Is the Space Industry Ready for Quantum?

Speaker: Kelly Backes, Lead Quantum Physicist, MITRE – 18 minutes

John Gilroy: Welcome to Constellations, a podcast from Kratos. My name is John Gilroy and I'll be your moderator. On this episode, we'll explore how quantum technology is moving rapidly from theory to practical application with the potential to transform everything from cybersecurity and sensing to satellite communications and navigation. In this episode of Constellations, Dr. Kelly Backes of MITRE joins us to discuss why Space ISAC launched its quantum community of interest, how the space industry can prepare for the quantum era, and which emerging technologies are poised to have the greatest impact on the security and resilience of future space systems.

Kelly, that's a lot to go. Want to jump in real quick here?

Kelly Backes: Yeah, I'm excited to be here. Thank you for having me to talk about the Space ISAC and its quantum community of interest. This is a very interesting time in Quantum and a great time to start having these conversations.

John Gilroy: Yeah, good, good. Yeah. So, let's begin with this. You mentioned Space ISAC. Space ISAC recently launched its quantum community of interest. So, what prompted the organization to make quantum a strategic priority now and what gaps is the community trying to address?

Kelly Backes: So, really quantum is no longer this far off research topic that's destined to remain in the realm of the laboratory forever. And this is the right time for this community to start thinking about quantum for a few reasons. One, space systems are built on long timelines. They operate in unforgiving environments and they have to be resilient. So, while this technology is still emerging, it makes sense to start thinking about it now so that we can insert it as it's ready. And as I kind of said, in space, we don't really have the luxury of waiting until something's fully mature before we start paying attention.

The satellites and supporting systems are designed, procured, launched, and operated on these long timelines. So, if a class of technologies could start to matter in say five, 10 years, the planning window is now. And I realized that I kind of immediately went down the flashy, the fun aspect of timing and logistics of inserting this emerging technology into the planning pipeline. But the time is also right to think about the impacts that these technologies are going to have. There is a push for more resilient operations in contested, congested, and degraded environments.

There's a growing need for better timing and more precise sensing. Sensing is really my area of interest and expertise, and I see that as having a lot of impact in the space domain. And then there's the reality that quantum is developing very quickly and there's a lot of noise, and it's time to start engaging with leaders in the space community to help them separate what's real, what capabilities are going to be impactful, and what is just that noise.

John Gilroy: So, Kelly, it's the middle of summer here in Virginia and you're at a barbecue or something, a cookout, someone says quantum. And when people hear that word, they only think of quantum computing. So, what are the most important quantum technologies? You mentioned sensing or communication, timing. Which of the most important ones, the space professionals, should they be paying attention to now?

Kelly Backes: Yeah, so I'm going to kind of start this on what sounds like a tangent, but I swear it is related. One of the most important things for the community to understand is that quantum is not just one thing and specifically, it's not on one development timeline. So, as you said, when people hear the word quantum, they often jump straight to quantum computing, and that's understandable because it gets so much attention and there's so much fantastic research being done in that space. But quantum covers a huge set of technologies, and this huge set of technologies is at very different stages of maturity.

So, not every technology that we're talking about is going to be decades in the future where some of the more far off research-based technologies are. Some already exist and have existed for so long, we forget that they're "quantum technologies." And so, a great example of this are atomic clocks, which are fundamentally quantum, but they've been around for decades and they've been in space since the 1960s and integrated into GPS since the '70s. So, that's an example of a place where quantum technologies have been already having impact for decades.

John Gilroy: Kelly, earlier you mentioned resilience. So, how do you see quantum technologies strengthening the security and resilience of space systems over the next decade?

Kelly Backes: So, one place where resilience is really important in the space domain is in the world of PNT, and sensing is very important here. So, if you can improve the inertial navigation, the state awareness, and the onboard measurement quality, then you end up being less vulnerable to external inputs. And so, in say a GPS night environment, this becomes really important. And as I mentioned, atomic locks have been used in space for a very long time. And the next generation of atomic locks, which give you that time holdover for longer and longer are starting to look like they could be deployed in the near future. And that's a very concrete, very timely example of resilience in the space domain.

Another aspect of it is quantum sensors can be incredibly nimble. You end up with these small systems that don't have to be tailor-made to sense specific signals. Quantum sensors can use the wacky properties of quantum mechanics to offer wider bandwidth or more tunable devices where you can really start using, and then I'm going to backtrack this in just a moment, but you can imagine using this wide bandwidth or high tuneability to be able to perform many more sensing tasks with just one sensor. And that adds to resiliency because say you proliferate a bunch of these little quantum sensors that can offer this wide tuneability.

