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CNAS Event Transcript: "Open Future: The Way Forward on 5G"

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I. Opening Remarks

Ainikki Riikonen: Good morning, everyone, and welcome. My name is Ainikki Riikonen. I'm a research assistant with the Technology and National Security Program here at CNAS. I'm extremely excited to welcome you to today's virtual panel discussion on 5G security, especially on an open interfaces approach for 5G networks.

II. Expert Discussion

Ainikki Riikonen: Today we're joined by four esteemed panelists. Elsa Kania is an adjunct senior fellow on the CNAS technology team and a renowned expert on China's technology innovation. Yuka Koshino is a research fellow for Japanese security and defense policy at the International Institute for Strategic Studies in London. Schuyler Moore is here today in her personal capacity and as a board member of Young Professionals in Foreign Policy. Finally, I'm really pleased to introduce Martijn Rasser, a senior fellow on the CNAS tech team and my co-author on our new report, Open Future: The Way Forward on 5G.

Martijn Rasser: Great. Thank you so much, Ainikki. Good morning, everyone. So great to join Elsa, Yuka, Schuyler and you all for this event. I'm very excited about this report and really looking forward to talking with everyone about what could be a whole new future for 5G in the telecommunications industry. It's very encouraging to see the growing interest in open interfaces. So, you have bills being considered on Capitol Hill. The FCC just announced it would hold a day-long discussion on the topic with technical and subject matter experts from industry and civil society. That's on top of all the work already being done by industry groups, such as the Open RAN Alliance and Open RAN Policy Coalition.

Martijn Rasser: We're going to cover a lot of ground today. I'll focus my remarks now on what I find to be one of the most compelling aspects of open interfaces as an alternative to the current 5G options, which would truly upend the status quo. The focus so far has been on banning Huawei and propping up Ericsson, Nokia, and Samsung, or perhaps even creating the U.S. national champion. But then we're still faced with a very limited pool of vendors, which carries supply chain and security risks and you still have to contend with Chinese industrial policy. What I find so compelling about open interfaces as an alternative is that it directly addresses concerns over untrusted vendors, such as Huawei, as well as tackling the broader inefficiencies of the industry.

Martijn Rasser: Such an approach offers the potential to tackle the 5G dilemma with innovation in a newly competitive industry that would help to lower costs and improve security. In my mind, that's a much more desirable solution than trying to tinker with the current paradigm. So, let me leave it here for now, but looking forward to great discussion. Thank you all for being here.

Ainikki Riikonen: All right. Thanks so much, Martijn for kicking us off. Now I'd like to turn to Schuyler.

Schuyler Moore: Hey, folks, my name is Schuyler Moore. Thank you all for joining us today at CNAS. Thank you so much for having me along. As Ainikki noted earlier, I'm here in my personal capacity and also as a board member of Young Professionals in Foreign Policy. My day job, I'm the director of Science & Technology at the Defense Innovation Board. But again, I'd like to reiterate that any comments that I say today are in my personal capacity, and I do not speak for the Department of Defense. To tack onto what Martijn has said and set the stage for

some of the conversation we'll have today, I'd like to point out a couple of specific use cases that the Department of Defense and writ large societies should be excited about looking at 5G and then also some potential concerns that we'll need to address along the way.

Schuyler Moore: In a military context, there is a huge potential for 5G. I'd like to get a little bit specific because I think it's easy to just say that more things will be connected and that doesn't really mean anything or show you what exactly that's going to do. But there are examples like AR, VR that are going to improve training by leaps and bounds that might be deployed to the edge and out into the field so that you have examples like an F-35 helmet where you can look through your platform or something like a tank where you can be inside and use that virtual realm to be able to look around and have better situational awareness.

Schuyler Moore: And then improving strategic decision-making by an improving real time awareness of each sensor that is out on the battlefield. There are examples like, with smart warehousing, where applied in a military context that you can have improved maintenance, ensuring that you have an understanding of each of your systems and what they'll need moving forward. So, really these use cases suggest to us that this is really a critical area to focus on. Again, as Martijn mentioned, is really going to create a new environment of capability going forward.

Schuyler Moore: Now, that comes with a flip side of challenges, which mostly includes security. 5G is incredible for the fact that it can push volume, speed, and number of end users that are involved in any network. But the number of end users means that there is security risk included and expanded attack surface. So, part of what I'd love to talk about today is about how you mitigate those challenges, how you think about it in the context of these other technologies and enabling methods that will need to be layered on top of 5G virtualization, software-defined networking, network slicing, and others to ensure that we are maximizing our use of this capability while also ensuring that we're doing it in a safe and secure way. Thank you.

Ainikki Riikonen: Thanks so much, Schuyler. It's definitely interesting to watch the Department of Defense as a stakeholder in this space and increasingly a player in it. Thank you. All right. Yuka, I know you've done some interesting work looking at Japan and the UK, so I'd like to turn it over to you.

Yuka Koshino: Hi. Thank you very much, Ainikki. Thank you for having me to speak at this event on a very important topic. Congratulations again for your launch of this report. In my opening remarks, I would like to make some comments about why governments play a greater role in promoting secure and reliable 5G and beyond. Second, why Japanese industries and governments have emerged as an active player to promote an open interfaces model. Thirdly, why collaboration with like-minded allies and technology partners is critical to develop and spread reliable and cost-effective solutions for 5G and even 6G.

Yuka Koshino: Firstly, the government's role in developing and deploying secure and reliable network infrastructure has become ever more important in the 5G era compared to 4G. As Martijn and Schuyler have laid out, 5G is fundamentally different from previous generations because it will connect basically everything from smartphones, automobiles, factories, nuclear plants, or military technologies, and will be the backbone of our everyday economic and social activities. So, security and trust in this infrastructure is ever more important because of the

national security implications. That is why governments have critical roles to play to ensure and promote open competition by trusted vendors in 5G markets.

Yuka Koshino: As the report pointed out, the disruptive nature of the open interface architecture offers opportunities to improve the highly concentrated nature of the existing network market. It is the government's responsibility to step in to offer policy support to foster R&D for open infrastructures, or cooperation with like-minded allies and partners is also going to be very important. Now here, Japan offers a unique case study for the United States as a like-minded country that leveraged this close government and industry relations to promote an open architecture model and to simultaneously restore international competitiveness.

