Focused group interview session 1

Focused on the type of wireless communication technologies that we can use for different types of applications. So, we have like for instance we have average size form here in India in our region and we want to basically develop a framework where we are developing an application procedure application based on monitoring row crop diseases. So, do you know? The kind of sensors we can use for these applications and also some of the wireless communication technologies that can be integrated with these sensors, cost effectively, power efficient and also from the range of from the aspects of communication, range and data latency data scalability requirements. So which wireless communication technologies are more effective for monitoring row crop diseases? Um, As for your like experiences in deployments or some other project experiences you have. So, my basic like idea is like to ask the question in a way that how the monitoring applications, specifically monitoring row crop diseases, varies with autonomous applications such as like smart irrigation and smart fertilization. In terms of data latency requirements in terms of data scale, we have in terms of data storage requirements. So, the basic question is like. Like does autonomous applications require low latency or higher communication bandwidth range? What is the impact of like mobility of the vehicles on the like wireless communication and what is the scale of data in this different application? So, this is like a basic open question I have.

Yeah, so like from all I guess try men like from my seat. It's always hard. I guess I always default to thinking about how we're going to move or transfer the data first right? 'cause like yes, that to dictate the sensor that we pick then. That's always seems to be the hardest part in my experience and doing this. As you know, if you're looking for season long monitoring right, you know and we want it to be timely so we don't want to rely on somebody having to visit the actual sensor to like offload data, right? So, you've got to have some sort of, you know data transfer mechanism. You know the most commonly used one I think to date, and it's still pretty heavily used as cell based, which is expensive and you know can have its own issues in terms of you know connectivity and reach and stuff. So, I don't know I like before talking about the sensors always. I tend to think about how are we gonna you know what what type of sensor in terms of communication do we need that usually in my work has always been the bigger issue it seems like.

So that's a very good response and like so for instance, we have a remote sensor. And also, we have some environmental sensors, so we want to like integrate those sensors with the wireless communication technology for. For prescription Maps or generating some of the models that can be helpful for monitoring grow crop diseases. So, what do you think is the latency requirements, data latency requirements and also the scale of data we can have from those sensors? Or any other type of sensors you have in your mind that can be used in this case and which can be cost effective as well. And also, like power efficient from your experiences from your projects.

We see three different types. We see sensors that have low volume of data and do not need to be. Recorded very often. So, for instance, it could be a soil moisture sensor. It's a single rating. You know, even if you send it every five minutes that you, that might be an overkill, certainly. Are you you could do even less? So that's that's one type of data and obviously low volume and latency is not critical. Second type is image sensors where you you want to install a camera. For instance, for the disease monitoring or or. Of, course if you have a drone or some other moving vehicles that you want to photograph. These latency, is not critical there, but there there's certainly higher bandwidth requirements. The area or receipt latency as being important. It depends on where the intelligence is. What I mean by that is if you are trying to irrigate automatically and say OK, I want to deliver this volume of water to the field, then

on one hand you control the valve and then the other hand you measure the flow and you want to be able to shut off the valve. Reasonably. Quickly, you don't want to shut off the valve 15 minutes later just because you're only sampling every 15 minutes. So, if the intelligence about shutting the valve and counting, measuring the amount of water is local is in the field and latency is not an issue otherwise. It could be an issue, just one last point. In our experience, communication, especially for moving vehicles, is not 100% reliable. You cannot always assume that the data can always be immediately sent and therefore the ability of her local sensor. 2 two buffer, to store a certain amount of information until it reaches back coverage is useful. I was going to say that's seems to be the trend is to capture as much data as possible at the edge. You know. So really, rather than just applying the technology randomly trying to look at what's the purpose of the data, as you've all said, what's the where is the intelligence need to be so if you can capture like with a WS platform, if you can capture more data at the edge then you're not having to send it off.

Yes, that's very informative. So, when you talk about like intelligence and autonomous application where we have like very low latency and we need like data at a specific interval of time. So, like how the data storage and data scalability in this context plays with? Uh, the data latency and power consumption. So, like for instance, we have some remote sensors. We have some sensors, GPS sensors on the vehicle and like they're communicating wireless communication technology.

Might be some like it so far. This instance like we have a lot of we have a lot of technology that we use for. For monitoring environmental conditions, so is like Laura wireless communication technology suitable for mobile applications for autonomous application? Or is it suitable? For any other application more suitable for any other application, and like which technologies are more suitable for autonomous applications and how the factors like paid a latency, scale and storage place in that. So, what are your thoughts on that?

I don't have much experience with sensors, but we have been working on a paper recently for rural wireless communications and we I think we have a few takeaways that may be relevant here. The first one is the digital gap, the allocation of communication resource between the urban area and the rural area is really wide. We found that typical. For example, for cellular networks. Yeah, for cellular networks the carriers tend to operate tend to prioritize the title density over urban areas over rural areas. We found that cellular towers are cloud clusters, a clustered in cities, but also along highways. So, when people travel they don't perceive the disparity as. The true case, unless you actually live in the rural area. According to our research, there is no simple solution here. There are a lot of techno. Allergies, but each one of them has some kind of disadvantages. It's like for rural, for Laura, that's a really promising technology. It has really low power consumption, very long coverage range, but it the throughput for it is just really low for automotive autonomous vehicles. The current available technology that that probably will meet the latency. Requirement is 5G, but that's still near future is not like. Currently available kind of thing. We think we just have to live with the tradeoffs is, it's like in now it's it's. It's there today and it will be here in the foreseeable future. So, what our mind the best solution will be. First, the farmers need to identify the application they want to cover. Need to identify the requirements by the. Application like in a case by case minor and then they need to choose the wireless. Technologies one by one. Basically, for each application and they have to accept the complex ability that complexity. Sorry of multiple technologies coexisting, they have to maintain that the.

The most practical solution for today is probably they need to get some really good backhand connection first, probably why via wired connections like optical fibers and then they can do. An extension of the coverage using wireless technologies and for soil sensors. Laura will be great. For typical applications, Wi-Fi will be cheaper. It's like it can support higher throughput. Cellular is very promising, but it can cost a lot. It's like that users have to choose.

The technologies dealing with the tradeoffs yeah on the Benton farm we are using a combination of both satellites. If cellular isn't available it will use satellite and that's been pretty cost effective. With used an RFID tag that connects to a tractor using GPS and that's working pretty well. Collecting temperature data and from another as you said, another complete. Application is, you know, using a completely different communication method, because that's what makes sense there, so it's kind of klugey right now until these all come into play, but it is working.

One note about Laura is it's probably not well suited for automotive applications because it as the current the current implementation does not allow for use while you're moving, you pretty much have to be stationary or at a very slow speed. I'm not sure if that's an issue with the current implementation or the standard itself, but that's something to note and to repair it on. What ya one said engineering is all engineering. Is is knowing the tradeoffs and choosing the correct ones that there's never going to be a silver bullet. So that's also something to keep in mind. There's not going to be a perfect solution.

So, as we talked about the some, of the like remote sensing technologies that might have some like already have open source data like that we can use, so that might be like pretty much cost effective and we talk about here about the data interoperability between different communication technologies or in terms of there is some open source data. That for in, for instance, for like monitoring row crop diseases, we need a data on topography venita data on the. On the soil health so. Do you think like there are some open-ended data sources that can be integrated and there is like within this in this application monitoring application we have some like remote sensing data that we can use with some other technologies such as lidar or something like that and is there any like what is? What about data interoperability between these technologies? Which technology? While this communication technology has more data interoperability? As compared to the other, which can have different heterogenous sensors that can be integrated. So, what's your thoughts on that?

I think it's two separate issues. How you get the data someplace and then how you create interoperability. I mean, a single platform can accept. Data from Laura from cellular, from an API from public API. And so, I am not sure I understand why the transmission technology, Is directly related to data interoperability.

So, in terms of. Types like if we have like different type of sensors we need to integrate with a specific wireless communication technology such as Laura. We have environmental weather sensors we have. On the other hand some GPS like autonomous sensors for like. Like GPS sensors, accelerometers, so in that case like have you do you like working on any solution on basically how those two types of sensors can be integrated with only one wireless communication technology and like in the sense one type of wireless communication technology?

Yeah, that's my question. I cannot feel it doesn't matter much in terms of how many. Type communication technologies you are going to use. One approach is to deal with the

sensors in centralized approach. You have one server talking to all the sensors collecting other data. Then in that case, as long as this server the host has the ability to talk to the sensor using the correct wireless communication technology, it doesn't matter much like which technology you are using. Their communication. Just establish the link. And the data flow along the link it so in that sense the communication is like a very low level, almost like you don't need to worry about it as long as it's there. OK yeah, and for into the data interoperability it's more at the software like application level. It's like when you deal with issues like that. Different software companies may need to talk to each other to make sure the. Results generated by them can be used by each other. We have the we have been dealing with lidar data a lot who have been using USGS data primarily and we just found another set of lidar data that's the Indiana statewide lidar data. That's currently hosted by professor from Purdue we found in for later is quite standardized. It's like everything saved in shapefiles. So basically, whatever you generate, as long as you save them in shapefiles, everyone will be able to use it, but that's a high-level consideration above the communication. Technology.

