubits at the time. But over the last seven years, we've watched a steady progress both in the growth and quality of the hardware, many more qubits available these days, much higher fidelities or accuracy on the devices themselves. And concurrently, we have seen the user community taking advantage of that, building out better algorithms and applications.

I'll give you one example of this. One of the areas that we care a lot about is material simulation, and we happen to know that on our best high-performance computers, there are limits to how accurate we can simulate certain classes of materials. Frankly, what's happening is that the memory requirements for an accurate model and simulation of those materials far exceed what's available even on a supercomputer. But on a quantum computer, which intrinsically can represent these models, there's a drastic reduction in memory requirements. And so, by the time you get to 50 or 100 qubits, you're actually competitive with world-class scientific computing systems in your modeling of materials.

So we have watched a steady progress, people picking which material problems seem to be a best match for this paradigm, as well as ones that do not. I mean, that's another good feedback is what are things we shouldn't be solving on quantum computers because we've already found a good answer. But I am anticipating over the next five to seven years, this will explode even further, again, as we increase the population of people that have access to the technology, understand what to do with it, and create more of these algorithms and applications.

Rashmi Mohan: Okay. I'm going to ask you a question about this, Travis. If we take this example further in terms of simulating material science or actual materials and you're trying to understand the composition of them, what would you do with that? Supposing quantum computing is a great fit for that sort of a research problem. And what do you discover through that process, and can you give an example of where that would actually be applicable in, say, the real world?

Travis Humble: Yeah, there's a couple of good examples out there that I think make very good descriptions of how disruptive quantum computing will be, and I'll use one that I think few people have heard about. It is based around a complex chemical calculation. Basically there within the environment, the natural environment, there are certain types of bacteria which are capable of converting nitrogen into ammonia. So this chemical reaction, nitrogen fixation actually takes nitrogen out of the atmosphere and can convert it into ammonia. Ammonia is an essential quantity for the stability of the environment as well as an essential fertilizer for growing crops and food.

Now, it turns out that our best-known artificial process for creating ammonia from nitrogen fixation is the Haber-Bosch process, which is actually incredibly expensive in terms of energy, pressure, and temperature. So in order to supply enough ammonia to sustain the world's food supply, the Haber-Bosch process consumes close to 5% of our natural gas supplies every year just to create ammonia that then goes into the food chain. If we could understand that chemical reaction that bacteria are doing at room temperature and standard pressure buried underground, we could make remarkable breakthroughs in the ability to synthesize this essential chemical, ammonia, that could then have an immediate impact on our ability for food security, addressing, of course, the concern about hunger across the world by enabling less expensive and greater access to fertilizer. So what's essential in this story is that the complexity of that chemical calculation is probably something that a quantum computer would be able to model and simulate efficiently, whereas our best high-performance computing methods are struggling with this because of the complexity of the energy and timescales that are involved.

Rashmi Mohan: Amazing. That was an excellent example. Thank you so much. It really helps put that entire journey together, where that research begins, how it could potentially be applied. You do read when you look at like, "Hey, what are the applications for a layperson and quantum computing you talk about?" You often hear drug discovery in pharmaceuticals and energy. I know that's one of the areas that you work on as well, but this was very real and really helps us visualize that entire journey. So thank you for that.

I have a follow-up question, but it's more in terms of often you hear or there seem to be a lot of the popular cloud providers are now offering quantum cloud infrastructure. How widely is that used today? Do you feel like there is actually a market out there where people are similar to what you were saying, where you have a very specific program where you're asking for researchers to come in and experiment on your systems? Do you think that people are actually paying for this quantum cloud infrastructure and actually leveraging or using it in a meaningful way?

Travis Humble: Yeah, so there are commercial cloud-based systems for providing access, and some of this is like third-party reseller access to the quantum computing vendors. Other are quantum computing vendors establishing their own cloud platforms. In all those cases, we'll just refer to these as the cloud access platforms. And I think that those are incredibly valuable. In fact, I think they're an essential component of this journey from the early fundamental science that we're doing in quantum computing to these real-world applications that we know are going to have impact. And the reason for this is that right now the technology behind quantum computing is fairly sophisticated and in a certain way, very sensitive. Here, what I mean by sensitive is that the requirements for the environmental controls, think of the temperature or the electromagnetics, even the cooling, the cryogenic cooling there brings with it power consumption requirements, stability requirements, vibrations, all of these things give you the feeling of being in an experimental physics lab.