Yuka Koshino: Firstly, like the United States, Japan significantly, currently, lost this global competitiveness after 3G. For 5G for instance, NEC and Fujitsu are two strong domestic equipment suppliers, but their global shares for base stations are less than one percent. However, the government's strategic and economic concerns over the rapid rise and potential dominance of the Chinese digital infrastructure married with the Japanese silicon communications industry's ambitions to restore the global market share through open RAN or the ORAN Alliance. Here, the historical close government-industry relations also played a key role. For instance, for Japanese operators were quick to decide to exclude Chinese equipment vendors from both the public and civil networks by early 2019 and responding to the industry's need for open interfaces.

Yuka Koshino: By 2020, Japan's economic ministry swiftly adopted open architecture as the core strategy for Japan to restore international competitiveness for 5G and 6G. 2020 was also a milestone for the open architecture in Japan to speed up the 5G network deployment using equipment of ORAN specification. The Diet passed laws to give tax breaks with conditions for operators meeting the open requirements. The Ministry of Internal Communications and the economic ministers are also funding, for instance, a total of ¥9 billion to develop systems to assess the interoperability between different vendors under the ORAN specifications. On June 30th, the governments also published a 6G strategy based on the open architecture model.

Yuka Koshino: Finally, I wanted to emphasize that Japan is the most suitable strategic partner for United States to promote the open architecture. These two countries are the technology powers, but lags in the telecommunications markets. Japan is the United States' closest ally with shared geopolitical interests and the visions for free and open Indo-Pacific with shared commitment, for instance, to realizing a global digital economy environment that is open, , and reliable, and secure. It could also leverage existing bilateral coordination mechanisms, such as the Japan-U.S. Strategic Digital Economy Partnership to further discuss these policy areas.

Yuka Koshino: Japan is still struggling to restore its competitiveness in the world, but it made a bold move to make open interfaces as its core strategy for future network. It also expressed interest and willingness to cooperate with other like-minded countries and partners to pursue joint R&D for 5G and beyond. So, for effective bilateral or multilateral cooperation in the longer term, it is critical for the U.S. government to articulate some kind of a national strategy based on these open interfaces. Thank you.

Ainikki Riikonen: Thanks so much, Yuka. I'm glad you brought up bilateral and multilateral approaches because I think that'll be, I agree, that'll be really critical. Also, I hope we can tease out a little

bit on 6G later on in our discussion. So, thank you for bringing that up as well. I'd like to now hand it over to Elsa. I know you've been following developments in China in 5G particularly closely.

Elsa Kania: Thank you. First of all, congratulations on a great and very timely report. I'm really glad to be joining you all to discuss this morning. 5G has been a very lively debate on the policy front because of what is at stake in terms of America's future and the trajectory of the emerging technological competition between the U.S. and China. As we've seen with the COVID-19 pandemic, the demand for 5G and the urgency and importance of progressing in its development and deployment has never been clearer than it is today. It's concerning to me as an American, however, that we're seeing some of the exciting innovations in 5G happening first in China, in some cases, whether that's a Chinese military hospital breaking new ground with a 5G-enabled surgery or some of the ways that the Chinese government have leveraged 5G in the course of the pandemic, such as for 5G-enabled medical robotics to support diagnostics and disinfection.

Elsa Kania: In the aftermath of the pandemic, as the Chinese economy is looking for new sources of growth and its recovery, Xi Jinping has personally highlighted the importance of 5G as among other critical forms of new type infrastructure as a priority agenda for China's development going forward. One of the reasons I'm really excited about this report and the policy recommendations you're proposing is that this focus on a more open approach is a chance to start to change paradigms and start to compete with China by presenting more of a positive and proactive approach that enables alternatives and new ways to work with our allies and partners, and to really leverage and realize the potential of public private partnership in the space through supporting efforts like ORAN Alliance and to have a really American approach to compete when we're seeing such a significant investments and deployments underway in China today.

Elsa Kania: Of course, at the same time, this is a complex global landscape. There's also interestingly a decent amount of collaboration with certain Chinese companies that are involved in these initiatives as well. I think while we try to grapple with the question of how to ensure security from a more systemic perspective, how to hopefully move towards a more measured and coherent approach rather than focusing only or primarily on banning Chinese companies, which is only one step that doesn't really resolve the fundamental challenges at stake in terms of security, thinking about how moving towards an open architecture could be more secure and collaborative, I think is a definitely a topic I'll look forward to discussing. We'll welcome the questions and continued insights from all of you.

Elsa Kania: Certainly, it's quite an important moment to be having these conversations as we're all stuck at home and thinking about what 5G could do for us, whether that's telemedicine, distance learning, or virtual reality to make at home experiences a little bit more lively.

Ainikki Riikonen: All right. Thank you so much, Elsa, for your comments. Speaking of positive, proactive, and a coherent approach, my first question for our panel today is for Martijn. It's—you talked about this briefly—but why open interfaces? In particular, what do you see as the greatest challenges to implementation?

Martijn Rasser: Well, let's actually start with what open interfaces actually are. Now the report has a tech primer that explains the key aspects. But in a nutshell, it means the ability of the equipment

of any vendor to work with that of another. With open interfaces, you can have modular architecture, as Elsa mentioned, for your networks. So that means that an operator can build a network using multiple vendors for a range of offerings rather than being locked in with a single large integrated vendor, which is the situation that we're in now. Part of what makes this possible is using software for functions currently done by proprietary hardware, and that's a process called network virtualization.

Martijn Rasser: In other words, vendors can focus now on parts of the RAN, so that's short for Radio Access Network, and not have to provide a complete solution to be a viable vendor. Now, the common shorthand, which we've already started using for this whole concept is Open RAN. These same attributes also pose some of the biggest challenges to implementation. Right now, the market for RAN equipment is dominated by four companies, Huawei, Ericsson, Nokia, and Samsung. They provide proprietary hardware, such as base stations that don't inter-operate. This means that you're locked into one of these companies as a vendor for large portion, or perhaps even your entire network. That's great business for them, it's not good news for operators. So, there are entrenched business interests in not having Open RAN become a viable option.

Martijn Rasser: The good news though is that operators are eager to break open this market so that they have much greater choice and vendors. This would lead to better and more varied offerings and likely cost savings as well. So, there's growing momentum behind the interest in Open RAN for these very reasons because again, like we point out at numerous points in the report, it really upends that status quo that is causing some problems for us right now.