I was talking about in the sense of data scale. So, for instance we have different type of hydrogen sensors. And we have a wireless communication technology that has the data scale constraint, greater storage or like data transfer constraint. So, I was asking my question in that sense and like it, it might relate to higher power consumption right on that device? And then like it will lead to more cost, right? In that sense. So yeah, my question was in that context. So, do you have a like part on or answer on that? Or the scale is not important as far as like we have a cloud storage, but like even if we have a we have a limited cloud storage, right? So, like it might require some applications. For instance, we take effect of data processing here. So, for autonomous application do we for intelligent systems? Do we require more data processing? At the uh, maybe at the cloud and or at the. Wireless communication technology and or monitoring applications require more data processing.

I'm not sure I'm gonna answer your question exactly, but in general data storage is very cheap. They get cheaper, it gets cheaper every day. Um, so that's not something that I think should be a huge priority on the cloud side especially. Sir, keeping terabytes of data costs next to nothing on the cloud side or on the edge side. I'm sorry, probably a little more important are the I work on a project called I so blue, which is an edge computing device on agriculture machinery. We have 500 gigabyte SSD's on him that don't cost too much and are smaller than a credit card, so that's more than enough for us for a couple of seasons of data and you could go much bigger without having any issues. Obviously, it will cost a little more, but in the grand scheme of things, I don't think that's super. The there's much the development cost of anything is going to far surpass storage costs.

Do you think like is there any relationship of the communication, range and bandwidth and how it varies with the autonomous applications and the monitoring application? So which application requires like if so? For instance, I'm talking about the communication range between the sensors and the gateway communication device. So like how the communication range? It is with the type of application we have.

I think according to our experience, the most. Bandwidth hungry applications will be among the monitoring ones like if you are using imagery, especially like real time HD video cameras, that will cost you a lot of bandwidth. But if you only want to. Maybe share some very basic low-level information between vehicles. The bandwidth may not be that high, but the latency is always an issue for autonomous vehicles because they need to really fast.

Yeah, I guess just just in general, I think that there's been a shift between like big data and collecting as much data as possible and then trying to figure out what to do with it. It's more now about building an integrated model and trying to figure out you know what it what is the day you're trying to capture. What are you going to do with it? How are you going to build this model? And then putting a system in place that does that? So, I think there's there's ways to address each of these challenges. As long as you know what the outcome is, so you gotta focus on the outcome and then put the pieces in place.

OK. So, by outcome you mean type of application we have like, well, what are you going to do with that? I mean the a more integrated model is really looking at how are you going to increase the profitability of the business? How are you going to improve operations? You know what are the different processes in place? What is the what is the data stream that you need in order to make those decisions? And then you look at the whole flow and put the right. You know pieces of infrastructure in place. But I think a lot of the problems in the early stages came from we're just collecting a bunch of data, just massive amounts of data, and you know, but even that is coming down in terms of, you know, so I guess Andrew pointed out, you know the costs are coming down, so we can still do that, but it doesn't make sense. We need to start looking at what are you trying to do and what were the results you're trying to achieve. That's what makes sense to me.

Alright, so my next question is about the data storage and processing so. I think I have already asked this, but like just to elaborate on my previous question. So, for instance we have. Open office applications such as smart irrigation and smart fertilization. Specifically, these two applications and on the other hand we have farm machinery navigation. So, which of these like require?

As compared to each other, require a data at a very higher rate and. Like how you decide it required it at a very higher rate, like is it due to the mobility or is it due to the more like autonomous application? More data processing required for having an autonomous implementation of the sensors. So, in that context, like how do you differentiate between these three specifically?

So, like I think what you're asking, at least the way I'm understanding it. You know. Typically, I would default to anything that's going to involve a vehicle you know potentially moving, right? So, if you're talking, you know a piece of autonomous farm equipment, right? Generally, would think of the data. At least of the data speed needs, there are going to be significantly higher. Most that's focused around safety, right? Anything that involves safety typically requires high data rates and often has redundancies. And so that you know, just amplifies the. You know the data with just sticks that you have to work through. (RB) But like redundancies, you mean we need to then process the data a lot right to? Basically, have the implementation of control applications right. Alright, but more by redundancy I was so in talking like a vehicle scenario, right? You have, you know, a lot of times they are. You know they'll have two sensors to do the job of. One for fail safe reasons, so that's kind of where I was thinking along those lines. Compared to, you know, for in some sort of an agronomic sensing scenario, right? You know, having a backup redundancy may not be as critical there if that makes sense. That's right, yeah, not sure if that really applies to your situation here, but that's kind of where I'm thinking.

So, as you talk about the vehicle's mobility and the autonomous application, how about the smart irrigation and smart fertilization? Like the data we require for these autonomous applications? What is like the latency requirements and what is the scale of data and processing requirements and like can we use Laura in this sense for these applications for smart irrigation or smart fertilization? Or there is some another wireless communication technology that is more suitable in that contest?

I certainly think we can use Laura. I mean, I think there's probably multiple, you know communication options for that. With, you know, at least that I can think of off first hand, right? I think you've got in. In those scenarios there's you know options available for, you know, for a year trying to do.

And like, does it depend upon the scale? So, if we have an average size field? And we are now, I'm now I'm concerning about my question is about the scale of data. So, for an average size field, 1 field or multiple fields, we require data. We have a higher scale. So, like do we need to use the typical sensors we have? We need to buy more sensors for like environmental meeting the weather and environmental conditions. On the other hand, we have psych like remote sensors, remote sensing sensors. So, based upon the scale. Do you think the type and number of sensors can change for a for monitoring application? Or, like any like smart irrigation or smart fertilization autonomous application. In a Journal context, what do you? What do you feel about that?

I feel that as long as you don't need image sensors, then the bandwidth requirements are negligible. Just to give you a context. So, in our system where single soul chip tag can connect to six simultaneous sensors were sending something like 50, 50 bytes, 50 bytes every five minutes, so it's nothing. I mean, even if you had a thousand of these. It's absolutely negligible in terms of data flowing, and that's similar to what we were doing with this smart vineyard application. I mean, they were using sensors to measure all kinds of things up and down the rows of vines because the they could. And they wanted to capture that data very specifically in that area. So, they had an enormous scale of sensors that were monitoring moisture, color, humidity.

So, do you think like environmental sensors are more critical in context of marrying, monitoring row-crop diseases as compared to remote sensing sensors or like? Like we can integrate both or like optimize their number in some way. To like basically adjust our cost.

I just wanted to add one more note on the scalability of the wireless communication technologies. It doesn't matter alot because of the coverage. Requirements different technologies have different coverage range and for example, even for something like cellular networks they have limited coverage. If you don't have access to cellular signal in your farm, you won't be able to enjoy the benefits from the ubiquitous coverage of the cellular network Wi-Fi have. Short to medium coverage, Laura has really long coverage and for many applications in agriculture, the latency doesn't matter much. For example, when you monitor the condition of soil, you may be able to cache the data and. Send the data through a slow link. Just gradually overtime. (YZ) Yeah, also you can also send it over time like it's not required at like the interval is very large. Yeah, in that case you have more things you can. Work with, for example. Some people say even if you are using. Some short-range technologies on the sensor side. You may be able to catch the data and then collect it. By driving cars with connections to the sensors, just like physically collecting the data nearby, you go there with some connection to collect the data. In that case the circular built. He is more like if we want to scale the case you need to manually go there somehow, but you can scale to areas where there's no connection at all.

I'm not an expert here, but aren't there also examples where you're storing the data on the device or at the edge and you're only sending you know alerts or notifications if something is out of range, so then that limits your. You know the communications requirements, so there's ways again around finding what

you're trying to do. You may only need to send short bytes of data with an alert or a notification when it goes out of range. You don't need to send everything.

So, on my last set of questions is on the cloud and or the storage and so. So, like how? How do you relate the data storage requirements of autonomous application? How do you compare the data storage requirements of autonomous applications as compared to monitoring applications? So, for instance, can we use like is you have any experience of using cloud storage for autonomous applications? Or any other project experience you have where you have high storage requirements. And your latency requirements are not very low. They are higher. So, does it vary with the type of application, specifically monitoring and or almost. So, you were saying about the overtime sending operator? So yeah, go ahead.

Sorry, I'm not sure I can answer your question to the best ability. I don't have a ton of experience in the autonomous sector. But a lot of I would assume that in it autonomous areas you don't really care about data that happened previous. You're not really going to need to store historical data. OK, except it with the exception of the monitoring applications for that autonomous. Application so I don't. I don't imagine there being very high data storage requirements, but there could be something I'm missing here. I'm definitely not an expert there.

OK. So, my question like was specifically to relate the data storage and how it relates to the communication range as well as the latency requirements. So, for instance, as you were saying about like, we can send data overtime, large amount of data, overtime for monitoring applications, right? But we if we need to send and load then the requirements are like higher. A low latency requirement, right? So, um from your life experiences, what do you feel about the relationship between data storage requirements and how it relates with? Oh, can we? Can we, for specific application, can we send the data overtime for instance for smart irrigation, small fertilization or for monitoring row crop diseases and have a huge amount of data we can train? Some model makes a model and then need to update some model on the cloud and So what is the and what is the criticality of data storage in that?

