ECE Alumni Connections: Reception & Research Talk 2020: Surath Gomis, ECE PhD Candidate

Deepa Kundur: Now I'd like to acknowledge this land on which the University of Toronto operates. For thousands of years, it has been the traditional land of the Huron-Wendat, the Seneca and most recently, the Mississaugas of the Credit River. Today this meeting place is still the home to many Indigenous people from across Turtle Island and we are grateful to have the opportunity to work and learn on this land. Today I'm speaking to you from Anishinabe Mississaugas territory and since we are not all together on campus. I encourage you to visit whose.land/en to learn more about the territory from where you are joining this meeting.

I would also like to take a moment to acknowledge the accessibility needs of our audience. The Faculty of Engineering and the ECE Department have tried to create an accessible space that all attendees can participate in. If you have any access needs that are affecting your ability to participate, please reach out to Laura Brown in a private chat.

Now I'd like to welcome you all to our first virtual ECE Alumni Connections talk. My name is Deepa Kundur and it's my honor and privilege to serve as the Chair of the Edward S. Rogers Sr. Department of Electrical and Computer Engineering, where I'm also a Professor. And one of the things that I have in common with all of you is that I, too, am an alumna of U of T Engineering, specifically ECE. I'm a '93 electrical engineering graduate and received my MASc in '95 and PhD in '99 so I may have met some of you in my capacity as Professor or Chair. But for others joining us here tonight I may have sat beside you in Professor Dmitrevsky's electromagnetics classes in the early 1990s.

As all of you know it's been a challenging year here for students and professors. Since the spring, the faculty has been closely monitoring the data and guidance from the government and public health officials. As a result of this information, the faculty has put a remote access guarantee in place for both the fall and winter terms this year. This means that all U of T Engineering undergraduate and graduate students will be able to complete their academic requirements remotely, regardless of where they are studying. But despite these challenges I've been buoyed by the resiliency of the ECE community. And since this has been a challenging year I wanted to share some of our positive moments the department has experienced over the past couple of months.

Some of you may have seen a recent Heritage Minute featuring ECE's first alumna on your TV and computer screens this October. Elsie MacGill was ECE and Canada's first female electrical engineering graduate and became the world's first female aeronautical engineer. After graduating from ECE in '27 and then pursuing graduate studies in the United States, Elsie returned to Canada during the war, where she became Chief Aeronautical Engineer at the Fort William Plant of Canada Car and Foundry Company in Thunder Bay. The plant was reconfigured during the war to accommodate large scale production of military aircraft and she led the engineering team that produced the Hawker Hurricane fighter. In two years 1450 hurricanes were produced and MacGill had earned the nickname Queen of the Hurricanes. In the one minute video highlights her contributions to the war effort and her pioneering efforts as an

engineer. She continues to inspire current and future Electrical and Computer Engineers to this day, including me.

On another positive front, we've received generous support from our alumni community despite the challenging economic climate. In this fiscal year alone our alumni have designated more than $1 million in gifts to their home department. The H. John McDonald Foundation, committed $900,000 to support ECE student scholarships. This gift honors the legacy of H. J. McDonald, a ‘51 Electrical Engineering alumnus. This includes an emergency COVID-19 bursary for some of our international students to help them to continue their studies uninterrupted by financial impacts related to the global pandemic. This was just one of a number of gifts we received from alumni, many of whom are in this virtual room right now. Thank you for your support and generosity.

We've also had the opportunity to celebrate our alumni, their accomplishments and contributions. Recently at the U of T Engineering Alumni Network Awards we proudly inducted alumnus Alan Lau, Electrical ’9 and MASc ‘92 into the Engineering Hall of Distinction. Alan is CEO and co-founder of Wattpad, the global multi-platform entertainment company, where he leads the company's vision to entertain and connect the world through stories.

And some of you may have had world-renowned control theorist Ted Davison as a professor. He was bestowed U of T Engineering’s highest alumni honor, the Engineering Alumni Medal. Congratulations Professor Davison.

Acknowledging the contributions of our alumni is important so I wanted to take this opportunity to let you know that nominations are open for the 2021 Engineering Alumni Network Awards. If you know of a stellar ECE alumnus at any stage of his or her career, who you think is worthy of consideration for one of these awards, please let me know.

I'm proud of our alumni, our students and our professors who continue to make incredible contributions to our ECE community and to society, despite what are truly unprecedented challenges of late. Thank you all for representing the department so well in all that you do.

Now, without further ado, I'd like to introduce our speaker for this evening, Surath Gomis. Surath Gomis is a PhD candidate in ECE under the supervision of Professors Ted Sargent and Shana Kelley. His research focuses on biomedical diagnostics tools in areas of cell-based therapy in disease detection. He is currently working on a reagentless biosensing platform to detect disease biomarkers for point of care tests and in wearable devices. Surath is an NSERC Vanier Scholar and a UTAA Graduate Scholar and has served as President of the ECE Graduate Students’ Society, as well as a Junior Fellow at Massey College. He is the current Co-Director of Science Rendezvous at the University of Toronto, Canada's foremost public science outreach street festival. Please join me in welcoming Surath Gomis.