Ainikki Riikonen: Great, Martijn. Thank you. You mentioned briefly about industry momentum from business interest. My next question is for Schuyler, and it is, what is the role the Department of Defense might play in 5G development? It's an interesting case because it doesn't have business interests in the same way. And then also you had mentioned briefly earlier about increased attack surfaces. Would you say that the department faces unique challenges for 5G security?

Schuyler Moore: Thanks, Ainikki. Sure. I can address both of those pieces. In terms of the role that DOD plays, I think that we're always trying to be careful in making sure that we are collaborating with the commercial sector and not overstepping the bounds of what is realistically the role that we can play. In the current situation, I think it's tied to your second question. Certainly, we have a role in clarifying the risks that exist around security, not only from a national security perspective, but also for any company that's working in this space and would be operating on these networks. And then the second piece I actually think is very interesting in terms of looking forward to 6G and future iterations of 5G, where there may not be a compelling business case right now for companies to really be leaning in and pushing the envelope in terms of research and development for those pieces. Also, certainly there are companies that are doing that.

Schuyler Moore: But DOD can certainly play a role in hosting environments for those companies to try to play in that space or investing money, again, in those very early stage technologies that may not exactly be as heavily invested in currently. So, I think that that's reasonably the role that DOD can play. And then also there are going to be pockets where DOD can push the envelope of application simply because we operate in a very drastic environment where we may unintentionally or intentionally discover technological advances that wouldn't have been

found otherwise simply by virtue of the environment that we're working in. So that's the first piece, I think, of your question.

Schuyler Moore: The second one on the security side is interesting because I think that this ORAN concept is critical in terms of expanding the aperture of vendors who can participate. But I would note that it is certainly not the silver bullet that's going to fix the security issue. Just because they're broken out pieces of the network, does not mean that you're banning Chinese vendors from all of it. I mean, if it's aggregated and modular, you can certainly still have Chinese vendors flooding that and still presenting the same security risk.

Schuyler Moore: Now, I would note that on top of that, there are certain methods that you can take to mitigate some of the concerns. It's things that Martijn mentioned but applying virtualization where you are abstracting above the hardware layer will enable you to have better control over who is using parts of the network for what. Similarly, if you're using software to find networks to abstract above the control plane, you have another element of control that you are able to mitigate who was using the network and for what.

Schuyler Moore: And then there are also just best practices that exists right now in the commercial sector like zero trust architecture that would really become critical in a situation like this, where your attack surface is significantly expanded because of the number of end users that are able to engage with the network. So, what you really need to be able to do is explicitly manage the interface between users, devices, and then pockets of the network that they really need and do not need. So, implementing some sort of best practices that currently exist in the commercial sector, particularly on the DOD side, will be critical.

Schuyler Moore: But DOD can also encourage pockets of the commercial sector that have not yet moved towards that to implement those same best practices. I would note that I think, national security is a really compelling incentive for DOD. I don't know that national security is as compelling as a business case. I think that that's perfectly acceptable and that in our communication to commercial sector, DOD can certainly do a better job and ensure that we are balancing those two items and showing commercial sector of how these best practices will support their operations in the near and long-term. Thanks, Ainikki.

Ainikki Riikonen: It's true. I think it's interesting you mentioned, what is the value of security in private industry. So, interesting to think about some of the cost-benefit analysis versus what we need for national security purposes. I want to tease out a little bit more on collaboration between government and private industry. So, my next question is for Yuka. I'm curious to hear a little bit more about Japan's role in terms of its leadership in 5G deployment using these innovative approaches. And then to anyone else in the panel, what would an open interfaces approach mean for international private sector collaboration or for nation-state multilateral initiatives? So, big two-part question there.

Yuka Koshino: Thank you. Well, there was a very great case study in the report about Rakuten using both U.S. and Japanese technologies on hardware and software. So, Rakuten for instance is leading the trend of interfaces by deploying the rules first end-to-end virtualized network based on ORAN specifications. But I believe that there are two unique factors that allow Japan to become some kind of a test bed for this open interface model. First is that Japan, I would probably say luckily had Rakuten, a disruptive new entrance to this highly dominated Japanese communications market. So, as an e-commerce giant and a previously startup, it's

now a very large company. But it has an investment capacity in R&D to adopt the most advanced network architecture.

- Yuka Koshino: Furthermore, in order for Rakuten to compete with these existing traditional operators, Rakuten had to find innovative and cost-effective solutions to expand market share and to attract mobile subscribers from zero. So, that was one unique factor. The second factor is something that I touched on my opening comment as well, but the historically close government and industry ties, I believe also allowed the government to understand the industry needs to promote open interfaces and to craft strategies and adopt policy measures to support companies to regain the international competitiveness.
- Yuka Koshino: I think one, for the U.S. audiences especially, and also Japan's METI, for instance, is the Ministry of Economic Trade and Industry. This ministry, for instance, is also responsible for crafting industrial policies and policies for international competitiveness of domestic company. So, that's the one unique ministry that Japan has that maybe some other countries does not really have. And then also, maybe the third point is under the Prime Minister Shinzō Abe administration, the government has centralized on its policymaking processes in the current day. So, now there's more interagency coordination in the Japanese government. The close collaboration between the communication ministry and economic ministries probably facilitated Japan's recent policy measures like tax breaks and other R&D efforts.
- Yuka Koshino: What other countries could take away from this example, probably first is that barriers are quite low for non-telecommunications equipment traditional suppliers to enter the mobile network market in an open architecture model. And then maybe second, it would be that close government industry relations would be a key to foster markets for critical technology sectors with national security implications. But I would also just mention that it is still too early to be too optimistic about the open interface models. It remains to be seen if this model in Japan, if Rakuten for instance, could overcome the various hurdles and risks that it has currently facing in deploying 5G. For instance, it has delayed its commercial 5G launch, which was supposed to be in June. So, there are several risks that remains to be seen.
- Ainikki Riikonen: Okay. We'll be watching closely to see how that rollout goes. I do want to open this question up to the rest of the panel, if you have thoughts on what an open interfaces approach might mean for international private sector collaboration or for nation-state multilateral initiatives.
- Elsa Kania: I think one interesting dimension of this will be, how do we think about the role of Chinese companies in the ORAN Alliance. In contrast to Huawei's position on this paradigm, which is decidedly skeptical and not terribly enthusiastic, with good reasons. So Huawei, among the other major companies in the space, would be among those most adversely affected if this ORAN started to gain steam. China Mobile, China Telecom, and China Unicom are all involved in the ORAN Alliance and are also involved in the launch of a new open test and integration center last fall, which is starting to test and experiment with some of these technologies and work towards progress and having a more mature and open architecture that's ready to deploy. So, an interesting question would be on one hand, we're seeing the U.S. State Department under Pompeo promote this Clean Network Initiative that envisions excluding all Chinese companies.
- Elsa Kania: Yet at the same time if we are truly committed to an open approach that would be modular would have the potential for interoperability and would enable multiple vendors to be

involved, then perhaps we should welcome the involvement of these Chinese carriers in the ORAN Alliance so long as this occurs with adequate transparency about the evolution of the standards and the technology, and so long as there's also good governance. It's one of the concerns about Huawei's role, for instance, in 3GPP, as well as other Chinese companies, has been that there's been some allegations of block voting of national interest driving the process, with direction from the Chinese government, rather than a collaboration among industries.