Oh wait, so like, for instance, you're working on I so blue. So, like, what is the so does iso-blue specifically store some amount of data overtime?

Yeah, so it will store um, you know, can GPS an cell modem strength? The question is, does that considered monitoring? I think I would consider that all monitoring data that's just being collected to understand what was happening in any situation that it was specifically the cell signal there, but. Currently, we're not making decisions. Based on that data, with the exception of the can data, so we'll use Cam data to determine if we're going to stay alive or go to sleep. So, on the machine turns off, there's no more can data on the bus, so we also go to sleep to conserve power on the battery. And As for data storage requirements, there's none for that. We have a counter that counts the number of bytes that we've received, and as soon as that stops incrementing, then we go to bed. So, there's very, there's no data storage requirements for that specific application. Um and I would imagine other autonomous. Um? Things are the same now. We might need to look at all of the canned as a whole to make better decisions, say to say to help tune the watchdog timer to more efficiently go to bed and stuff like that, but I think that's starting to straight back into monetary.

OK, well that's very informative. So, as you talked about the. As you said that the storage requirement might be less for autonomous application because you need to like. I process the data and then send it in load at a very low latency requirement, right? So how about like? Is there any relationship between

the power consumption? So, like for instance you have ISO blue, how you compare it in terms of power consumption with Laura? when compared to Laura is an interesting question, um?

Because I'm not really sure they're comparable Laura specifically. My understanding of it is it's a wireless standard, and we're actually looking at integrating Laura within I so blue. Um, I would expect that once we integrate Laura, that will increase. The power consumption to a degree. I would be surprised if it was significant. Um, an example being that we just ran an ISO blue with the engine off for about an hour at lunch while the operator was taking a lunch break earlier today and we saw no issues there, and I wouldn't expect that to change while integrating the lower radio or anything like that. And currently we use cellular to communicate so.

Thank you, it's very informative. So yeah, so that brings to my last question of session. So, like as you talked as we talked about power consumption and communication range. So, so how do you feel like? And from your experience and knowledge like the autonomous applications require sensors and wireless communication technologies having more power consumption requirements as compared to. Monitoring applications, do you like comment on that?

Oh, in specific cases, I feel even even if we're talking about one application like a terminus application and the requirements on the wireless communication technologies will change depending on what you want to achieve here. But if you just want to, depending on typically speaking, if you want more throughput and higher coverage. You will have to consume more power. Yeah, it's like you can't get rid with with all of them, yeah? OK. So yeah, go ahead. I keep coming back to similar to you know others answers. I think it it's going to depend right on what the specific goals are. You know for what you're trying to achieve, right? I don't know that they are in a lot of these. There's not one broad answer that applies to every scenario. I don't think right? It's gonna depend on exactly what someone is trying to do and the set up. And you know, even things like field size and shape are going to come into play. So, think about wireless transmission. You know if you've got, you know, like line of sight issues in the field, right? For certain for certain types of data transfer, that can be a problem.

OK. So yeah, it's very important, I think. Also, you talked about the field size and all the scale matters here. The data scale, right? As we have a higher data scale for some of, maybe for like remote sensing sensors where we have a lot of images and coming from different fields, we have a higher scale and then we require some, maybe either some higher bandwidths and also from.

Maybe latency point of view, we can transmit the data overtime and have low storage or higher storage based on that. So, like specifically if we talk about smart irrigation and smart fertilization in this contest, do you think do you have any experience from your project that the scale of data required is more from different fields or it is specifically? If you're using smart education or smart for television is for a specific field? We are using a data. I mean, I'm talking about terms of like data scale or model like more accurate model. Or is it like fine we can like just analyze the data for specific field and then automate the irrigation and fertilization process?

Focused group interview session 2

The interview questions so far my first, so we divide the allateef wireless sensor framework in three layers. The first one is the perception layer where we have the different type of things under this type of sensors, from where we gather the data. So, my first question is based as open ended question that what are the different type of sensors that we can use to develop applications for monitoring applications for row crop diseases? Let's say on average size from.

So, this is going to be this is only diseases I mean you can you can have color cameras, multi spectral camera, hyperspectral cameras, so these are the sensors that are normally you choose for. For monitoring view crop diseases in drops or even or even in any other crops that you would like to. So, we monitor diseases, and particularly when we talk about diseases using sensors, let's be be very clear that we are trying to be monitoring foliar diseases.

Yeah, OK, so I mean. It foliar diseases. Then I mean leaves on the plant are one of the easiest things to detect with remote sensing and so. That would open the door to all types of. Optical sensors, I guess. Remote sensing.

So how about like the smaller sensors for measuring the microclimate conditions? Well, that can impact. Do you crop this like having impact on Blue Cross? Yes, here when you talk about the entire system of how diseases happen, yeah, then then definitely most plant is required. Pathogen is required, environmental variables are important. Yes, when you are when you are looking at the question in a holistic manner, definitely all three need to be present before a disease expresses on plants. Another disease, the disease triangle.

Yeah. Yeah, so are these like sensors, mostly wired or like their wireless sensors and like how about the heterogeneity of these sensors like and also like if you consider an average size from like 256 octaves, what can be the potential like number of sensors that we can install?

I mean, if you're if you're detecting something on the leaves of crops, then you would use satellite aerial or drone typically, and so. I mean these are sensors or few in number, but they're collecting a lot of data over a wide area. And I guess I'll just say also that you know adoption surveys have shown that you know. Uh. Using Precision AG for pest management has been one of the lowest areas of adoption. And you know, I think there's some reasons for that, because and especially with diseases there, that's been a really slow area for adoption because. There are, you know, for the most part you can't see the disease. You what you see on the on the leaf is the plant's reaction to the disease. You know, whereas you can actually see a weed that you could actually in many cases you can see the insects, but you typically don't see the virus or the fungus or the bacteria that's causing most of those.

Yeah, I definitely agree with that. I don't think adoption for like, even using drones or or satellite imagery release from the farms that I know the adoption rates. I don't, I don't know anyone using it. We all just still scout. You know, some people use it to see stand, you know after they after they plant they'll see you know count stand with withdrawal sometimes. But that's just kind of a. I don't know people, just. Have it as excuse to buy a drone I think.

Yeah, in fact you know my group is very actively engaged in collaboration with with weed scientist and plant pathologist on identifying weeds and then also identifying the the expression of stress plants through their leaves that we also called his disease and what I have found and again based on literature because we. Have a couple of papers on literature review. That that already 4 for submission in a very interesting manner where we have posed some questions and then we have provided answer based on what the literature suggests. So, what I can say is that the literature is. It is mostly concentrating on identifying these stress plants under very, very standardized conditions, and when the when that is standardized model is presented with the real-world data, the efficiency drops down drastically. So, then we have looked at some of the approaches and we at this point of time are 200 to 250% better. In terms of providing the the accuracy from the from the real-world data on a model that is trained on a very standard data set, so we are very very excited with that possibility. And and then you know. Just a couple of weeks ago I made a presentation in a conference, a tech in Kentucky, and there I also. I was asked this question by one of the. Participant and this is very, very relevant that what is the scope of some of the high resolution satellite data that is going to be potentially available in the near future and there has been some research done in the past where researchers have looked at what should be the spatial resolution at which the satellite can be used for identifying weeds or or identifying disease plants. And I'm just quoting from one of the. The research results where they suggested that a 2 ½ meter resolution would be good enough to make determination and how that is study was conducted. Essentially, they used a UAV at 10 centimeter resolution data set, and then they aggregated that pixel information to eventually find out that what beyond what pixel level they could not make an Association with with either the weed or. Or the disease plan. So there isa new series of satellite by it's called iOS satellite and they will start launching from next year onwards and by 2024 they will have a full constellation of six satellites and what they're trying to achieve is 1.2 meter panchromatic resolution and 2.4 meter multi spectral resolution and so that is really very very exciting. And one image will capture an area of 40 square kilometres, so this is likely going to be a very exciting development in the remote sensing that at least I will be looking forward to.

Turning a censored option on farms. I think in the in the weather front it it's you. Definitely see it more and concern with local weather stations to monitor like rain in your area. I see farmers using those or like or like climate. You know. How is that? They're using data from, not from from not those local weather stations, but trying to give you a field by field prediction based on weather models to how much rain hit this field, and that's useful when I see. Farmers using that so I don't know. So who is providing that kind of a service? Cyrus Climate has it has a service. OK OK alright thank you.

So, I just wanted to share my experience about two years ago I had the chance to work with drawings from the GI Company. So, at that time they were very helpful for getting the topography of different farms. That went well, but then the farmers wanted to know. Some information could be fine. Found about landfills so at that moment there was a huge void to process that. With respect to 12 data at that moment, nothing was there. Right now I think companies like TG I they offer you services, process images. You can use send the drawn at a

certain altitude and then the. Well, everything is cloud based. You upload the images and they will process and give you some approach. It's getting better.

I heard you mention topography.It just came to mind. Um, I know, at least in our area, a lot of our prescription Maps were using their using topography data to generate the prescription Maps, you know. So, it basically uses biography data that to catch the low points in the field so you know how much you know your wet spots, your field versus your dry spots, and change the population accordingly. And they're actually using that more in our area than they use pass yield history and stuff like that so.