Surath Gomis: Thanks Deepa for that great introduction. Let me just share my slides here.

Title slide

Alright. Fantastic. Again, thanks Deepa. And like she said, my name is Surath, I'm a current PhD candidate in ECE. I feel very humbled and honored to be presenting my research here for you, the ECE alumni. I can show you what kind of research we continue to do here at ECE and U of T as well as a lot of the interdisciplinary work that we're doing to solve big challenges like the challenges we see with COVID-19, specifically here for COVID-19 testing.

A rushed response with COVID-19 testing slide

So getting right into things. Thinking back to the start of this year, there was quite a rush to response with COVID-19 testings, and that's fair. This was something that was very unprecedented. We didn't know how to handle it and it led to situations like this; these very long lines. You had to wait outside to get tested to know if you had COVID-19 or not, if you were feeling symptoms. But of course, there's a lot of challenges and there's a lot of issues with this kind of scenario. Obviously the long lines, you don't want to be waiting out for too long. The long wait times in line and also waiting for your results. It's getting cold now and that's going to be a challenge in terms of accessibility to these testing centers, if you have to wait outside for long periods of time. And sometimes when closures get more restrictive, testing capacity goes down, and sometimes these tests can only be done on an appointment basis and only if you're symptomatic. And that's not the greatest solution in the grand scheme of things, because you want everyone to be tested to really know for public health to know what kind of recommendations to make. And finally, there's this kind of idea of, well, okay, if I think I need to go get tested for COVID-19 but I don't really want to be outside and potentially expose myself to individuals who may have COVID-19 or even be in these lines where there could be a lot of hotspots for COVID-19. So that anxiety and all these kind of mental health struggles are also another thing to think about with this rush response to COVID-19.

And, of course, there's the dreaded nasal swab. No one wants to stick this long looking Q-tip up their nose. It's quite uncomfortable, from what I've heard. I've never actually done it myself, but I really would not like to. And it's really all these reasons that dissuade people from getting tested or make it very challenging to get tested.

The long testing supply chain slide

And it's not just issues of uncomfortableness or all these challenges of getting people to get tested, the actual supply chain, as we call it for testing, is a very long process that leads to a lot of delays. So if you think about what we think about testing. You go to the testing center to do your test that's kind of your bubble that's all that collection point there on the left hand side of this plot. But really, the majority of what happens with testing is all along these other points. So there's the transportation of all these tests samples that were taken on the day to a lab, you have to actually process the lab samples in the lab using PCR, so as a molecular based assay, which takes itself quite a long time-- a matter of hours. There's a lot of consumables that you can use for these tests, lots of different reagents. There's other reagents that need to be transported to the collection sites, you have to collect all the data and give it back to the users. In general, I think you can understand that there is a lot of bottlenecks with this method of testing. With the transport and the processing and also thinking about on the global scale of things.

Canada has to bid for how many swabs and how many chemical reagents we can get, compared to other countries, who also need it and all of this leads to these inefficiencies with our current testing strategy.

Dream device for pandemic readiness slide

So what would be the solution to all of this? What kind of dream device could we see to be ready for a pandemic and to continue using as we go along this year? We want something that's rapid so you can get your results really quickly. We want it to be non invasive so there's greater accessibility to all individuals who need to take the test and to keep it so it's comfortable to do and we want to do it on demand. It's kind of this idea of decentralizing testing. Rather than going to the testing facility, going to the hospital, if you can do it yourself, bring back agency to the user themselves to do the test, know the result right away, don't have that stress about what the result will be. These are all different conditions that would make for this dream device.

Our response to COVID-19 started 10 years ago slide

And thinking about the dream device, I use the saying, kind of jokingly, but our response as a lab to COVID-19 kind of did start 10 years ago in the sense that our lab, we've been focusing on by medical diagnostics to try to solve these kind of rapid point of care tools for a very long time. Us as engineers, scientists and actually, I'm in the building right now, a lot of us engineers are hiding actually in the Leslie Dan Faculty of Pharmacy. It was actually a new building, I think it was opened around 2006 right on University and College intersection. And so in my lab I'm under supervision of Professor Ted Sargent, who's in Electrical & Computer Engineering and also co-supervised by Shana Kelly in Pharmaceutical Science. So it's a great collaboration between the engineering side of things and also, of course, the science side of things. And what we do, essentially, we do a lot of biomedical diagnostics tools and we do it from that kind of point of care scope where we're trying to create these new technologies that can be rapid fast and much more accessible to the at-home user. A lot of these tests that I kind of just showed there on the bottom right here, we do a lot of these kind of sensors based on this kind of DNA construct. Essentially we're using DNA to sense different biomarkers that could exist in bodily fluids. So the virus itself, it's a biomarker for the disease COVID-19. There's different proteins that could be biomarkers for disease progression and there could be nucleic acids that could be markers for different diseases as well. And so these kind of devices we create, we use a DNA on the surfaces of electrodes to be the sensing mechanism to detect these biomarkers. If you look at these images, we're talking about micro-scale technology. So the electrodes, those kind of yellowish surfaces that you're seeing those diagrams there, those are on the order of 100 microns in size.