As things change, as you need to do more, you can just retask the sensors you already have rather than having front-end sensors that are specifically designed for specific signals or specific frequency bands. And I said that I was going to backtrack this to make a really important point in misconceptions about quantum. I was dangerously close to saying something that is in line with one of my quantum pet peeves, which is people often think that quantum sensors or quantum in general is going to come in and take over everything. We won't need antennas anymore because quantum sensors will do everything. And that's not true.

And what I just said, while it sounds very similar to that, quantum sensors and quantum computers and quantum everything are going to be very impactful in specific niche places. And so, there might be a mission space where you can imagine really wanting a set of proliferated tunable sensors that can react if you lose a few, whatever. But for example, that system's never going to be the best at detecting a signal of interest that you might really care about. So, you have to think about those trade-offs. And then on the computing side, you're never going to have a quantum computer in your home office.

You really want to think about quantum computing and you're not going to use a quantum computer for everything the way you use a regular computer. We really want to think of it more as almost an extension of the way we think of larger servers or places you go for compute power for specific problems. But a quantum computer is not even for large compute problems, a quantum computer is not always going to be the best solution, but where it makes an impact, it will really make that impact.

John Gilroy: It sounds like there's different kinds of quantum applications. So, Kelly, what are the promising near-term applications of quantum for satellite network? PNT, earth observation, maybe space domain awareness?

Kelly Backes: Mm-hmm. Yeah, so I've already hit on P&T a lot, so I'm going to touch on that a little bit more and then try to touch on some of the other applications that you mentioned. So, P&T is one of the strongest and most practical areas to watch. So, I already mentioned clocks improving timing. There are a number of quantum inertial sensors that can provide important complimentary capabilities as with magnetic sensors where you can start doing magnetic navigation. And atomic magnetometers, for example, are a really appealing option for the sensors in a MagNav solution. On the other side, you can also think about generating the maps that you need for magnetic navigation or gravity aided navigation.

So, you're both going to want to use the atomic magnetometer to do the navigation, but to do that, you need to do the mapping. And there are a number of quantum sensors that are promising candidates to also perform the magnetic mapping, and the same is true for gravitational mapping. And this mapping isn't just good for the navigation side of things. They're also earth science and earth monitoring applications and being able to do gravity and magnetic field detection in those environments.

John Gilroy: REBA's going in the industry, there seems to be a lot of hype about quantum here. So, many organizations are still trying to separate hype from reality. So, what misconceptions about quantum do you encounter most often?

Kelly Backes: Yeah, so I already mentioned my favorite one, which is quantum sensors are going to make traditional sensors obsolete, which is absolutely not true and limit the way you think about it because you only think about replacing traditional sensors rather than enabling novel sensing capabilities, which I think is a much more productive discussion. One major misconception about quantum is often the swap question.

When you see quantum sensors right now, because a lot of them, and computer... I keep talking about sensors because that's my area of expertise, but this applies to quantum computers, quantum communication systems, because fundamentally there are two real ways to access quantum states to do the quantum whatever you're trying to do really. You need atoms and lasers to use the quantum states in the atoms, or you need cryogenics to cool your superconductors and use the quantum states there. Both of those, when you look at them in a laboratory or on a bench, what you see is a high power device that doesn't look particularly rugged and does not have a particularly good swap.

But that's because these systems are mid-TRL. We're still tweaking them, we're still figuring out how to work them. But a lot of the parts that go into these systems already have high TRL versions of them. Just because we use a large laser on a bench top now doesn't mean that the eventual deployed version will have to have that same large laser. As I mentioned, atomic clocks have been in space for decades.

Most of the components that you need to build, say a Rydberg atom sensor, which is a popular quantum sensor people talk about, or a nitrogen vacancy diamond sensor, which is one of the promising quantum sensors for magnetic field mapping, those use most of the same components, the same kind of similar lasers, albeit different wavelengths, vapor cells. And so, you can imagine packaging these more novel devices in similar ways to atomic clocks, which have already hit down that packaging and swap question.

John Gilroy: So, Kelly, how important is collaboration between government, commercial industry, and academia? How important is it to accelerate practical quantum capabilities for space?