Thank you, so let me add a few other things here too. Just here in the rest of you talk is that with diseases there's a lot of good information that comes from the external factors. Like you know what is the previous crop? That's a if. It's like corn on corn. That's a really big factor for a lot of foliar diseases. What's the percent residue cover in that field? And then all the weather information, the humidity and the temperature all drive things. Topography like was previously mentioned. You know, North slope, South slopes, high areas, low areas. All that kind of stuff would feed into sort of a disease prediction model that you know could be site specific and and use that way too, which wouldn't necessarily be sensor based. I mean some of this I guess would be, you know, originate in sensors, but it would be more. You know, putting the story together kind of thing too. And then you know, let me just throw something a wild card out there too. If I could dream. What about some kind of a low-cost sensor that you know is like the covid test? That is some kind of a strip that you could put on the leaf corn leaf and tell whether you have northern corn leaf blight or Gray leaf spot, or verticillium or whatever. You know that that baby is going to be standard 100 years from now.

So my next question is about the on field autonomous applications such as smart irrigation, smart fertilizing, and these sensors that we can Mount on farm machinery for during the harvesting season. On seeding purposes, So what, what how you can like specifically, some of the sensors that come into your mind from the projects that you have.

Yeah, in fact, in fact I I'm working with a company where we are developing. Smart irrigation system for high value crops and one of the challenges that. That I'm facing is not coming from the IoT side, but it is coming from the sensor itself. The sensor that we use for sensing moisture has to be in full contact with the soil and what happens there during the process of shrinkage and swelling. You know that contact is weekend, so there are some air pockets that gets developed and they just screw up. The entire reading that you are getting so while we are thinking about developing a smart irrigation system, we need to have very smart algorithms that that catches that some anomaly is there and then we just go out and find out what is the cause of that anomaly and just address it ASAP. So, this is one of the challenges that I've run into for the last two years continuously. That we have been running into very different types of soil then and we are saying that. We still do not have a very reliable solution available.

Adding to that. You recently worked with the Tails 12 sensor. Awesome sensor measures. Metric water content. Beauty and temperature. But they actually sell. The meter is the name of the company they sell out tool to properly set the sensor at different depths. And that helps, but

if you don't do it. We will be facing a lot

of issues.

OK, so one of the biggest environmental problems right now is water quality. An, one of the coinciding with one of the biggest expenses for farmers is there fertilization costs, and so both of those offered opportunity and were, you know, soil testing the same way that we have for decades and we're hungry to go to something that is much more site specific, but it's just not economically feasable. You have to go out there and take subsamples and uh. You know the common thing is 1 Hector 2 1/2 acre grid and that isn't near detailed enough to address the variability that's in the field. And so to me, like the big gamechanger that we really need is some kind of a low cost accurate phosphorus potassium soil Ph type of a sensor. And that, to me would revolutionize crop production more than anything.

On the autonomous watering front, something that it's not really sent related I guess, but but 360 yield just came out with this unique system. I thought that might be cool to look at. I don't know if it pertains to your research there they're having a like autonomous like boom that you you leave in your field and it pumped well in your field. I don't know if you've seen that and then you can allow your row crop with less with less water and stuff. It's kind of. It's kind of neat idea, I don't know. I don't know how they're going to power the thing. Like if you're going to go fill it up with diesel or something all the time, but I just thought it was interesting. It's called 360 rain.

So yeah, I had a point. It's related to the previous question. Sensors like that. Basic lamp that you can put on tulips. They are very expensive. But they can tell you how to plant is doing. For example, in nutrients OK. I just wanted to add that and. Yes, sensor calibration. So, it sensors the it's very challenging. You try something at some point of the field. Move one mile. At work. Money. Yes, so why? When you're planting, I saw another company come out with this. That that runs down your row, you know, like a disc opens up your row and then there's a little plastic thing that closes your row and they put sensors in there to monitor like soil temperature, and I'm not sure what else there. There's a few other things but that's kind of an interesting way to get, you know, a full field level sample across your whole field. You know, as you're planning, without having to go out and take grid samples across the whole field. Yes, it sounds good.

Yeah, so my next set of questions is from the communication layer various like communication technologies we can use and integrate with these sensors. So, my first question is like how the type of application? So for instance we are basically developing a monitoring applications for low crop diseases and on the other hand we have autonomous on farm field. So, applications such as proceeds and irrigation and fertilization. So how the data latency plays a role here and like? What are some of the like good communication technologies in terms of like communication, range and power consumption that we can adopt to basically integrate the sensors with these communication gateways? So yeah, what are your thoughts on that? Which one?

The one that you are using, Laura that comes to mind because of the long range? That you can communicate signals so that definitely has an advantage over whatever we are using another. Another very interesting thing that needs to be taken into consideration is that whenever we are

establishing two-way communication between our server and the sensors so many times. You need to make sure that the. The old data set that you did not want to keep is overwritten and you do not have any. Remnants from the previous data available and that causes some issues in improperly collecting the data, but as far as like we have run into issues even with the MQTT protocol. Whenever we were trying to communicate between by sending the two-way communication so MQT protocol, although it is, it is cheaper to use, but my students. Give me a feedback that it is not perfect at this point of time.

Yeah, so how about the data transfer rate requires so like for example we have monitoring row crop disease application, do we require data of at a very frequent basis like data latency requirement is more precise in that kind of applications or it is more precise in autonomous applications where like we have smart irrigation, smart fertilization or long purposes for education.

I can tell you what we are doing, we are. Although we are collecting data frequently using our sensor, when I say frequently that means every 15 minutes we are collecting, but we are. Transmitting it every hour also. So that's one of the ways that we have been able to. Control it an since the crop that my research group is working with is very high water requirement crop and its banana so we have we have not come into any issues at this point of time that we are missing or providing irrigation. Because traditionally farmers provide a number of irrigation. 4050 sixty irrigations. But getting that information. Every hour is still being felt good enough frequency, so depending on what type of application we are looking at, probably this is a research question that needs to be looked at.

How about like some of the technologies like fab you and says you're working on I so blue, right? So, like that can be used on farm navigation from machine to navigation. So, like how like in terms of like does that I so blue thing. So, the are you trying to work like to increase the data latency for that or degrees it like? Or like what is the communication range requirements for that? Is it compatible with Laura and like what issue you face in Laura that you can't use it in the mobile autonomous application?

Um, I guess confirm on the navigation front, which I salute. We're not really using it for like GPS navigation for like our TCM corrections which are using for RTK GPS is. It's like the transmit rates like around like 150 bytes, a second data that you need an right now. Most people are getting that over long-range radio or cellular. Um? And then, uh, the ISA blue data were sending that over cellular. As far as the. The need I guess the need for that to be the latency needed that, um. I'm not sure. That you would if there's any like real big requirement then of needing the data right away. I the only thing I can think of is knowing like we were talking about using it for um in a grain cart to keep track of how much grains in each combine as they're going through the field and but I could see you know local Wi-Fi. Using local Wi-Fi for that instead? You know you're not. And so using going over cellular or some other connection, you know. So OK, throughput for that want to be that high. Either you want to need, you know tons of data for that.

So so now that you talk about Isolux Cyrus, specially if you consider integrating lower to mobile devices, say machines combine vehicles. Where with Laura there is a big challenge related to Doppler, which basically Chiefs the frequency as as one of the points moves from another. So, yet we have to test if there is a significant shift when the vehicle is moving. But if we consider the speed of farm machine like a grain cart or. Combine. That's one of the big challenges to see how the movement affects the communication between 2 Laurel devices and 2nd with ice blue. Cell using cell network to send data has challenges because if you're working on a rural area you don't have warranty coverage, so there are going to be gaps. And you don't know how long will the connection be broken yet? Because that depends on the pattern where the vehicle drives around and also it depends on which carrier are you using to provide connection to your device. And it also depends on how fast and how quick you need your data. So, if you prefer to the Laura and how. Long you update your lo Lauren measurements. Then you might. You might choose to say, OK, I will kill the data that I'm not able to send at this moment, and as soon as I get connection then I will start sending all my queue data. So that's how I so blue is doing right now, so.

That consideration, yeah, I think I think that question you answered about about depending on the application when you need your data is kind of the biggest question and depending on what you're trying to accomplish. You know that's kind of application specific need, but I could definitely see you know if you if you if the data Laura is what you have here in this this presentation slide, I can definitely see that being useful. If you get, you know that data all the time and then you know if you want to record with ice Blue. If you want your real data at the end of the year, you know you don't need that. By the 2nd, get that at the end of the year, you know that the high bandwidth data you don't you want necessarily need you know. And you also need to consider the cost of running a streaming device running on cell data because you have to pay a monthly charge and that might be 60 bucks to hundreds of dollars. If you want an unlimited data plan and also consider that even paying doesn't warranty full coverage and full availability yet. But I think that's the biggest point. Most of these most of these farm machineries at least. Then listen and my expenses and you know, corn and bean crops were most of cellular devices I'm already for other like RK for example, so the cost isn't really that big a deal, but the coverage can be a problem. I worked with the RTK provider my way RTK and certain area right. We must do Verizon and we have pretty good luck with that. But I know in some areas that it is a problem.