And there is a lot of progress at the moment in trying to transition those technologies out of the experimental physics lab into a real-world setting like a data center where they could undergo sustained operation. While we're going through that process though, being able to get people on the systems today has enormous value for the discovery and development of these applications before the technology itself hits this high readiness level. In addition, there is also an essential component that goes beyond just the research itself, and that is this educational and workforce development aspect. Many people need to understand what quantum can do before we all understand what its impacts will be on society. To do that, we have to have an in-depth education campaign in which people basically get access to quantum computers so they understand what this word really means, what it's capable of, and in many instances can provide insights into what it can be used for. I think the cloud access platforms right now serve an incredibly important role in enabling that type of education as well as the research and discovery that we were just talking about.

Rashmi Mohan: Got it. I mean, two parts to that follow-up question. One is it cost prohibitive at this point for somebody to be able to say, "Hey, yeah, I want to actually use this infrastructure and try out a few things?"

Travis Humble: So I think the cost for using the cloud systems, it's going to depend a lot on your own budget and what it is you're trying to accomplish. What I have seen is that many of the providers will actually have trial platforms or trial services or periods, partly because it is a new technology and understanding whether or not it is the right approach for your own personal research or education is something that we're all trying to figure out. So I have found that they are really generally very flexible and open to conversations around these services. And in addition to that, we're all looking for feedback on what would be the best way to provide these services.

Here at Oak Ridge, the user program that we have, we've recognized that every time we add a new technology, there needs to be an orientation, a training campaign, even for people with PhDs and expertise of many years, these technologies are oftentimes unfamiliar and require a high level of commitment in order to bring down the barrier for their use. So I think all of these reasons make it entirely cost-effective given certain missions in the research and education space, and of course the flexibility of the vendors to work with people on this.

Rashmi Mohan: Got it. Okay. Yeah, that makes a lot of sense. And then to your second point around education, as this technology is more widely available, especially when through our cloud providers, do you also see that we are actually getting into colleges, universities, and schools and having, I mean, is our curriculum catching up with the pace at which this technology is moving? Are we encouraging younger folks to actually experiment, learn more about the field? Do you feel like there's enough movement in that direction?

Travis Humble: I feel like we are doing a fairly good job of trying to get these things in order. What I will say is far more phenomenal to me is the demand for us to do this. A bit like you were talking about in your opening, with the example of teleportation, when people hear about this technology, they want to know more. It is one of the most discussed topics in colleges and universities. We are getting inquiries all the time from people asking for introductions, asking for ways to onboard or orient themselves with this, both from a student perspective, but also from a teacher and professor perspective where they are trying to capture on this new possibility as well.

We were talking about the curriculum and the multidisciplinary aspect of it, that this is a migration of many different fields into a new area. Some of that are things like physics and material science, engineering, computer science, mathematics. The convergence of all of those, actually there takes a little bit of sorting to understand who is responsible for what. Something that I have seen emerge over time is that physics departments are now becoming much more strongly focused around the information science, quantum information science of materials and atoms and photons, how do we build the technology, whereas computer science and electrical engineering departments are getting more focused around the device level, the system level, and then some of the tools that will be required for this infrastructure, think of programming languages, compilers or debuggers.

And then, of course, there's many other disciplines that are asking, "Well, how can I make good use of this technology and this infrastructure?" So the complexity here is that it is a multifaceted field where there are many different stakeholders from traditional disciplines that have a hold on it, and as we organize and coordinate across all of these, we're learning exactly what a curriculum looks like that can meet the demand that we're seeing from these many different places.

Rashmi Mohan: That's very encouraging and exciting as well to see that this could be a burgeoning field for a lot of young folks in computing to actually pursue. What would you say, Travis, are the challenges today that you see within your world, whether it is in the world of quantum computing or specifically in the lab that you run? What's holding us back from more say either widespread adoption or are we at an inflection point where we're seeing significant change?