Elsa Kania: In this regard, perhaps the ORAN Alliance could be a test case for whether working with players like China Mobile, and the U.S. government supporting this kind of open industry engagement and collaboration is a viable paradigm going forward and how to ensure that we pay adequate attention to security in the process and open up the field for competition and recognize that there will be some Chinese companies involved, which makes having robust measures, as Schuyler was discussing, to mitigate the security risks at all levels and all layers in the network, all the more critical.

Ainikki Riikonen: Thanks, Elsa. Actually, if you don't mind, I'd like to dig a little bit more into that. You mentioned China Mobile and China Unicom, which I'm thankful for because in 5G world, Huawei is the first that comes to mind. It's known for being vertically integrated in all those proprietary things that open interfaces look to break down. I guess my question is, how compatible is an open interfaces approach with some of China's companies like Huawei or perhaps ZTE? If the U.S. government and Japan push forward and champion this concept, how might the party-state respond? How might this impact some of the politics in standard-setting bodies?

Elsa Kania: These Chinese carriers do appear to be relatively enthusiastic all in all about the ORAN Alliance, at least in terms of their active involvement, I believe. China Mobile is actually one of the founding members and co-chairs its technical steering committee at the moment. I think this does show that the relative monopoly that Huawei has established is not the ideal status quo, even to certain Chinese companies that do want more options, more flexibility, or that believe that this architecture and the design principles informing it, it could be beneficial and worth pursuing and interesting as well that beyond these carriers.

Elsa Kania: Tencent has announced some major investments and is working on 5G open platforms that could have interesting applications in gaming going forward. I think that we could very well see China through the efforts of these companies actually seeking to lead within the ORAN approach as well. That, I think does raise perhaps some concerns from a competitive perspective, or at least does highlight the importance of ensuring adequate transparency and good governance, as I mentioned within the processes through which the standards and foundational technologies for ORAN are being developed, as well as trying to ensure that the United States is active in supporting our own efforts here, including in moving towards more experimentation and deployment.

Elsa Kania: U.S. carriers and American companies are involved in some intriguing and encouraging initiatives on these fronts as well. But yeah, I think that when clearly when Xi Jinping has highlighted that 5G is a priority across the board. We see even cities in China, like Shanghai launching their own 5G action plans and initiatives. I think the U.S. can't assume that we will inherently have an advantage in a more open approach. We could very well see the Chinese

government pivot to promote and invest more heavily if this alternative paradigm appears to be gaining a dominance and prominence relative to Huawei.

Elsa Kania: Of course, I think Huawei continues to be a de facto national champion on many fronts. I think despite some of the recent measures and restrictions, the Chinese government appears to be on track to continue to support it. I have a hard time imagining Huawei going under, even though some of the damage because of its loss of access to the chips and semiconductors, it still relies upon or really below. That's a whole other debate in terms of how to think about the justification and the ramifications of some of those policies, including for American companies. But yeah, I think we definitely can't assume American advantage on any front these days, at least not without sustained investment, not just in the research and development, but also in having a workforce and the engineers, as well as just technical professionals to develop and build and deploy 5G and start to move towards a point where we have enough of the network to start to explore the promising applications of it.

Elsa Kania: I think that beyond the focus on the software here and the virtualization, there still will be places where Chinese companies have the potential advantage. For instance, in the 5G antennas that are still critical, some of the important components to that like gallium, one of the rare earth minerals that's important to that, China has 95 percent of the world's supply on that front. Huawei has a pretty dominant proportion of the patents there and still has a pretty strong position when it comes to these antennas. Yes, I think certainly a combination of focusing on moving towards this open approach, greater virtualization, but also recognizing that we still need to have some of the basics of hardware and infrastructure underlying that, and there may be ... Going forward 5G may not be a single thing, it's more of a marathon than a race.

Elsa Kania: We could very well see multiple approaches and architectures coexisting, including for different applications, inside versus outside, consumer relative to industrial. I wouldn't be surprised to see the Chinese government continue to hedge its bets across different approaches and investments. I think the U.S. government, while moving in this direction, as your reports suggest, should continue to think about the whole range of options that are coming into play with 5G today.

Schuyler Moore: I also can tack onto that. I appreciate all of that, Elsa and, all of the thought that you've given this topic. I have had this conversation before in terms of how critical this conversation is right now about 5G and China's role in it, but also making sure that we don't get tunnel vision on Huawei specifically. And then also, frankly, the broader Chinese industry where this topic is important and these security risks exist, and this potential exists agnostic of the other entities or companies or countries on the other side. Just as Elsa said, this is going to be an iterative process. You're going to have a snapshot of 5G that continues for 10 years and does not iterate, but there will be different versions of this, there will be different players that come onto the field.

Schuyler Moore: Although the new cycle may portray it that way, China does not have a monopoly on security risks. So, the U.S. needs to be aware of the fact that while it is certainly a significant risk, there are others that exist that continue to make this topic very important. So, keeping just an exclusively narrow vision on either a single company or even a single country will be to our detriment in the long-term, I think.