Yeah, I would like to add that. Application, for example, with the smart you're gay Shun. You don't need like using the cloud for most of their decision-making processes. If you have smart fertigation or real time like pH and electrical conductivity control. You are just wasting money if you are doing that process on the cloud and you will be vulnerable to. Lack of Internet and also processing that data you're using. For example, the Amazon web services. He will cost a lot, so in that case it's better to use a microcontroller or appeal, see. That will take care of. Analyzing like in real time. Actuator two to turn onto out. Let's fertilizer applied. It also serves the purpose of working as a backup if you don't have Internet, you are fine. The PLC will. Working if you want to keep track of the pH and electrical connectivity, you can do that quickly and that will be. More than enough.

Um, now that Santiago has a point, you also need to consider. How often do you want to update your measurements? So also, you need to consider how big is the variable you're measuring. So, if you if you have a clear view of what are you measuring? How often do you miss your if you variable doesn't change too often then it's overkill to be sampling 8 every second so you can't save a lot and probably this is one of the biggest advantages of Laura, So, you don't. You can cover a big range an sending a very low rate. Yeah, instead of like, depending on a cell network modem never planned for just measuring a slow bearable like temperature so. Just something to keep in mind.

So that leads to the next category of question. This is the last category I have about the processing of data and storage. So, once we have the data from the sensors and it travels through the gateways and goes to the cloud services or through some API where we can process the data and generate some, generate some insights for either for like developing the autonomous applications or monitoring. Diseases so like how you can process the data, the data for monitoring applications such as low crop prices is so and how it differs from the processing in terms of the scalability of data. The amount of data that we have and also the latency rate required and the interoperability of data from different sensors. So, like in that sense, yeah, how we can like make the processing of the data more cost and energy efficient. And in terms of applications, does it? We also very on the applications like monitoring Group properties is and it differs from autonomous applications.

No, as as has been said that for for row crop disease monitoring and prediction. Adoption rate is very low and it is still re searchable topics so so commercial solutions are not available, But as Cyrus was mentioning earlier that you know plant counting and email monitoring, those are some of the applications where there are several solutions available. Ann and I was searching for the name of the company. Earlier and now I know it, its name is pick Terra to pick. Terra is a Swiss company an PICTERRA and I would. I would like you to visit that and seems like they have some very interesting solutions that are backed by I on on their website. Several interesting cases studies so they have a case study where they are measuring tomato plants and even by eyeballing you would see that how accurate they will. So, so depending on at what stage we want to to measure whatever plan trait, such kind of tools are available, I have not used it because it's a paid system, but I have brought it to the attention of my graduate Sprinter 5th. Anyone wants to compare their performance with what they are developing, then definitely we will go through that. Similarly, the Amazon, the Microsoft and Google's they have coming up with. Some artificial intelligence-based solutions that have a lot of potential for adoption in agriculture. So, I'm looking forward to that, but my biggest concern is and this concern is not my concern alone. I have heard it in in conferences that have been organized around the topic of where the the decision AG or Precision AG industry is heading towards. You know, the currently the large ecosystem that exists of several smaller companies competing. With almost very similar kind of products, need to pay way to to really some big players who can who can provide terms and conditions that are that are acceptable to producers who can take steps to really inspire confidence in the producers so that they are ready to share that data. And once that happens, as

has happened in the in the. The general IT space where we can talk about Microsoft and Google then and Yahoo's like that who have some domain specialization. It is going to be free for all kind of thing that they will be 100 companies in Europe 200 and US 500 and Asia. Things like that and everybody is trying to offer same service and farmers are confused as to who to select. No. Hill.

Like in terms of like open source data and like. Are there any open sources that you know from your experience, from where the data can be extracted for basically developing these applications? Like if you are in the US region, yes, yes. In fact there are. There are a few data sources that are available for. For developing your models for disease to detection and prediction, one of the most widely cited data sources, plant Village, it has more than 30 five categories of plant. More than 50,000 images that are available. But then Plant Village has one of the limitations that all the data is acquired under very, very standardized conditions. Then there is another publicly available data set that is planned. Doc plan Doc has images. Yeah, that come from field conditions. But then plant Doc also has a lot of variability because some of the images are of leave. Some of the images are of stem. Some of the images are of the entire plant, so once you try to filter only images of certain types that is, you want to consider only the leaf images. Then the size of the data set is a small. Similarly, Steve words is another day plan, datasets and and some of the other datasets that I'm. Unable to recall their name, but my group has actually looked at 6 publicly available data set and we have a paper that is right now under the second round of revision where we are discussing as to how useful those publicly available datasets are as far as predicting plant disease is concerned. So, we have found that yes, publicly available data set can be used to some extent to train your model, but when it comes to generalization? Ability of those models then their performance needs to be of an acceptable level.

I think an issue that needs to be discussed too or at least made record of is that you know there's this open source data, but a lot of the data that it is necessary for, like this disease detection and management or other things on the farm, nutrients etc comes from different sources. You might have some that would come from an egg input provider that would be doing custom applications of pesticides or fertilizers. There might be some coming from the farm machinery. Come from from the farmers perspective or a consultant. Or you know if you're if you're ordering aerial imagery, there would be that source and other sources too, so getting those all to talk and agree to go into your model is something that I know a lot of people are trying to work on. Yeah, thanks, thank you, that's insightful.

So, like if you compare the amount of data. In terms of like also like in terms of applications you have, for example, the applications for autonomous and re generative models for artificial intelligence and others side we have the monitoring applications. The data from that. So, like can you compare the amount of data and the heterogeneity of sensors.Based upon the applications.

Yeah you have hit the nail with bringing in the sensor data heterogeneity. Anan how whether we have enough metadata available so that we can compare the. I doubt that we have that level of detail available, and that is what is also driving one of the startup companies that has come out of UIUC where they have been looking into this and when they reached out to few of us in Purdue they were also promising that whatever data they are collecting, they will make it publicly

available. So although I talked about. Five or six different datasets that my group has looked into. But we definitely feel that that more and more data sets need to be made available. And when I say data set, I'm refering to annotated data set so that you can exactly find out at what is the disease and you can you can use that annotated data set into training your different machine learning or deep learning model. So that is one of the missing pieces, because although we. We reached out to Plant Village plant dog datasets, but then we had to do the annotation by ourselves. So so a very large scale annotated data data set is still needed and that is that is 1 area where I. I'm hoping that more and more generals will be inspiring the researchers to really sharing their data set and that way in which the whole community and also lead into a lot of. More and more, I would say hackathon type of events where some novel solutions could be developed and and disseminated. Because Kaggle has used some of the datasets that I informed about. So and you know, Cagelles kick Kaggle provided data set is used for several hackathon events worldwide.

Well, I guess I can share my experience, so I used to work in the Flowers industry. So basically, each farm will be its own model and they will be reluctant to share that. We even the neighbor Farmer. So, getting that information out. He said because challenge because. You don't really have to say it. To compare with. If you are you're mediating. If you are fertilizing. Very some point is missing. So larger companies. For example, in Colombia huge company that has farms in different regions. And they have the chance to gather data I guess from thousands of farms. So, at that level. They have the mother. They are able to predict and Control things. Properly, but you will not find that information. Yeah, 'cause I'm also different different vendors. They use.Some DLC's for irrigation, yeah, we'll see. To give you the. Flow rate, pressure, pH of that so that it is very hard to. Join that piece of information we. The Fertilizing team for the. Different sections of the farm. So as previously mentioned, integrating like different. Yeah, actors is it.

Focused group interview session 3

I will start with the questions related to the perception layer, little type of sensors. So, what are the different type of sensors that can be used for gathering data regarding monitoring applications or flow copy seizes on an average size form and the other question is issue with it. Is the approximate number of sensors that can be used? Considering the average size farm of 256 sectors in Indiana region?-

If you're looking for open ended answers correctly. There are all sorts of sensors on agricultural machinery with the engine and the transmission of tractors and combines and sprayers, of course, implements that do things to the ground. Planters, sprayers, tillage, implements, etc. Some of those have many instruments, so those all actually are sensors to know that. Which is a plow was in the ground is a sensor essentially so there are lots of those. There, are sensors in the air in the soil for moisture temperature. Can some chemical sensors are growing in popularity? There's many at the moment, but there will be some. So, there's a whole category of those kinds of sensors. They're open and shut switches, just the status of things. Is the gate open? Is the gate closed? Is is this the auger on? Is the auger off? I mean very simple sensors like that can also be used for lots of things. I'll stop and let some others chime in. Yes, anyone else wants to answer this. Yeah, so I think 1 nice way to classify the sensors and

DB started out well is you can think of sensors that are there in this various farm equipment. So that is one kind of sensor and a lot of the times these farm equipment's can be smart right? So, they will have to interface with for example soil condition. So, let's just consider like maybe row crop where they're being planted Context so that you might have,

you know, sensors in this agricultural equipment. So that is one class of sensors. The other class of sensors they can be to do with all sensors that have been deployed in the form itself, right? So, you're trying to see what the different soil conditions are, so a lot of that has been done at video and these could be moisture, temperature, nitrate, and the fancier ones that will be nice will be are you admitting floor? OK, um, sorry I got distracted and the fancier ones could be like the carbon sensors. There are also sensors for microbial suspensions, so in one of our, previous proposals we wrote a little bit about it. If you want to go fancier in terms of, you know various organic supplements and we want to maintain the soil microbial concentrations so those would be microbial sensors and carbon sensors. I think those are the ones that are not currently being employed, deployed in the area farms, but they might be very interesting sensors to look at. On the other hand, I think the environmental sensors, right? So, the soil sensors, the equipment, sensors, and maybe the environmental sensors to do with wind speed. If there is pesticide spraying, maybe how much of it is being carried away by the wind? So things like that, so I think it would be nice to have that kind of classification that there can be sensors at various levels for form data. Stop there.