And so we've developed a lot of these different types of sensors, in the lab, for detecting from proteins and different viruses and things like that. But we've been doing it in the lab and the ultimate goal of any type of technology is to bring it to the people who need to use it. And one of the ideas is that, well could we somehow take the sensors and develop a biosensor for the home, or for the on demand kind of application.

Developing a biosensor for the home slide

If we wanted to develop something to meet those requirements it would have to be reagent-free so we can enable single-step and non-invasive diagnostics. So this idea of reagent-free is that you want to get rid of all those extra chemicals and things that have to be transported and paid for to do a test. You want to make it single-step so that the individual can do it themselves non-invasively and get a result right away. So this is kind of where that collaboration between scientists and the engineering side come in. So Jagotamoy, in the picture there, is an electrochemist. He's a research associate in our lab. And that's me, I'm the engineer, the electrical engineering student. And he brought this question to me of like how can we do this reagent-free sensing mechanism to make it more accessible as a point of care diagnostics tool. Still using the DNA strategies as probes, because you know that's kind of our bread and butter, using these electrochemical DNA strategies. We were thinking, okay, instead of using the kind of techniques we originally used, we kind of look at the diffusion of DNA and things like that. What if instead we actually analyze the electrical characteristics of DNA, kind of take a more physical approach to how do we devise these sensors. So we kind of came up with this one strategy where, so again that yellow surface there is our electrode and then you have this double stranded DNA probe that's essentially attached to these electrodes. On the top that little crescent moon shaped thing that's just a recognition element. So that's something that can recognize your biomarker that's kind of floating around in your solution. So that left image there's that unbound probe and now when you know the biomarker of interest comes around and binds to your probe it's now a bound probe. And so we want to be able to measure the difference with some type of signal between the unbound and bound version of a probe. So the thing we did differently this time--like I said, we were interested in the electrical characteristics of DNA--we kind of use the idea that, well, DNA is negatively charged. What happens if we just apply a positive potential to that electrode? So there's going to be electrostatic interaction. The negative is going to be attracted the positive. And what that's going to do, because DNA is rigid, it's going to cause this DNA to fall down to the surface. And the idea is that, well the unbound probe will fall at a certain rate, but then a bound probe will fall at a different rate.

An engineer's mindset to biosensing slide

So you know we have a kind of engineering mindset into biosensing now and going forward with it, here's kind of like a more science-y, chemistry looking depiction of what our sensor is. So again, it's that DNA linker attached to this antibody, which is the recognition element. So the antibody can recognize a certain protein which is that biomarker on top. And this is all attached onto an electrode and we're just looking at this thing falling down to the surface when you apply a positive potential. And so that's very science-y looking, but when you think back maybe to your undergrad, if you recall the inverted pendulum when you were doing control systems. Similar approach where you have this kind of rigid broad with an attached ball on the end and you're kind of looking at how it moves back and forth. And so that's really what we did.

A first principles analysis slide

Taking the sensor I looked at it from more of a first principles approach to figure out, okay, well can we detect a difference between this sensor being bound or unbound? So, in terms of the first principles approach we analyze, okay, we're going to have some type of mass at the end of this rigid DNA linker

and it's going to be influenced by a lot of different forces, it's going to be influenced by the electrostatic interaction to the surface, so that's just Lorentz Force. It's going to be bouncing around because it's going to be repelled by all the other probes that are in our system, so all the other DNA that's attached to the electrode. It's going to be coulomb interaction between them. And then there's also going to be drag. So that's kind of one of the big indicators. So when this probe is falling, if there's really large things at the end of it it's going to have increased drag that's slowing it down. And so with this what I wanted to do was essentially look at its unit step response. I just wanted to see, okay if you apply very quickly to the positive potential a little square function, what happens to that system, what you know what's it's time constant, what are we looking at? And essentially I had to numerically do this by solving for its system equations of motion. This is kind of a simplified version of what those equations look like for all the different forces. Then from there we can get numerical solutions for how long it takes for this probe to fall to the surface. But of course numerical solutions are great, but we always want that one analytical solution that answers everything. And also for intuitiveness to kind of be like, okay well this is a simplified model of what we can anticipate how this is probe will fall. And so I was able to kind of simplify the model and look at the characteristic time constant of the probe, which is this tau (τ). And essentially it has all these different parameters which change how quickly this probe falls, or how slowly it falls. One thing to know on top is that the big 'R', that's the size of that analyte that's attached to the sensor. So the bigger it is, the slower this probes falls. And that's a key factor of what we expected to see in our system when we actually made it.