- Ainikki Riikonen: Those are great points, Elsa and Schuyler. Thank you. I just want to thank also our audience who have started sending questions in. If you'll permit me, I have a couple of outstanding questions, but then we'll be turning to those shortly. So, if you have questions for our panel, please feel free to send those in with the Q&A button at the bottom of your screen. In the next couple of minutes or so, if you're on the phone, please go ahead and press star nine if you'd like to raise your hand. Speaking of tunnel vision, actually my next question is for Martijn. Would the elements of an open interfaces approach also benefit other technology areas outside of 5G?
- Martijn Rasser: Yeah, that's a really interesting question, Ainikki. I think the answer is definitely yes, since 5G is going to be an enabler for a whole range of capabilities, self-driving cars, virtual reality, telemedicine, internet of things. So, having greater vendor diversity for telecommunications allows operators to provide better, more varied services. Also, I think because you're ultimately able to provide a more robust secure and resilient 5G infrastructure, you also start building increased trust with users.
- Martijn Rasser: Now, then with that trust, you get confidence to try to use communications networks in new ways that could help companies improve and expand their current offerings, could perhaps create whole new industries. So very similar to what we saw with 4G, where you have companies like YouTube and Google and Netflix and Uber just create whole new business segments. You have the potential for the same thing to happen with 5G. To just touch on some of the themes that Schuyler and Elsa were just touching on, having options and flexibility in how you build and develop your networks, that's going to help a lot for all the downstream capabilities that 5G capabilities will afford. So, on that front, I'm quite bullish that open interfaces can really help accelerate what the true potential of 5G networks could be for our economies and our society.
- Elsa Kania: I will just say quickly that I think this approach has a lot of viability and importance beyond the context of 5G as well. I'd point to the Open Technology Fund, which has been a really great success story in developing and supporting progress and internet freedom technologies to circumvent censorship and surveillance and ensure security. It's produced some really great products that some of us use on a day-to-day basis, like Signal. Yeah, it's been concerning to see, recently, alarm that funding may be being withheld from the Open Technology Fund by the current administration, or that it has not been as robustly supported and able to continue its efforts with this open and open source approach as one would hope, especially given the importance of these technologies, especially to those who are living under repressive regimes and who can rely on and leverage these tools to have a more open and freedom of communication.
- Elsa Kania: Yeah, I hope that this debate on what it means to have a more open approach and open paradigm for technological development can be continued and sustained beyond 5G since there is a lot at stake, when we think about not just a technological competition, but concerns about how to ensure that our values and our principles are consistent with the approaches to technology we're promoting and the alternatives we're trying to advance relative to China's model of cyber sovereignty and a much more closed and proprietary ecosystem that has taken part within the great firewall.
- Ainikki Riikonen: Okay. Thank you both. I have one last question prepared here today. Again, thank you to everyone who's been sending your questions in already. Please feel free to keep sending

those our way. My last question here is, Elsa you had mentioned about 5G enabled medical robotics. Yuka, I think you had mentioned some delays in terms of rollouts. My question is for anyone on the panel. Is the pandemic slowing down the rollout? Is it making it more urgent? What do you see as the way forward in the next couple of years, given the current situation?

Elsa Kania: It seems that the pandemic has been accelerating 5G deployment within China, given the importance the Chinese government has placed on it. I'm concerned that at the same time, we're seeing a slowdown in the U.S. and Europe and elsewhere around the world, just given the extent of the disruption that COVID-19 is causing. But I hope that we can also, given kids are going back to school and so many communities in the United States are still not connected, that kind of connectivity is a basic prerequisite for having access to social services, to education that we here in the United States as well, can really recognize the urgency that comes with this crisis and continue to support as part of the stimulus and otherwise efforts to deploy 5G or even just basic broadband to communities that aren't connected and to upgrade and enhance the resilience of our networks and our critical infrastructure across the board. Given we've seen major power outages, natural disasters, it's not just cyber threats.

Elsa Kania: The real world can be an adversarial environment, especially these days. I hope that as we think about the long-term challenges that are ahead, especially in terms of distance learning in education, the use of virtual reality enabled by 5G and new techniques for more adaptive learning, that greater demand and attention to those applications could be one takeaway from this, as well as, of course, telemedicine, healthcare, rate of remote access to services. These are all really important and impactful applications that can have a tangible impact on people's day-to-day lives.

Martijn Rasser: Yeah, that was well said, Elsa. I would just say the current situation with the pandemic that we're dealing with just underscores how critically important communications networks are. If you're connected, you can do quite well in terms of your day-to-day job functions and keeping in touch with family and so forth. So, this whole crisis that we're in right now really points to how important it is that we make sure that our networks are secure, they are robust and resilient. I think it also points to that whole narrative of this, this race to 5G, this urgency, is ultimately a false narrative. It's a marketing gimmick primarily pushed by Huawei, I think, and done so quite effectively because you could argue that yes, they were ahead in deployments and were prodding other countries to do the same with their equipment.

Martijn Rasser: But when you look at the bigger picture, okay, perhaps a delay of a few months because your personnel isn't able to install certain base stations and antennas and so forth, but to the point that Schuyler raised earlier, this is a long-term iterative process. So, over the course of a decade, does a few months of a delayed base station installation make that much of a difference? Probably not. I think the emphasis should be on making sure that the networks that we're building are indeed the best and the safest that we can possibly put together, and that whole notion of having to rush out and get it first is probably not the best way to look at the issue.

Yuka Koshino: If I may answer this question as well. I think it really depends on the countries, about the impact of the pandemic in terms of 5G rollouts and thinking beyond the 5G. For instance, with countries that have the capability or the technology for network equipment, like Japan,

I think it definitely proved that. I mean, the pandemic has accelerated the virtualization and the need for 5G and even I'm thinking about 6G and beyond. But for other countries that doesn't have these domestic capabilities, or hasn't decided on the supplier vendors, I think the pandemic had turned the countries to shift to domestic health policies. It has certainly delayed their decisions on what kind of equipment and which vendors they want to use for their domestic 5G.

Yuka Koshino: Also, indirectly from the pandemic, I would say there's another calculations that countries now need to make under the increased competition on technology and economic competition between U.S. and China that has heated up during the pandemic and the various sanctions on. For instance, the banning of the tech exports from Taiwan and how that could factor into the actual security of the 5G that the country is trying to deploy. The UK, the country that I'm currently in, is a good example of how it made a decision, but then had to reconsider and go back and do duties assessments. So, I think overall, whether pandemic has accelerated their deployment schedule really depends on the countries.

III. Audience Q&A

Ainikki Riikonen: Wonderful. Thank you. With that, I'm excited to turn over to some of our audience questions here. I'm actually going to put two together for our first one, and this one is for Schuyler. Let's see. This comes from Declan Tidd and he or she asks: From what I understand, 5G frequency waves travel a very short distance, especially in the 24 plus gigahertz range. Additionally, I've seen that these waves have difficulties getting through walls and glass. How will 5G benefit the DOD in battle space theaters, or would it primarily be used for defense infrastructure? And then second, we have a question from Will Mackenzie, similarly on DOD. What approach to spectrum management, for example, spectrum sharing, spectrum reallocation, will best protect DOD missions while meeting growing commercial demands?