Kelly Backes: Collaboration between all entities is incredibly important because they all play a different role and they all sit at different spaces in that TRL scale. And if anybody drops the ball on a technology or doesn't come to the table in this collaboration, the technology will never make it out into the field, into the mission. You need academia to take the risks on the new weird idea that a company's not going to pick up because the business case isn't quite there yet. And once academia has proven, "Hey, this thing works and we can use it for the fundamental science that we're using it for, but it starts to look really interesting."

And then organizations like MITRE, where I sit, start looking at those and be like, "Okay, that magnetic field sensor that's in this academic lab, they're using it say for dark matter research, but the signature of this wacky sensor that's being used for dark matter astrophysics, that starts to look pretty similar to these other applications. Could we take that sensor out of the lab, do some of the early work developing it for mission-specific applications, and start making it look more appealing to industry and building that business case to transition to something more manufacturable?" Having the links between all of those stages is very important.

John Gilroy: Let's bounce back to ISAC here. So, do you hope the quantum community of interest will play in helping the industry prepare for the coming quantum era?

Kelly Backes: Yeah, I see the quantum community of interest within Space ISAC is being a very practical bridge between these emerging quantum capabilities and the real needs of the space sector. Because outside, a lot of the folks that are developing these technologies at that early TRL stage aren't intimately aware of what the space community really needs. And I'm coming at this from the side of a quantum technologist who does mission and application-focused design device research.

And I know a lot about space and I know a lot about the space community largely because of engagements like this, but the engagements of the boots on the ground in the space industry are critical to my understanding what the real needs are and what I need to do in the lab or with the staff that work in the labs with me in order to solve the design questions. So, what is the physical environment of being on a satellite like is a really important question. How do you make an exquisite magnetometer, for example, operate in that environment? And how do you do that prototyping in the lab? And then what are the sensing needs that you have to design for? What bandwidth do you target? What signal is most important?

What are the sensing gaps? The academics or the researchers aren't going to be able to answer the questions of what are the sensing gaps? What are the current vulnerabilities? And so, that is where a community like this quantum community of interest can be really important.

John Gilroy: Kelly, when we began this interview, you talked about long-term and some of the things have to be started now for five or 10 years down the road. So, I'm going to put you in the hot seat here and talk about five or 10 years down the road. So, looking ahead, what quantum breakthrough do you think will have the greatest impact on the space industry?

Kelly Backes: Oh, I love questions like this. They make you a lot of friends and they make you a lot of enemies. I'm going to acknowledge the fact that I'm a quantum sensing researcher and therefore I have a lot of bias towards this field. And yeah, if I had to go for one technology, I would go for quantum magnetometers because there are so many applications that they would help address. MagNav, I keep saying MagNav. What I mean by that is magnetic navigation, which has huge potential to impact the GPS denied world. One sensor I would highlight here are quantum magnetometers generally, which I know is a bit of a cheat code because there are many different quantum magnetometers.

You have NV diamond magnetometers, you have traditional atomic magnetometers, and you have my personal favorite squids or superconducting quantum interference devices, because I've done a lot of work with superconducting systems in my career. But quantum magnetometers generally both are higher on the TRL scale compared to other quantum technologies, and they have a long list of potential impacts. You have magnetic navigation, which is one of the very promising GPS-denied navigation. The sensors that I would like to highlight here are quantum magnetometers. And this is a little bit of a cheat because there are so many different types of quantum magnetometers.

There are NV diamond magnetometers, atomic magnetometers, and my personal favorite, which are super conducting quantum interference devices or squids. And I say quantum magnetometers because they're both kind of higher on the TRL scale than some other quantum technologies, and there are a number of applications that they can address. One is use in magnetic navigation, both, as I said, on the mapping and on the navigation side for GPS-denied environments. But also magnetic mapping is important for geoscience applications, for situational awareness applications, for tracking low frequency changes in fields.

So, in general, I would say quantum magnetometry because the TRL and the timing is right to have impact in five to 10 years, and they don't just solve one problem. There are a number of missions where quantum magnetometry could have a big impact. And I will say, again, I'm a little biased because this is a field that I work in.

John Gilroy: Well, Kelly, I think you've given our listeners a better understanding of the space industry and quantum itself. I'd like to thank my guest, Dr. Kelly Backes of MITRE. Thanks, Kelly.

Kelly Backes: Yeah, thank you for having me. This was fun.