Travis Humble: I do think that we are coming close to this inflection point where quantum technology is going to shift its balance so that it is a little more even-footed across the fundamental research space and the applied or application space. What is happening is that the technology is becoming more sophisticated, its availability is increasing, the workforce that is trained and ready to use it is increasing. We're seeing a lot of investment both from governments including the United States as well as public and private industries to encourage the development of these applications.

There are some crucial tests for this. I was mentioning one earlier about the comparison between quantum technology and our conventional approaches. There's a lot of talks around benchmarking or demonstrating what we call quantum advantage, where you prove that the quantum computer itself is doing something that you could not have done by any other means. Those types of inflection points will lead, I think, to a burst of activity. What is probably the most critical thing to take into consideration is that quantum computing is not developing in isolation. So at the same time, we are pushing forward this agenda of quantum technology, there is of course a revolution going on in artificial intelligence, there are innovations that are happening in microelectronics, and then of course the usual demands of how society is always asking for more information and better connectivity.

So these things working together are probably far more essential to me than how quantum computing will thrive and operate on its own, because I think in the long term, it's the integration of all of these activities. What I'm not seeing at the moment, and this is partly because I think it's only becoming clear now that we need it, is how do we integrate quantum with all the other innovations that are happening in the computer science space. There's been less attention paid to that as we get quantum standing on its own two feet. But now as this balance is shifting and we're becoming more mature as a field, I think there is an opportunity for us going forward to think about how computing at large with all of these different topics can advance and evolve into the future.

Rashmi Mohan: Yeah, I think that makes a lot of sense, Travis. Are there any specific metrics that you think or indicators that you're measuring or looking for? Is it that quantum computing will help us with speed or accuracy or a more secure environment, other than the fact that it'll actually solve problems that say today's classical computing or high-performance computing cannot? I'm wondering how do you measure that progress?

Travis Humble: Well, Rashmi, I think you actually captured most of them. Time to solution will always be an important metric for our evaluation of these technologies. We're partly hoping that quantum computers will get us answers faster, that we won't have to wait around as long if we're trying to perform an optimization of a large data set or trying to simulate a chemical reaction to give us insight to drug discovery. So they can definitely decrease time to solution. Correspondingly, better accuracy in the calculations themselves as well as the expanse of models that we can now explore, that we could not explore previously. I think those are also very good ones.

But one that most people have not yet paid attention to, which I do think is very promising, is the energy consumption of these technologies relative to their conventional counterparts. Even if we were not to do things any faster or improve the models with which we are calculating, or even the accuracy with which we're calculating, quantum computing fundamentally is moving the smallest quantity of matter in order to perform these calculations, and consequently using the smallest amount of energy for those calculations.

So an enormous boon from the quantum computing field that I think will eventually emerge is the impact that it has on power consumption and energy efficiency for computation. I don't, again, imagine that we're going to replace all of our current computers with quantum computers, but there may be things that we're doing now that are very energy intensive, think about machine learning or artificial intelligence, where quantum computing could reduce the energy cost, and that would have a profound effect, not only on the transition of the technology, but also on the forecast that we have for these other areas.

Rashmi Mohan: That's very promising, Travis, thank you for going into that in depth. For our final bite, I would love to ask you, what are you most excited about in your work or in this field, and how far are we from teleportation of humans?

Travis Humble: So I'll answer the last one first. I think teleporting humans is still quite a ways off. It's not even really very well-defined how we would accomplish that at the moment. We are still getting our hands around teleporting the states of atoms and molecules, so be patient on this, but those early steps are already having profound impacts, and I think this is what excites me the most is that quantum computing is a revolution in technology, both in the conceptual understanding of what it means to be within this universe and have access to quantum mechanics, what we can do with that, but it is also extending the frontiers of computation beyond anything that we thought existed before. And that I know will have a long-term impact for centuries, and that is very exciting to be working today on a field of technology and science that will last well beyond my time and into the future that can be an important enabler for what we as a society are trying to accomplish, and then hopefully end up making the world a better place.

Rashmi Mohan: Fantastic. Travis, thank you so much for giving us a glimpse into the future and taking the time to speak with us at ACM Bytecast.

Travis Humble: Thank you, Rashmi.

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