Theory becoming reality slide

So theoretically we see the characteristic time of an unbound sensor is going to be slower or shorter than that of the bound sensor. So you get these different current responses. And then we create these sensors. We went into the lab, we made the sensors out of DNA, we added the antibodies, we added different proteins and the signal response we got was actually pretty close to theory. So we were able to actually detect a difference in the signal of an unbound versus bound probe. So a probe that is detecting let's say some type of protein for a disease by using the strategy.

A versatile diagnostics strategy slide

What we're also able to do is that -- the fundamental idea of this probe is that you can detect anything, essentially, if you have an antibody for it. So we were able to detect many different protein biomarkers associated with cardiovascular disease, cancer, allergies, inflammation. We were able to do detection in many different types of biofluids as well like saliva sweat, tears, urine, blood. And also we want to show that we could actually stick a sensor in your mouth and detect something in your saliva. So we did this in the mouse model, a mouse model that had heart failure versus a mouse model that was healthy and we were able to see an increase in signal over time having the sensor in the mouth for that infected model. So we were really on a roll at this point. We felt that we found this kind of reagentless strategy that you know we could really detect whatever we wanted as long as there's an application for it.

Then COVID-19 happened slide

And then COVID-19 happens. The universities eventually start to shut down, we had a lot less access to the labs. This is a Toronto Street during those first few months. It's crazy to see how barren it became as no one was around. Even for us in our lab, there's restricted access to the lab facilities based on like a skeleton list. So for a long time we had to stop what we were doing in the lab space. But that didn't stop us from continuing with our idea of how we can take our biosensor to hopefully help with this COVID-19 crisis.

Could our sensor detect COVID-19? slide

We questioned, could our sensor detect COVID-19? I mean, it seemed to make sense, right? We're able to have this time constant. We figure out, okay, we have the sensor attached to a protein we can detect it. Viruses have surface proteins as well. They're bigger, but that probably would mean that that the 'R' in the equation is going to be larger, the time constant is going to be much bigger. So it'd be something like this where you have this really massive virus attached to your sensor. That's SARS-CoV-2, which is the virus that causes COVID-19. And so when I did log the theoretical modeling for it, this is kind of what we got. So we see unbound signal. If you were to seize a protein, just for comparison, you get like an increase signal. If you have a viral particle, that's really massive attached to it, you'll get this very, very long prolonged response. And so we had a few people able to go back into the lab, start preliminary experiments and they were able to find that this is actually what we see with our sensor. We are able to see that very long, dragged out current response with the attachment of a viral particle. And those are the three individuals who are really fundamental in this work, taking it off the ground, especially at the start COVID-19 when not a lot of us were back in the lab.

Engineers working with infectious disease experts slide

With that we've demonstrated okay, that's good work for COVID-19, now we need a big team-- a bigger team-- with people specializing in COVID-19 to continue this exercise and continue this research. We were very lucky to get access to the Toronto COVID-19 action fund, sponsored through U of T and also a lot of alumni as well. And we were able to start collaborating with a lot of the big names in COVID-19 like Samira, Allison, Jim and Alan. All very important doctors, clinicians and also professors who really helped push different aspects of our project forward. Such as our animal studies with COVID-19 animals, to get human patient samples from COVID-19 patients of their saliva so we could test it. And also doing a lot of the fundamental work of seeing, can we detect viruses, can we have antibodies that are good to use for SARS-CoV-2.

We could detect viral particles fast and at a low concentration slide

So we did a lot of analysis and a lot of experiments to see what is our sensor capable of. First, we were able to show that we can detect virus within five minutes. So these tests that we did in our lab space itself. We're not allowed to have access to COVID-19 viral particles within our own facility. That requires higher biosafety levels. So that's, that's where Alan Cochrane came in because he's developing pseudo type non-infectious particles, viral particles, that have similar properties to COVID-19's virus, but are not infectious. So we were able to use those to show detecting viruses in this five minute time frame, which is much better than the many hours that would take for using qPCR. Furthermore, we are able to show

that our sensor could detect clinically relevant viral loads. Any person who's sick with COVID-19 might not have super high viral loads. Some people might have very low amount of virus in their system, they might not even have symptoms, asymptomatic individuals. But we are able to detect very low concentrations of virus, which makes this a lot more usable for the asymptomatic, and symptomatic conditions.

We could detect COVID-19 in patients slide

Also, we were able to get human patient samples. So this was, this is a really critical step in terms of seeing if our sensors could be usable in the actual testing space. On the left side there that's, again, just what the current outputs look like in terms of the traces of the unbound versus positive samples and negative samples. Negative samples is, of course, the healthy patient. And the center there again five minutes of…within five minutes, we could see a current increase as there is binding of the virus to our sensors. Finally on the right there is just that initial panel of testing out our sensor with negative control patient samples and positive control patients samples. So, positive control are the samples from individuals who had COVID-19, who contracted COVID-19, and the negative is of course the healthy and the control also similarly healthy. We were able to see a dramatic current increase on the positive samples, indicating that our sensor was able to detect SARS CoV-2.