Schuyler Moore: Sure, okay. I'll tackle that first one. Thank you, Declan, for your questions. In terms of millimeter wave and its propagation, I think that it's certainly well covered topics. Certainly, there are challenges right now in ensuring that millimeter wave is actually usable in certain contexts. I think of this in a DOD context, but I think it's agnostic of DOD. I think it's writ large as something where millimeter wave should be approached with practical optimism built in with a healthy amount of graceful degradability to other forms of connectivity. So, you pray for clear skies and no people walking in front of your millimeter wave. But you assume that that might happen, and if so, you need to be able to drop down to sub-6, to 4G, to 3G further down. So, I think that DOD certainly takes that seriously in terms of resiliency and ensuring that your systems have connectivity.

Schuyler Moore: Perhaps a rudimentary way of explaining this might be you ideally want to have the connectivity to see a 3D image of a person walking around in a battlespace and understanding what buildings are where, but you will accept a stick figure walking around in a very, very sketched out version of that because that is better than nothing. So, the ability to walk down from network connectivity as needed, depending on what your abilities are, will be a critical piece of that. Now, I would certainly note that this is something that both the commercial sector and DOD is working on. Sub-6 has been saying it for a while now, but sub-6 has been getting pretty crowded and also millimeter wave holds a really exquisite capability. So, I think everyone is really working to get past that propagation issue. But right

now, yes, absolutely that's a significant limit. I think that being practical about the potential and limitations of millimeter wave will be critical.

Schuyler Moore: For the second question, in terms of spectrum management and how DOD thinks about that. Before I speak, I want to make sure that anybody who jumped on the call late, I am speaking in my personal capacity, I am not speaking for the Defense Innovation Board or for DOD. This is simply in my personal understanding of these topics. For spectrum management, I'm sure that folks have seen in the past couple of weeks that there's been agreement opening up about it. A good chunk from three-four to three-five thereabouts of spectrum for sharing. So, I think that for DOD, the debate has been around that question of sharing versus clearing spectrum and moving elsewhere.

Schuyler Moore: I do think that for DOD, some of those operations are systems that operate in subsets are critical to national security. The risks associated with entirely moving them, and the gap in operationality would be dire in many cases. So, the sharing option is certainly something that helps bridge that gap in certain ways. It is by no means a perfect solution, there will continue to be challenges and conversations to be had about how exactly that sharing works because I can fully understand why commercial vendors would maybe balk at the concept of having to share, especially if it means that DOD may have priority and maybe able to just elbow everybody out of the spectrum if they really needed to, whether in terms of geography or time. Again, it's a conversation that needs to continue to be had, but also there are technical solutions that are being worked on that will improve spectrum sharing and limit that elbowing and allow for both users to actually get that comprehensive use of that network without feeling like they're having their toes stepped on.

Ainikki Riikonen: All right. Thank you so much, Schuyler. For the second question, I'm going to, again, pair two together. One comes from Eric Wenger and the other one from Jon Pelson. Eric Wenger asks, we sometimes hear the view that the U.S. government should invest in companies that are incumbent sources of hardware RAN. We believe in said market-based approaches. Opening the RAN interfaces to competition will lower barriers to entry and spark a new wave of innovation. Can the panel offer a view about this view, agree or disagree? And if so, what should governments be doing to level the playing field for the market? Do Prague proposals point the way forward?

Ainikki Riikonen: And then as a pairing question that kind-of counterbalances, Jon Pelson asks that, carriers don't put a lot of leading-edge stuff in their actual field networks. They want vendors with proven reliability, scale, demonstrated cost benefits. Do you think it will take years before ORAN networks are actually deployed by a major carrier and who might lead the way? This question is about you opening the playing fields, but do all companies really want these open and how do we bridge these two?

Martijn Rasser: Well, I'll jump in first and address some of that. First to Eric's question, yeah, I would agree with that. In my opening remarks, I noted that one of the things that I find most interesting about an open interfaces approach is that you step out of that paradigm that we're in now, where you only have a small number of hardware vendors that provide the necessary RAN equipment. What I think would be very beneficial, not just for the United States, but for just the telecommunication sector globally is if you can introduce vendor diversity, and then not be dependent on just an oligopoly for the necessary RAN equipment, that I think is one of the most promising aspects of this whole concept.

- Martijn Rasser: As far as, how long it would take to deploy, I mean, there's lots of Open RAN deployments currently in operation around the world. There are several networks in the United States, there's numerous ones in Europe and South America and in East Asia. The Rakuten deployment is the biggest one so far. The current 4G Rakuten deployment is an Open RAN deployment. Now, Yuka, did mention that the 5G deployment is delayed, so it's still wait and see how well that goes. But there are very good proof points, but I will grant the issue of scalability isn't fully proven yet, although all the signs point that it shouldn't be an issue in terms of actual scaling up these regional networks that are currently in operation. Those same principles should apply to a nationwide network as well.
- Martijn Rasser: Ultimately, I think the timeframe would be in the low single digit years to really understand how feasible it is to do this on a global basis. I would also point to the operators are very interested in seeing this happen. If you look at the membership makeup of the Open RAN Alliance and the Open RAN Policy Coalition, it's Telefonica, AT&T, Verizon. All the major global players are very keen to have options in this market because again, they don't want to be beholden to just a small number of vendors that can provide this type of equipment.
- Ainikki Riikonen: Great. Thank you. All right. My next question is looking further forward. How dependent on 5G standards will 6G be, if it's indeed viable?
- Martijn Rasser: Well, I think the short answer is we don't know yet. Now, there is a lot of interesting work in 6G going on in terms of next generation approaches. The terahertz range for example, is one of the areas that's being looked at. But what 6G will be, that, no one knows yet. I think in the next four to five years, we'll have a better understanding of that. But the actual standard setting for that, we're probably six, seven, eight years out from really understanding what that's all going to look like. But that's a great point because we need to really start thinking strategically now about what Beyond 5G technologies will be.
- Martijn Rasser: Japan is probably the farthest ahead of all the major telecom technology countries. They have a fairly solid Beyond 5G strategy in place with a pretty detailed timeline of what they want to achieve and when. China has announced that they are investing heavily in 6G R&D, although the details are a little scarce. But Finland, the United States, and other countries are doing the same thing. I think what's missing in most cases is that strategic vision, the guidelines that people would need to start thinking about it in particular, because you want to start planning for development and deployment. So, the spectrum issue is going to be key. But even here, the FCC has already made a segment of terahertz spectrum available for U.S. research institutes and to start doing some initial research into what potential 6G technologies could look like.
- Ainikki Riikonen: Thanks, Martijn. Do you guys have any follow-up comments?
- Elsa Kania: Just add to that I will be in a little bit skeptical of talk of 6G when 5G is still at a nascent stage in so many fronts and we have yet to explore or exploit the full potential of 5G. As Martijn mentioned, China's Ministry of Science and Technology has launched a 5G group focused on research and development and exploring that potential, so I think it doesn't hurt to be thinking ahead. If we are looking beyond this decade and further into the future, I think certainly having a, perhaps learning ... For the United States, if we are trying to learn the lessons from our slow start in looking at 5G, certainly we're trying to think ahead about 6G, what that might be and how we might start to position ourselves now to avoid some of