You also have, you know remote sensing type things that are that are going to be impactful and and I think you know. Like your neighbor is a sensor to already specially comes around to diseases, right? So no one. I think important sensor is also like communication of observations. You know as diseases tend to spread right? So if you know what's around you or or you know of of environmental conditions that aren't necessarily at your farm,

but maybe in the area that might help change your evaluation of like the likelihood of something happening or what should I be looking for? So, and then the human is, of course is a sensor. Now, how do you make the human more effective at? Scouting, you know, based on that knowledge of like what should I be looking for? So, if I only have so many hours to scout, most effective thing just got 4.

One more thing that I want to add is. Or there's a thing called bring your own device, so bring your own sensor, which you can say. Use your cell phone or your tablet and then because they already have a bunch of sensor, built in, their honor gyros and a GPS in them. People can just write apps or just turn on a setting in your being some of the existing app to use them as sensors.

Andrew mentioned the remote sensing. Sometimes it isn't so remote, sometimes it is, but images whether they are still or video. Uh are certainly a source of sensing and then that opens the opportunity for, well, not just red, green, blue, black and white, but then hyperspectral as well. And then I want to make sure we note audio can also be the sensor. Actually, when a person is doing things. It is one of the most common sensors that you use to detect something is fishy like this machine is not operating right. How do you know? Well, you heard a different noise than you usually hear, so audio as a sensor could be very powerful.

a quick addition to that is you can add to that that you know depending on where the sensor is deployed, right? So, the sensor could be on an aerial drone or it could be deployed in the soil. So, depending on or it can be deployed in their farm machinery. So just another way to classify depending on what we're trying to measure. Or it could be satellite sensors, I don't know, maybe it's outside my scope but just another way of looking at the way they are deployed.

So, this is right over here. I would like to just add one point to Doctor Chatterjee with just mention and you're right about it because probably my company is working on developing the digital farming and digital agriculture equipment's and there is something called a TV to digital signals. An, satellite signals are absolutely possible and that is what actually lots of companies in USUS is based on. This satellite communication and that is something that we are currently working on with trying to develop the technology and talking to supplier. If we can get all that in and get that inside one. Android Box so that you know. So, for example, that goes to a farmer or anyone. They just have everything in one box and we provide them the MDM NWD watchdog technology through which we control the data. We flash the images and for example if there is any breakdown in any situation we all have the backup stored data for it. So that is something that is actually in development and I'm pretty sure that was gonna be the trying to do really resonates with what it's going to be in future. Alright, thank you very much.

So my next questions are. Associated with this one only. So as we talked about the monitoring of local offices, so are there any we can use for on field operations for like for smart fertilizing.

I guess those are we already listed. OK, if you if you think of actually spraying and stuff, I think something comes to my head just to put some animation into it like terrestrial robots or UAV bear. You would have sensing an actuation right? So there is a sensing component and very importantly in cyber physical systems there has to be an interface with actuation, so having that sensing and actuation when you considering various kinds of auto, not enormous spray, it would be either from aerial drones where you would have sensing and

actuation in the form of sprays from their phones, or you could have it. Using terrestrial robots. So maybe the agent that is doing that activity, having that actuation implanted in that agent just now. The dimension of thinking about it.
So how the heterogeneity of different sensors in terms of data interoperability impacts the IT can impact the power consumption and also relates to how it can relate to the cost and also in regard of the data latency, the latency from the sensors, how it can impact the power consumption. Uh, and how it is based upon type of season agriculture application. So, for example we are using some sensors for an application for precision agriculture application that requires data. regular interval of time in terms of like high latency or that request data with low latency. So how the application different application, for example monitoring applications, can differ with the modification smart fertilizer?
Application that regard.
Yeah, this is something that I've always grappled with, so let others talk because I'm actually curious about the ability to modulate the kind of analytics that you're doing.
Depending on how latency sensitive that specific activity is, and in general I don't think the latency thing is ever at the millisecond level or the second level. It's always at a higher level of granularity because you know if you're like sensor monitoring, for example soil monitoring. I'm like the comparison that I'm making is compared to self-driving cars or what have you and hear others may be able to chime in if you have like a self-driving tractor then I guess some of the latency sensitive mapping from the self-driving car industry comes in where you might have to do on device analytics to take care of that latency issue. But in general, I think more of the typical agricultural applications have a greater bandwidth intensive latency where it does not have to be at the second level. It can be at the. Minute level or the our level. So yeah, I I think that's an important thing and maybe I'll let others chime in and then I can get to tell you at depending on what the latency requirement is, you can have different ways of doing that analytics.
Or I was just going to say, I mean, I mean, I think I guess essentially agree that at large. Amount of the agronomic data is often. Not very latency sensitive, you know, I mean. Days might start being a problem in weeks, probably our problem. If you're going to act out of a millisecond, certainly not a big deal, but I do think as you start seeing. Automation and autonomy in vehicles and equipment and sprayers and things like that. You do have this sort of local. Analytics are processing problem that does have latency issues. So, you know like we were just talking. If you had some sort of censored on your irrigator that could you know spray based on, you know based on sensor readings. Of course, irrigators are not moving 100 miles an hour, but you probably do need to be able to make decisions here faster than a second or something like that. And we are starting to see that you know. I remember there's a laser-based weed. You know that you put on a boom and it actually it's the weeds with the laser you know, and that's a lot of image processing. That's all happening local and you know, so I think I think I think you're right most of the time the data doesn't really need to have this highlight. Low latency link back to some major processing, but edge computing I think is still going to be a key element in advancing some of these technologies. Technologies are making impractical.
characterize things as agronomic so that would be the plant in the soil. If there is remote sensing or otherwise you know yes there is time to move that to the right place. Do the computation, generate the prescription and then send it out. But, also increasingly there are

machines that on the front of the machine they sense what needs to happen here and on the back of the machine it happens so in that case there really is no latency like it's. You know it's gotta be within a fraction of a second depending on the speed of the vehicle, certainly anything that's navigation related if it's autonomous, has to be sub millisecond, because otherwise you're going to be running into things or spraying the wrong things in the wrong place. Let's see. So with regard to making strategic decisions or the logistics decisions about where to move machines and sort of what to send to a field. Those can deal with latency. But if you're acting at this particular spot. Then certainly some aspects of the sensing are very latency sensitive, even if the only thing that's critical is exactly where are you in this moment? Well, that's very critical 'cause if you're in the wrong place, you're going to spray the wrong thing Plant the wrong. See. Do you know the wrong action?

Thank you yeah, so along those lines, one of the things that had asked Intel in air for example, is that when they take images are there are they interested in activating in response to what they're getting from the image? And so right now? For example, they're not interested in doing that, so it might have changed hence, but this was a few months ago that they basically grab these images and then they transfer them to their gateway or cloud or what have you. But like Dennis mentioned, as these become smarter in the sense that sensing and actuation is actually coupled in real time. C as the cracker is moving through the field, or if there is a drone that is sensing and at the same time spring then I think it becomes important to at that sub millisecond level that you would actually have to do the computation and then I think you have questions later on that I can tell you some ways in which you can improve the latency of the. When I say improve it means lower the latency of the application. In order to do that in real time or semi real time.

So, the other question. I have one follow-up is, does the? Heterogeneity of different sensors impact in some way, like the from the cost and energy perspective, is that there is any Association with that. So, for example, we are using some wireless sensors. And other, on the other hand, we're using some wired sensors. So, which of them will have like more power consumption or less power consumption? And with regard to that cost as well, from your experience on different projects, we can comment on that.

So, I can't speak. Can you hear me? Yes, yes, OK. I can't speak to some sort. I've worked on projects that range from plant science to animal science and animal science. Context, sometimes we have sensors that are proprietary and the vendor just tells you. Here's the rest API that you can pull the data in from so we can't quantify what the power consumption is for that. But then you have on the plant side. Sometimes you might have sensors like the from the farm Beats platform where you could determine how often how often you want this data. So, then that determines the power consumption that's going to be drawing. And so that that's to give like different perspectives on sometimes you might not know how it's affecting the power consumptions. And sometimes you can see immediately that the battery level is one of the sensors that you were looking at and how the power is being drained.

Would it be right to say that most of these sensors are wireless sensors? Or that's not true? Just because of the fact that they have to be, I'm thinking of the soil once most of them are wireless as in. But yeah no. So, the ones that are installed in the soil. Because I think that is an

important criterion, right? Because then you would have to use lightweight applications so that you don't drain the battery fast. So as far as I am concerned, most of the ones that we are deploying are ones that are running on battery and therefore we right now we don't do PP computations in them. But if you do that then we have techniques in which you can conserve the battery because then that becomes a big criterion. You don't want to go to the farm every day and change your battery. But yeah, I I don't know of too many wired sensors and looks.