Making a portable test slide

We've been able to, again, do all this testing in the lab but moving forward we wanted to make it so that you don't have to have this assay on the bench. This kind of big machine that you do your probing with. Because we're applying voltages to our system, we use what's called a potentio-stat to do that, and that instrument, the lab-rated instrument is quite large. It's something you're not going to be carrying around in your pocket any time soon. But there's a lot of newer electronics and technologies that help to miniaturize these devices.

That was kind of one of the things I was interested in doing, how do we scale down this measurement device? So we want to take a measurement device, something that can fit in your hand, with easy functions so it's not connected to a wall. So I did a lot of prototyping with this one SoC that's developed by Analog Devices. They're actually really getting into the electrochemical sensing space so that was really great to see. And then also our sensing probes. We want to miniaturize them down. So we have these probes right now, which essentially are electrodes printed on to glass -- we're using photolithography. And then all the interconnects of the sensor to the actual measurement device are connected with 3D printed parts and different wiring. So the idea is that you get kind of a sensor or a whole system that's integrated, which essentially is a box with your sensor attached with a wire. The idea is that the sensor itself to be placed in your mouth to do detection of saliva and the handheld device which can do the readout.

Our next steps slide

So with our next steps, kind of going from doing a lot of validation and then creating this kind of more portable device. We want to continue that further because we do see a lot of promise in being able to

take this technology further and further. With further animal testing in clinical samples, developing a panel of different tests for not just SARS CoV-2 but flu RSV and different types of viral infections. Especially now, it's becoming flu season we want to make sure that we're positive that if you do a test, it's for a COVID-19 and not just the flu. And so continuing on different regulatory approvals and things like that as we continue to develop the hardware. So miniaturising our device into something that's a lot smaller. Currently we're actually going through the Creative Destruction Lab, which is a tech incubator that's housed here at U of T, who helped with start-ups that are going through the space of kind of validating their technologies to go into market. So we're very early stage, we're still working on the lab, but we do see potential in this technology becoming something that could be used by the at-home user.

The future of pandemic management slide

So with all of that, I just want to end off with what we see as that final, future pandemic management device. So in the future, we think we'll have this kind of handheld device. It'll have some type of disposable probe and the probe is specific for the virus of interest. So the idea is that it will be something that you could do a daily test to make sure you haven't been exposed before you go out to work, before you go out to social gatherings. Another case could be testing your child for a viral infection before they go to school. There's a lot of different test cases or test scenarios where having this device ready to go at home would make it so much easier to get quick results to know if you have contracted COVID-19 so you can go through your daily life a lot more easily.

The future diagnostics device for pandemic readiness slide

That's really the future of pandemic readiness and then the future device we see, like I said, is that kind of concept that I showed you in the previous slide. This is the concept for our device where essentially you have some type of inexpensive device that's a one time purchase, it can be in your home, it can be in the clinic, and it can be used by nurses. And this is something that will be usable for any type of biomarker detection. The thing that changes is that disposable sensing probe that you put in your mouth. So you can have a probe that's for COVID-19. It doesn't require extra reagents. You just take your handheld device, you stick your probe in your mouth and you do detection with a result that would display in five minutes. So, I mean, that's… it looks like a thermometer, that's kind of what we think it would be like. We want something that's simple to use, like a thermometer to make testing for infectious disease, a lot simpler and a lot more accessible.

Thanks to our funding agencies and collaborators slide

So with that I wanted to thank all our funding agencies and collaborators for all the help that they've given us in these dire times of continuing with our research and being able to produce high quality research that we hopefully will see coming to the public at some point in the future. Also I want to give a special thanks to you as alumni for your continued support to U of T, to the ECE department. Me personally, I've been able to get scholarships and funding through the UTAA as well. So I'm deeply humbled to be speaking to you about the research I've done. Thank you for the help you've given me and also to a lot of other graduate students and researchers throughout ECE. So thank you.

Deepa Kundur: Thank you so much Surath for that fascinating talk. We have some time to open the floor to audience questions now. There's two basic ways if you want to communicate a question. You can use the chat icon, which you can get access to on the bottom of your screen or you can type a question there or you can click on participants next to the chat icon and you'll see a panel that pops out with an opportunity to click on a 'raise hand' function. And that's the one with the hand icon. I'll be happy to moderate and read your questions to Surath or call on you to unmute your microphone if your virtual hand is raised and if you'd like to ask a question.

Surath, I'll begin by asking you a question. What's really fascinating about the work you're doing is it's so very interdisciplinary and as we see, we're all ECE alumni here and it's interesting to see the field become such an integral part of society and that is representative of the work that you do, because it's so integral to health care as we see here. What were some of the challenges, would you say in the advantages in in looking at things from an interdisciplinary way? What strengths did you think you have with an ECE background?