these problems we recurring and make sure we have the spectrum supporting the basic research in a really forward thinking manner and have some of the foundational infrastructure, even just the workforce in place, within that industry is a place to start at the very least.

Elsa Kania: I'm sure we will hear much more about 6G in the years to come. But I think for the time being, keeping the focus on how to ensure that 5G itself is secure and reliable, especially when we've seen the backlash, conspiracy theories, the not-in-my-backyard mentality with some of the new deployments coming out. So I think there's a lot of work to be done in the meantime.

Ainikki Riikonen: All great points. My next question then is the experience that we've had so far ... Oh, sorry, Yuka. Go ahead, go ahead.

Yuka Koshino: Sorry. If I may add about, since Martijn talked about Japan's Beyond 5G strategy on 6G, there are several—of course, we don't know the specifics about the 6G yet—but according to the Japanese strategy that just came out at the end of June, it seems like they're prioritizing the open interfaces, but also technologies that could minimize the power consumption, for instance, or there's some kind of domestic alliances formed by NTT and NEC, for instance, on a technology for an innovative optical wireless network. There's also some points about using the quantum technology. So, probably these are the areas that Japan is aiming to standardize in 6G.

Yuka Koshino: In terms of the timeline, it seems like 2025 is one of the years that Japan wants to set some milestones to showcase their technology. But also, I just wanted to point out that it was very interesting to see the government strategy that really emphasizes the early stage collaboration with international, other like-minded partners. I think one of the challenges right now is that, without a clear government strategy, like Japan, it's probably going to be quite challenging to find ways to seek for joint R&D opportunities.

Martijn Rasser: Yeah, I think that's a great point because if you want to start looking at photonics, for example, as an application in Beyond 5G technologies. So, it would be extremely helpful for like-minded countries to get into alignment on that type of research direction early. The sooner you start figuring out what the core aspects of Beyond 5G looks like, the sooner you can start doing the development work and the standard setting and so forth, which, to Ainikki's point earlier, will hopefully help us avoid a lot of the difficulties that we're facing with 5G today.

Elsa Kania: I would just add that Huawei claims to be spending 20 billion this year on research and development. Certainly, Tencent has major investments as well. Within the United States, ensuring that American companies have incentives to be investing in R&D through measures like tax credits and having U.S. government support for the long-term research going forward, and thinking creatively about how we approach S&T strategy or strategy for innovation that really concentrates across the board on having the talent, having the opportunities available to start looking at some of these options that are more on the horizon is the best way we can compete in the meantime, and ensure that the U.S. is positioned to explore these various options as they start to become more feasible going forward.

- Ainikki Riikonen: What I'm hearing here basically is that timeline and strategy are really important. In the 5G case, we've seen that the U.S. and a lot of other democracies were a little bit slow to acknowledge certain risks and then to offer some alternatives. My next question for the panel is, what lessons can nation-states take going forward to basically avoid doing what we've done just now?
- Schuyler Moore: I can start with perhaps the perspective from DOD and how we've looked at this. I think that there are lessons learned in terms of communication—content and method—out to commercial sector and to the providers to adequately express the concerns that the DOD community has, but then also, again, reaching out and listening to understand what the concerns might be from commercial sector, again, around these security issues, so that you can get ahead of those so that you don't start running down a path and then suddenly hit roadblocks that could have realistically been avoided. I think another really important piece is practical acknowledgement of where technology is and where, again, to your point about timeline, certain technologies may be applied or not.
- Schuyler Moore: A couple of examples of that are millimeter wave, again, to circle back to that previous example, is an exquisite capability that holds a really interesting potential, but is not currently quite ready for prime time, but something that we're definitely working on it in the long-term will have an impact on capability. Similarly, ORAN is something where I think a few folks have touched on this, but its ability to scale right now and how long you have to have those conversations with companies to understand where realistically do you see this going in? When is it going to be deployed? So that you can then back out the requirements for policymaking and certain conversations that you need to have internally in government, will help the process in general. But again, honest assessment of where we are really at...
- [Break in recording.]
- Schuyler Moore: So, you have zero trust architecture as a concept for very specifically managing network security, but there has increasingly been a use of the word zero trust to describe more of a mindset towards broader applications than simply network security. And in the context of supply chain security, I think that certainly holds true, in that you don't want to say that you don't trust anyone in the supply chain, but it's more just that you were assuming everyone... assuming at any point that there may have been a compromise somewhere along that chain. And for that reason, you build in the necessary structures along the entire chain, to ensure that either you can trace where something went wrong, or if something went wrong, then it gets held at the gate, either at the network or within the network, when you're trying to get into the little siloed of pieces of information or data that are critical to you.
- Schuyler Moore: And so I think that in general, it... Almost acceptance of the fact that the supply chain will continue to expand is going to be a critical piece of that, and then mitigating it by ensuring that every single piece, from the hardware to the firmware to the software, you're implementing best practices in terms of security, will do the best that you can to mitigate those challenges that you just described of having these increased numbers of folks coming into an open architecture.
- Martijn Rasser: Yeah, that's a great point. I think in particular, the Cyberspace Solarium Commission, the report that they came out recently has... They've laid out a really comprehensive strategy,

exactly along the lines of what you were talking about. So that may be a good model to look to for these types of issues, as well.