Well, I mean it. It depends on what you mean by wireless sensor. So, no. So yeah I have wireless segments answers most of these setups are wired sensors that go back to some sort of base station that then is wireless. So, you might have. Four or five or six sensors attached to one unit, so I don't know what we mean by wireless sensor. If that counts or not. If that is, if that counts as a wireless sensor to say yeah, probably mass majority of them are that in some way. You know at some point it's wireless. You know, just because, like you say, that you know is building an infrastructure to have wired communication all the way out in all these fields would be important. You capping cost ineffective, but I think you know from energy usage is an interesting problem because. It's like. Do we care about the energy usage we care about? Like how long it'll last if it's dark for you? Know if we had, you know, stormy Week or something. So, like the good part about AG is that it's outside and so I energy harvesting techniques are prime like it's the best place in terms of all the things you can think of is one of the better places to do. Energy harvesting solar panel. There's other options too, and we see like weather stations that have once a minute. Reporting cellular networks, you know, kind of all these things that we would consider high power and not really feasible that are out there, you know. But because you don't need thousands of them, you can put a big enough solar panel on him to support that, so I think it's like this weird question of if you're deploying thousands. There's a whole different problem than if I'm just needing. Deploy one per 10 acres or something, and the tradeoffs there. You know, I don't think there's one answer is, I guess what I'm trying to say is it's really installation specific. Just as you were just talking about, how do you define a wireless sensor non-wireless sensor? There is the also the group of sensing where yes it. We might say that it's really all you could put it in a category of wireless, but essentially it's attached to an engine of some sort. So, like there are, there are sensors that are you have AC power like you have in the in the home and the business in a factory. Well those aren't wireless if they're connected to that power source. If you have a sensor that's connected to an alternator in a battery on a vehicle. Well, that's sort of the same category like you don't have to worry about power consumption of a sensor in that since the ones that you only have to worry about power consumption is these that are not tide to an engine of some kind.

So insightful, so my next set of questions are from communication layer that is wireless communication technologies that can be used for integrating different type of sensors. So, for let's say we are like developing a preseason application based upon monitoring row crop diseases and we need to integrate different sensors with the gateway or any other wireless communication technology we want. So, what can be the most effective and efficient way? Now if we talk about efficiency in terms of cost, power consumption and scalability, and when we talk about effective in terms of communication range between the sensors and the gateway

device or any other wireless communication technology were using and also the capacity of holding the sensors of the wireless communication technology. So, my question in regard is does it depend upon again the type of precision agriculture application we are using? So, for example we're using monitoring. Acropolis is, on the other hand, we're using smart irrigation, smart fertilisation, and on the other hand we're using it on for farm machinery navigation. So yeah, that's a better picture of the question. So, what are your thoughts is that is a big question.

It's probably not. The answer is probably not very useful as I think. Again, it depends, right? And certainly like. Something like Laura LORA, one maybe more specific would be appropriate for like one of these, you know, hundreds or thousands of sensors spread out over a huge area. You know and Something like that would typically be, you know, power or battery, small battery or energy harvested kind of thing. The sensors, probably by nature, not a very fast update rate, or doesn't measure very often. And so, it Maps to that technology well, but there are a lot of other things you know or Laura won't solve the problem in the space of AG One would be just, you know, machine automation. You know, like you'll never going to be able to to have a cloud connected machine that's maybe utilizing the cloud's ability to do real time computations and have that connected through Laura like this is probably just will never work for latency reasons. For bandwidth reasons I mean for a lot of them, even though power is not a problem. But then you know, because powers in a problem you're opening yourself up to a lot of other technologies, but that doesn't necessarily mean the infrastructure is there. So, we like to put cell modems and tractors. When we put our iso-blue right, but it only works when the cell networks there and around here. That's fine, but when we go out in Colorado, there's all sorts of spots where cell networks not there. So then then what do you do? And so, then you get these intermediate. This newer technology that are emerging CDRS, and TV white spaces that like. Bridge the gap. So, I've been saying this a lot lately too. It's like you know, I don't think AG has one answer. It's like there's probably realistically, you know, one farm in the future is probably going to have lawyer radios. It's going to have CDRS radios. It's going to have Wi-Fi in places it's going to sell, sell radios in places, and it's probably more important that we start working on figuring out how to bridge data across these technologies so they so they can utilize each other when it makes sense, rather than focusing on how do I build Sens array that uses this network?

Open there is like if you consider it a long-range technology, right? Especially like in the IoT sick Fox Cellular there is very little interoperability between them, so I think interoperability is becoming I. In the last farm beats stuff there was a little bit of networking thing. I think you guys had a paper as well on this mission, wasn't at you or I feel like it was you from Cornell. Or maybe this you were talking about in different parts of the farm. You'll have like different kinds of networking depending on how. What are the conditions in the farm. So, I think there. If you are kind of considering a combination of one way to classify, again, I think it's nice in my head to think of a way to classify things would be short range, long range and medium range, right? So, we're thinking of short range you can consider BLE right? Bluetooth, low energy? Or that you are the Ant protocol, right? And as a proven ultra-low power wireless protocol, so you could have Bluetooth, Bluetooth, low Energy and aunt right? So, you can consider those as being under short range long range. You can have LORA can also have van and mesh Laura Arnold. Mesh Van's obviously it has the

advantage of being an open source technology where some of the others like NB, IoT, SiG Fox, Cellular. These are all proprietary and I think open source obviously has its own benefits, right? There is the the NB. IoT is definitely nice. You can have NB IoT tier towers, but it is more expensive. Varies when is actually I think not. I think I know that they are connecting doing Laura van connectivity which will be nice. It will have this open source thing in addition to if you want. Parts of proprietary technology. So, I think going along that line short range will be BLE and Bluetooth long range will be Laura, NB, IoT, siG fox cellular and then if you consider mid-range in labs for example, you have Wi-Fi in our embedded testbed we have Wi-Fi, so that is one way of looking at it at it. Depending on the kinds of connectivity you need in terms of long range migration, short range.
So, the follow up on that is like is. Is there like any kind of Association with like if we are using a kind of an application that requires very low latency that is like farm machinery, navigation or other autonomous thing. So is there any Association like we need to use particular kind of short range or medium range or long-range kind of wireless communication technology will be more beneficial in terms of. Um, in terms of. The application, the purpose of the application and also like if you're if you're having high latency, then like we're using Laura, and if we have some loaded latency required, then Laura might not be useful because it has the risk limitation on the the sending data at a very low rate. So, in terms of that,
like. What what's your thought?
I guess we don't see why is. Hey, I think latency mapping to networking I'm I'm not going to be the first one to talk about it because I don't consider myself to be an expert, but I would think latency wise 5 three is important, but obviously in the farm you'll have obstacles like my tree, but I'll let someone else answer that question.
I don't know that 5G will ever work in rural settings because 5G means different means. How many it means 5G different things I think, and so the the whatever the right word is the unbelievable number of close towers that it requires in order for it to be implemented.
Well, that ain't gonna happen in a real space, we can't even get infrequent towers, let alone frequent towers.
Yeah, I mean I, I think millimeter wave may become useful in farming applications, but not as a backhaul, or not as a database backhaul. You know, I think you're going to start seeing these super high spectral imager images. Imagery in cameras becoming commonplace on vehicles doing analyzing the plants as they pass by, and things like that. And you're going to have this need for this really high local pipe in millimeter wave and. .5 G is what 4G was supposed to be, but they couldn't get to it, and 4G was what 3G was supposed to be, but they couldn't get through it when they came out with that. So you know 5G. It's always going to be, you know, bigger and better, right? But but usually it means shorter and denser like like you were alluding to and and so I think. You know, probably from like a wireless high speed, low latency, wireless sort of backhaul. You know 3G is probably like the right balance. You know in terms of density, verse bandwidth that you need for most applications, and we haven't really seen that. You know the economic gameplay out there where where it makes sense for Verizon, AT&T and these guys to build enough towers to really cover roll America. And so I, I really think it's like I said it's going to combination of all of these radios, and I think the real like research that's that's needed here is more on the networking side and not so much on the on the wireless physical

sign in this idea of like, OK, I have all these technologies, but they come and go and like reality is that they're going to come and go because you're out in. In this environment. And so how do I pick which links to use to send what data? And that's almost like a real time thing, like your network of things needs to be able to handle this and mesh data through them. And sometimes the answer is going to be. I'm going to put it on that machine and he's going to drive over there 'cause there's better Internet over there and I don't need it. I just need it by the end of the day, so I'm not going to try to get it up over my bad back. All I have now I'm going to prioritize this other data that's more important and so you know, I think it's like almost this networking layer on top, or it's like. This is what my capabilities are right now, and this is the data I need to transfer an who needs what based on what priority, and then it kind of moves data around the network so so that when you have that glimpse to sell, it's like OK. I really need to get this alert up because because the engine is about to start on fire or something, you don't need to tell the guy and I'm going to Thomas Robot. No ones around to see that I'm about to explode. It's more you know it's more about that. Like how do I get the right data to the right place at the right time?