Surath Gomis: Great, that's a great question, thanks Deepa. I think it started fundamentally from forming this type of bio-sensing strategy. So I'm not electro-chemist as a background I'm an engineer. I did my undergrad in Engineering Physics. So I have a very physics minded mindset when I approach a lot of problems. Jagotamoy and others in our lab who did a lot of the bio-sensing work, they're electro-chemists, they have chemistry backgrounds and different science backgrounds. And there was kind of an unmet need, of how we can make this kind of reagentless assay. And part of being able to figure out how to do that reagentless assay involved, thinking about the problem of bit differently. From instead of the lens of a chemist where you're thinking about maybe a diffusional properties of DNA that's in randomly oriented and moving around to kind of more of that first principles physics concept of what we ended up doing of having the DNA fall down based on a bunch of these different interacting forces.

And so I'd say that was one of the big advantages of having that interdisciplinary mindset because we had the chemists who understood how to make these kinds of devices and devices type of experiments. But then we have engineering minds who could think of the sensor as a machine essentially and design these machines to be able to predict the detection of different proteins and things like that, or the binding of proteins and seeing how that affects the sensor in different ways, to design newer types of probes that are new and different than what was possible before.

Deepa Kundur: Great, thank you. So we'll start with a question from our chat and you know once again you're also welcome to use the raise hand function. You just need to unmute your mic if you want to ask a question, verbally. So this is the question from Bill: What is the vulnerability of the probe to contaminants?

Surath Gomis: Thank you. Thanks Bill for that question, that's great too. The vulnerability of the probe to contaminants… I think I'll answer that question in two parts because the idea in the future of how we use these probes-- if it became some type of commercial product-- is that these are probes that are sealed within some type of single use type of container. Similar to a syringe or anything you use once. It's sterile when you open it up and then use it and you have to dispose of it.

So the idea there is that there shouldn't be any contaminants as long as you open it and put it directly into your mouth because it will be sterile from the get go. In terms of contaminants in the lab space, when we're testing out and validating our experiments, there's potential for that in terms of how clean we are with our experimentation. And actually, maybe a third kind of other answer to potentially what you're asking with your question is that when we put a probe in a mouth it's not just that we have the protein interacts, we have saliva which could have food gunk in your mouth. You can have all these different things that could also interfere with our sensor. Those are things that we continue to explore and do research on as well to figure out the contributions of different viscous matrices that saliva is consistent of and see how that affects the signal. So that's continuing to move forward, but it's actually very promising that from our initial kind of data we can see that we can still see the change in signal from bound unbound even in these complex matrices with different kind of contaminants floating around.

Deepa Kundur: Thank you, Surath. Our next question is from Andy. And his question is: How close are you to creating that beta prototype and what is the current approximate cost for your alpha prototype?

Surath Gomis: Yeah, great. So how close are we to creating a beta prototype? We're still pretty far away, I would say. You know, a big part of the development in terms of … when you think about the development of a biosensor there's two parallel lines to it. There's that one line of developing our sensing strategy with the actual assay itself. So developing quality controls in terms of how we determine true positives vs false positives and things like that. So that's a lot of the scientific work we can do in the lab.

In terms of the alpha or beta prototypes for the actual electronic device itself. Those are things we can do a lot of prototyping very easily in the lab space but once it goes to the commercialization side of things, there will be a lot more quality control that we need engineering companies to help us with in terms of manufacturing, even the sensing probes themselves. That will take a lot of development as well. We're using these DNA antibody kind of probes on a sensing surface that are submerged in fluid when you put it in your saliva, but to contain these sensors before you're going to use it they have to be freeze-dried on to the sensor. And then you have to figure out all the engineering challenges of how do you produce a sensor that has this DNA that's attached, that has these attributes that are attached. So these are things that our supervisors have had experience doing with previous companies. But those are definitely challenges that will take a while. And if I were to estimate the beta and alpha prototypes, or the alpha and beta prototypes we're talking about into next year--a few months. We're starting to look at the alpha prototyping, outsourcing to a company who can do a bit of work for us and so that's happening right now. And hopefully within the next few months, we can see something start to come out.

Deepa Kundur: Wonderful. Andy has another question, a second part to this question: Do you see the day that you can wave the sensor in the air, for example in a room with people, and detect if there's any COVID-19 in the air with a version of your device?

Surath Gomis: Great. Oh, Andy, I love that question. And the reason I love that question is because we thought about that. So initially, when the pandemic hit, a lot of us went virtual and we actually did a lot of strategizing of how can we take that sensor that we developed, this reagentless sensor, how can we use it for COVID-19? I only told you about the strategy that we ended up going with, but we were interested in a lot of different things. Like, could we put the sensor on the outside of a mask for healthcare workers? So when they put their mask on and they're in their space if they're exposed to COVID-19 in the space maybe the color of the mask would change and they know that there's infection going around there. Or can we put our sensors into the air vents in a room? Because if there's air constantly circulating around and perhaps viral particles in the air, if they could attach to our sensor in these air ducts-- because we're talking about continuous flow --and you can see a signal measurement and then you can have some type of read-out in the room that says 'okay, well there is COVID-19 in this room or the SARS CoV-2 virus.