Martijn Rasser: Also, there's an interesting question here about the Sino-Russian relationship on 5G. Elsa, given that you've been writing on the broader bilateral relationship lately, do you have any thoughts, any insight into the particular question that Grant asks?

Elsa Kania: Sure. That is a great question. And the question that Grant has raised is why is Russia seemingly unconcerned about Chinese involvement in their 5G networks. And I guess my response would be, I think that there is some concern from Russian leaders about the growing dominance of Chinese technology, even within Russia's domestic market, and Huawei has been moving into Russia in a big way, especially as they've lost ground and lost access to other markets and other partners. And I think the Russian government probably has a "trust but verify" or "don't trust and verify" mentality on this. There have been complaints from Russian experts about incidents of cyber theft or poor quality of Chinese technology. So I think there is some concern there, and certainly the Sino-Russian relationship is complicated historically, and with the contemporary dimensions of it, but there is a growing emphasis on high-tech cooperation, as my colleague Sam Bendett and I have worked on and tracked over the past couple of years.

Elsa Kania: So, I think we will continue to see a growing engagement on these fronts because there is a mutual benefit and shared imperatives, as both China and Russia have less access to foreign, especially American, technologies and opportunities for engagement. And Huawei, for instance, sees the benefits of hiring Russian engineers and technical specialists, and trying to leverage the talent and expertise, to advance its efforts, and also continuing to promote the deployment of its technologies within Russia. So, I think there's a level of opportunism there. And I think trust is relative, and Moscow may trust Beijing and Chinese technology quite a bit more than they trust the United States.

Elsa Kania: And so, I think that at the end of the day, it's convenience, the opportunity to move into 5G, and perhaps some confidence that Russian cyber security professionals can manage and mitigate those risks.

Ainikki Riikonen: All right. We're starting to wind down. So, I'll just ask one more question and then open it up to the panel for any closing thoughts you might have. So, in our discussion today, we've talked about government-industry relations boosting competitiveness, what it means to have a strategy for technology. And so what do you think are the key, if you had top three key tenets of what U.S. or other democratic leadership can take going forward for technology competition across the board. Martijn, do you have any thoughts on this?

Martijn Rasser: Yeah, absolutely. I think, well, first and foremost, any sound technology needs a clearly articulated vision of what it is you're seeking to achieve. So that should be first and foremost. I think in particular, given the strategic competition we're in, there has to be the realization that there's no effective unilateral approach to technology policy. So really taking a multilateral approach with allies and partners, wherever it makes sense, is the wise choice.

Martijn Rasser: And ultimately, it's a matter of making the right investments. So particularly in the case of the United States, we're still very much coasting on investments in R&D that we made back in the '60s and '70s. If you look at what our economy is based on, semiconductors, the

internet, the global positioning system, these are all investments we made decades ago. And we really have to start thinking about what investments for our future need to be. Things like artificial intelligence and quantum science, genomics.

Martijn Rasser: There's a whole range of issues that we need to pay closer attention to, and not just looking at R&D spending, but looking at human capital, and that's education, but that's also high skilled immigration. Because again, America isn't producing enough science and technology graduates to meet the need. So, we have to be smarter about how we manage our human capital, both within the United States and in cooperation with allies, as well. So just as a few initial thoughts, those would be three priority areas.

Ainikki Riikonen: All right, great. And just in our last minute here, Elsa, Schuyler, and Yuka, do you have any closing thoughts that you'd like to share with our audience today?

Elsa Kania: Let's see, I guess I'd say first that openness can be a competitive advantage, whether we're talking about open approaches to technology or openness to immigration. And I think whether we're thinking about competition or the kind of country we want to be, trying to sustain that openness on many fronts is really critical going forward. And I would add, as well, that I think when we're talking about emerging technologies, these issues can be very, very abstract, and there can be a lot of hype, a lot of alarmism. But I think we really need to draw the connections between the kinds of capabilities we're talking about and the potential for tangible benefits to Americans in their day to day lives.

Elsa Kania: And why do we believe 5G is important? Why do we think it's so critical to progress in AI, and how do we re-center our notion of national security and technology in a way that really centers the security and wellbeing of Americans, the sustained development of our economy, given the criticality of recovery and the depths of the crisis we see ourselves in? And I think the more we can really connect the dots and create buy in and try to create the will to really move forward on these fronts, I hope we can see the positive potential of these technologies in many fronts, whether we're talking about education or healthcare, and compete in a way that is consistent with our principles and values going forward, while keeping security in mind and recognizing the systemic threats that we're seeing, not just from potential adversaries, but in the world around us.

Elsa Kania: And yeah, I try to be optimistic these days, to the extent that's possible, given all that's happening. And I think there is certainly much look ahead to.

Schuyler Moore: Sure. I'll add onto that, just a few comments. So absolutely agree with everything. And I particularly appreciate this conversation because I think that it's going a level beyond what you're buying to how you buy it, which I think is a critical piece of having that holistic conversation about some of this tech. And then as always, with any form of technology and including 5G, the reminder that I would always push out to folks is that it is an enabler. It is not the end goal. And so, I think that Elsa certainly spoke to this, but you have to remember what you were trying to do with it, rather than suddenly just achieving it without having that real idea of how you're implementing it at all.

Yuka Koshino: So, I agree with a lot of the panelists and I think I especially wanted to echo what Martijn mentioned about how unilateral approach will not solve or foster technology developments. And that multilateral cooperation would really be the key. And I also wanted to emphasize

that governments... For instance, open interfaces was an industry-driven initiative, but it's always very important for governments to structure the markets and even to foster competition or free market competition. It's really the government who can help and support policy measures, to foster the open competition in the market. And also, government has a very important role to coordinate with partners in other countries.

Yuka Koshino: And I specifically wanted to emphasize that, although its inclusiveness is going to be the key for the future, not just the 5G, but for anything related with national security, any industry related with national security, including 5G, but also for instance, we have COVID-19 right now. So, these health equipment and anything that relates to national security concerns would be critical for like-minded countries and trusted partners to collaborate and to jointly shape the market structure. So just wanted to add that as my final thoughts.

Ainikki Riikonen: Wonderful. Thank you so much. We're just slightly over time here. Thank you so much, Elsa, Yuka, Schuyler, and Martijn for really enlightening discussion today. I certainly learned a lot, hope our audience did as well. Thank you to everyone for joining us today and for your questions. Stay safe, and we'll look forward to seeing you at our next event. Thank you so much.