So yeah, to answer your question, we were thinking a lot about that. The only thing --we haven't actually tried it, though. We use our device under liquids so in saliva, in blood or anything like that, or in tears. We haven't actually tried it just exposed to air, but we do think it could be possible. It's just something we have to explore further. And it'd be very, very great to see a solution like that come because there are environmental applications for a sensor as well, in terms of using this for some type of environmental sensing.

Deepa Kundur: Wonderful. And we have one more question. So I encourage anyone else with further questions, please to raise your hand or to place it in the chat. Okay, great. So Chloe's question is this: How far or close is your team from commercializing this, what's the process for that like with regards to getting health certification approval?

Surath Gomis: That's a great question as well. So we're in the process of… we've incorporated like a start-up so we can start rolling with getting investments, or investors interested. Going through the Creative Destruction Lab process is also helping a lot with framing how do we take a product like this to market effectively. Right now there's a lot, obviously, there's a lot of start-ups that are coming out in this COVID-19 space trying to create these rapid point of care solutions for rapid testing, things like that. But in the space too, it's very easy to get rushed. It's very easy to get rushed and maybe some of these technologies will fall through if they weren't able to do enough validation to really sustain themselves.

So I think we want to be careful in terms of ensuring that our technology is validated extremely well with all these patient samples, doing actual clinical trials and things like that as well. Which is kind of the standard process anyway, but this is a process that takes many months. So right now we're in that very early stage, kind of conceptual device stage. From there, it's a matter of doing all the clinical work, the clinical trial work. Then there's also obviously like the FDA regulatory approvals and things like that as well. Which there have been more rapid ways of getting, especially these COVID-19 tests, faster through these emergency usage programs that the FDA is putting out to get clinical trials expedited. There's a lot of different ways we can go about this but, there's still definitely a few months to go and a lot of different health certifications and approvals through Health Canada, FDA, classify what type of device we have as well. There's a lot to think about, that's for sure.

Deepa Kundur: Great. And we have a few more questions. So our next one is from Lauri: Will this device be suitable for detecting other viruses in the future?

Surath Gomis: Thanks, Lauri. Um, yeah, that that's the idea. Because the only difference that we need is the change the antibody used that's specific to whatever virus. So right now we're using the SARS CoV-2, sorry the antibody specific to the s-protein of SARS CoV-2. So that's how the virus attaches on with its surface protein that binds to our antibody. If you want to detect for a different type of virus you just need to know what its surface protein is and have an antibody for that. In general antibodies are very accessible in research and also for making devices like this.

So in terms of doing detection for different strains of the flu, that's another thing we're thinking of to do in conjunction with COVID-19. RSV is another type of viral infection that we're interested in looking at. A lot of children will get that viral infection. Also having all of these on a single panel sensing probe would also be very interesting because it would be good to know if you have SARS CoV-2 or influenza or RSV all in one test.

Deepa Kundur: Great. Our next question is from Andrew and it's: What's the process for designing or developing a new sensor probe or receptor for a different or new type of virus?

Surath Gomis: Thanks Andrew, so the process in terms of the experimental two is that we've essentially optimized the length of the DNA linker we're using, or the double stranded DNA linker. So that's that rigid rod that's just pivoting along the electrode surface. The only difference to detect another virus is again changing that antibody, like I mentioned, and all that is that you just have to conjugate a new antibody just using a bit of the chemistry for the antibody conjugation. So all you need to do, at least from a kinetics perspective with a PhD student in lab, is you just need to order the antibody that's specific for the virus you're interested in and do the exact same type of conjugation chemistry for it. So it actually makes it very easy, that it's just almost like a hot swappable antibody onto our probe. So we can do detection for a lot of different things.

Deepa Kundur: Okay. Thank you, Surath. So I see one more question from Peter. So again, we have Surath for a little bit longer, you're welcome to ask further questions. Peter's question is: How do you deal with different patient temperature effects on the measurements?

Surath Gomis: Thanks, Peter. That's a great question. I'm going to answer a slightly different question first. You bring up the idea of temperature and with a lot of the testing we've done with our sensor we do a lot of testing with different experimental conditions of what the fluid's like. So we've done testing with different salt concentrations in our solution. So, depending on what type of bio-fluid you're using, there could be different salt concentrations. We've done viscosity of the fluid, because if you think if you have a very viscous, very gross saliva sample maybe the probe, the kinetics of it, is such that it's falling slower because there's a lot more resistance from the fluid matrix itself.

In terms of temperature, this is something we haven't explored too, too heavily yet, but it is something that we definitely have to look into as just an additional parameter to consider when we're looking at our results. So essentially what happens is that if you have a different viscosity material, your current

traces will offset by some type of function. And it's just a matter of understanding okay, so if you have -- essentially making a standard curve-- if you have X contribution from X parameter that will change your interpretation of your current response. So in terms of temperature that's exactly what we have to do. We have to look at how does the current response look like if you have someone at this temperature versus this temperature and then create the equation of the standard curve for that.

Deepa Kundur: Okay, great. Thank you, Surath. So are there any more questions at all. We have one new one from Andy: What is the biggest technical challenge that the team faced and how did they overcome it?

Surath Gomis: It's a great question Andy and that's always the hardest question to answer because there's so many technical challenges. I mean, initially the big challenge was just access to the lab space, access to clean rooms as well. So we're making these sensors, we use a clean room facility to do the fabrication, the microfabrication, the photolithography, the passivating of our gold for our electrodes on to these glass plates. There was less access to these clean room facilities at U of T, just because of closures and things like that as well. That made it a bit challenging.

Also a lot of the big challenges, the hurdles we had to overcome, included getting all the different collaborators to do the experiments. So we would never have been able to do this if we didn't have access to the serotype viral particles from Alan Cochrane, who helped us validate our technology. We'd never be able to do without those or the antibodies that Jim Rini gave us or the patient samples and all the animal studies we're going to be doing that Allison and Samira gave us access to as well. So it's hard to go to just one I guess specific challenge, because there's been a lot of new challenges that we had to face this year because of COVID-19. Even now we schedule in to go into the lab space. I'm in the pharmacy building right now. I'm not wearing a mask, because I'm in my own enclosed room.

But yeah, with all the associated challenges I think things that shouldn't have been big challenges did become bigger challenges. Maybe that's the best way to put it.

Deepa Kundur: It looks like we have another question from Rudy. And Chloe has to follow up. So we're going strong. Rudy's question is: Who are the competitors going forward?

Surath Gomis: Great question Rudy. So I guess I didn't really talk about this too much during the presentation and I'm glad it came up now. So PCR tests are considered the molecular grade tests. So those are tests where you actually have to take the viral samples themselves, digest them, get the viral RNA out and do amplifications on them. Then there's our type of tests, which is more or less an antigen test. We're actually detecting the proteins that exhibited on the surfaces of these viral particles which don't require you to do digestion of the virus and look at its genetic material. So in terms of competitors, we're dealing in that antigen testing space where there's a lot of different start-ups and bigger companies coming out to do very rapid diagnostics. One of the challenges that faces a lot of different antigen tests is accuracy. Generally they're considered less accurate than going straight to the genetic material to look at SARS CoV-2 and there can sometimes be a lot more false negatives. So you might do an antigen test, but then it might say that you don't have COVID-19 when you actually might or experience symptoms. So that's what you need to sometimes do both types of tests, necessarily. But in

any case in terms of competitors we're dealing in that antigen testing space. Abbott is a big company that does a lot of different diagnostic tools and they've developed… they're reagent based sensing technologies. But it's something they want to put in the clinic for nurses to use, that's very rapid test.

So that's one example. But for the most part, there's not too many competitors who are trying to do this at home test. They're doing tests that require reagents, require special technicians still so that's kind of what helps differentiate us a bit. There's definitely a lot of competitors out there to consider.

Deepa Kundur: Great, thank you Surath. So we'll just wrap up with two more questions. We'll start with Andrew and then Chloe, who just wants your contact information about collaborations. And I think what might be efficient is Laura could send it to her over the chat, if that works. Okay, so our final question is from Andrew and he says: Can you share anything about how other rapid viral tests work? Are there a variety of methods or do they all share the same fundamental approach?

Surath Gomis: That's a great question as well. So in terms of other viral tests, rapid viral tests, they usually do use different types of approaches. They're not all DNA based like us. We kind of fit into that regime of this electro-chemical based detection. There's a lot of other assays that are colorimetric or they might use essentially, detecting of the virus through the application of different reagents and things like that to the system. To be frank, I can't speak too much about a lot of these different approaches outside of the electro-chemistry space because we've been really focused on that.

But in general, the approaches, they're all seeking to be more rapid through how quickly you can detect the virus itself. And a lot of times that is using an antibody so that that's one similarity that a lot of these tests have. Generally it's kind of the transduction technique that's going to be different. So you might have a little card that has a bunch different micro-wells and you put your samples in there and then there's a color change so there's a colorimetric response to that to say if one wall has the virus or one doesn't. We're doing this electrochemical technique which is a current based output. There's other techniques that are more impedimetric based. So that's like an impedance change, if you have a surface coat of antibody you have something to bind to that antibody and then you just pulse an electric field, the resistance within this material changes and you can detect something differently that way.

So yeah, there's quite a few different methods out there. Sorry, I can mostly only speak to the electrochemical based assay, but that's definitely something we can even talk offline about if you'd like.

Deepa Kundur: Well, thank you again Surath and thank you to the audience for joining us today and for the excellent questions. Special thanks to Laura Brown and Jessica MacInnis for organizing this virtual event. Before we sign off, I want to encourage you all to join our online alumni engagement network, U of T Engineering Connect. This is a great space to stay connected with each other and to mentor or be mentees for some of our younger alumni in the audience. You can sign up in just a few seconds at uoftengineeringconnect.ca.

I think it's more important than ever now to maintain these connections to our students, to our department and to each other. Thank you again for joining us tonight and I look forward to your feedback. Good night.