I'll add this to Andrews coming to really use the word and got complete. I hope this shows up in your report somewhere here. We're talking about talking about all this need for autonomous vehicles, autonomous operations, but the truth is, we don't yet have autonomous data. And that's what for the Andrew speaking to like data just needs to get to where it needs to go without a person involved all the time and making a decision of how does it get there. And so when we true and use the odd thing thing is already digital, it ought to be relatively easy to make it be autonomous. Things that are mechanical and etc. Well, that stuff but. Yeah, autonomous data. That's what we need. Sign me up for that. (DB)

That's why we now have what we call Community cellular networks that are being built. You can check out. I think it's his name is Curtis Hammerl University of Washington, so they're trying to do this thing where. They realized that with every single new technologies, as soon as he gets close to the rule region, it dies out. The next technology comes through. Then they, like Andrew said, they just never quite make it. So then what they're trying to do is to make that bridge too. They're still trying to get 2G with just SMS and voice to rural communities in the Philippines, so that's how far back we are in rural regions, and there's some value to what Andrew said where you need this sort of hybrid networks where you just. It's like you move on the stack. You go from low data rate, get the data somewhere and then drive it to the next stack so you can have more bandwidth and then so you keep moving until eventually God willing will ever get to 5G. Yeah, so long those lines I think that is a nice prepays to I was saying is you can have like software defined networking right? So depending on the size of the data rate you want the bandwidth spreading factor. You basically see what is your so they'll be an automated thing. Of course if there is more autonomous data but that you have these autonomous networking decisions where is very you basically essentially have an API where you have the software defined decision engine to decide on which networking. Modality is helpful for that specific situation, so almost like using machine learning you would basically automate that right? So you would have these interoperable networking scenarios and depending on what you need you basically put in the spreading factor, bandwidth data rate and you spit out the networking. So that would be a nice way to do it. You know some of the more advance five dates at work can happen in ACH settings. Yeah, so I think that ties in nicely to what Andrew

was saying and Gloria was saying. So, the. Associated with just to add real quick, we don't need to talk to you about it, but I do think like Starlink in these sort of. You know very low Leo satellite Internet's are going to be impactful in the egg scenario. I think they're probably going to still be some of the most expensive bits that travel, but with the needs for. You know, there's autonomy brings on the needs for consistent real time connections that maybe it's more for emergency purposes or for a much smaller subset of data. You know it's going to be useful tool where you have it, is one of the few things that we've seen that's going to provide connectivity across the country at a pretty constant rate.

So, follow up on that you mentioned about the scale of data, the data scale and issued with the data scale. Does the different type of communication technologies we have like Laura TWS, Bluetooth and Zigbee? This is also there. Does the scalability factor is associated with the? Communication range and also with the power consumption. In terms of like, for example we are, we are hooking up 100 sensors with one gateway, four of like Laura, and we're hooking up like a total, like 150 sensors with some other communication technology, wireless communication technology. So, is there any Association with that? Does it vary? The amount of data from different devices.

So I'm asking like the amount of data we have and the communication range we have so far. For instance we have like 100 devices, 100 sensors we have with some Lora gateway and we have the other we have on the other side. We have like just 50 sensors and we have same Our gateway so does it.

Does it impact on the power and does it have a solution with communication range?

So, I can tell you about the power because I have a table from a paper that I just measured open, so I couldn't have rattled us out of the top of my head, but for power we did a comparison for some of the different wireless technologies and you can even write this down because I know this from the work we have done that mention this paper. So for I'm rattling the soft it's 92.9% because we were interested in the power consumption for data transfer and our goal was to decrease the data transfer. For Billy, it's obviously much lower. Especially Bluetooth low energy, right? So 85.8% for Laura it is 99.9% to Laura and Sig Fox. They consume a lot more power than daily, so the numbers there are for Lawrence Xbox. It's 99.9% both of them. And for Billy it's 85.8% an for the two wireless technology protocols that are widely used each or two .11 PSM&E 2 two point one 5.4. They're about the same for the first one, it's 92.9, and for the second one it's 90.6%. So these are the percentages of the power consumption. So I think just to map to a higher granularity, BLE is quite a bit lower, so 85 versus 6 box and low RES 99.9. So you may have to consider that if you're thinking of data transfer using these different wireless technologies.

Mr Radios, I mean, I think I think it's important thing to remember is that there's a. There's a capacity of your channel and there's nothing you can do about it, right? So it's all about, it's all about where you push the power. So BLE is low power on the client side because the server side became significantly higher power. Same with Laura. Laura's gateways consume huge amount of power so that their clients don't have to. You know. I mean, it's a balance. You can only get so much data rate for a certain amount of power. It doesn't matter how you do it, but you can control through modulation. Teams where the power is in through protocols, you know so so Lorawan may not be the most energy efficient solution. But it's likely one of the better on the client side, but overall it may not be better than something else you know. (AB)

Yeah, so like in terms of the same factors, we have costs, power, scalability, latency and intermittent availability and scalability. So how we can efficiently and effectively store and manage the data and depending upon for example, we again the question varies with the application type of application we have. So for instance we have row crop monitoring, we have smart irrigation, smart fertilizing and auto normals formation in navigation. So how how we can what else was different platforms that we can use for data storage and processing that will be more effective and efficient? And as it depends upon the. Uh, factors that we discussed about the latency and communication range and scalability.

So like I said, I'm gonna rattle it off because I actually put some pointers there based on some of the work that we're actually doing actively right now. So three things that come in mind, one is obviously multi sensor Fusion, right? So how do you fuse all these different datasets that you're getting from these different sensors? And you might have to do a combination of Patch and screaming and analytics, so you might have some trained model and then you might have to do online updates to the model based on the new datasets that are coming. Or when the you think there is a significant model shift from the existing model training, right? So you might have to keep retraining the model using online data so that that first one. Again like classifying, I could call it like multi sensor Fusion but at the same time you want to provide a usable API right so that people can understand at the front end the results

may be properly visualized from the different sources and they might be some sensor sources that are resulting in noisier data than the others. So you might want to normalize. With respect to that, and there are other ways of doing dimensionality reduction, right? So, so if you see noisier data, you can do more dimensionality reduction or noise removal for that, or outlier removal for that versus the others that are clean or so. So that is one way of doing differential analytix. The other is related to latency, so if you're concerned about latency you might want to do more of the processing on the device or on the edge or in the cloud depending on the latency requirements of the process, right? The latency requirements and the power consumption. So we actually have found that if the latency requirements are low and you basically want to consume the power, and that's where we did this comparison between the different wireless technologies that Laura is much more power consuming than Billy, then you might want to. Depending on what networking modality you will have and the battery requirements of that sensor, you might want to kind of bound the amount of data transfer that is happening from the sensor to the gateway, right? So that you're not using up that power really. Fast, so depending on that you might want to run the analytics at different levels on the sensor at the edge for on the cloud, right? So that is depending on latency requirements depending on power consumption requirements, right? So that is one thing that I wrote and then the other thing is you can't run these beefy neural networks, right? If you're doing object detection right, and if you're wanting to do object detection on these Raspberry Pis or Jetson nanos, right? You might not be able to use these very large neural networks, right? You might have to compress the models alot. To be able to run them on the sensor or the edge, right? So, running the analytics locally or at the edge will require some adaptation to the neural network in order to run them within your essay. Pounds write latency, bumps, and the other is transferred to the back end, right? So, when you're transferring to the back end, if your content is too complex, you don't want to hog the entire bandwidth, right? So, for example, if you have object detection and your kind of constantly trying to transfer a major re data, you don't want to hog the bandwidth. By continuous transfer. So, it's not only the latency and power requirement, it's also the amount of data. So, for example, image data video data will be very busy, so you want to limit the transfer so that you're not hogging the bandwidth and you're not. You know, increasing the latency. So, I think those are those are three ways to look at it. I might have actually mostly said 2 one is. How do you compare the three? Would be sensor data Fusion. Then treating the model in a way to compress the model and then the third would be how do you transfer the model between? If you can think of these three, the sensor. The edge on the cloud. How do you decide how much to transfer the model? For example, Cloud will give you most accuracy, maximum accuracy and you can use very beefy models that are pre-trained, but you might not be able to quickly update your model right? So those are some of the considerations to take in mind for the analytics side, OK? Alright, that was insightful.

would I would like to add is it depends on your. I guess it was let it would like to touch it, touch it said sorry she said where it depends on your pipeline. So, like if you're trying to make it so that one set of data set as soon as it gets into a place it triggers another pipeline to go down the line. Then you might need that determines what type of. Storage you can use so like for farm beats like they're storing data in a table. Then a table can trigger something down the line so they have to pull that data out of table to trigger something else. So then when I'm

trying to build on top of farm beats when I'm getting my data I have to use a different database like Cosmos DB cause that has that trigger that I can give us like change, use the change, feed the code data set have changed so then I can trigger everything down the line. So in a way it's what type of pipeline you're trying to build and how reacted you want it to be. Then that determines what the data. Like the data storage technology will be.
OK, alright I missed out on that, so that's excellent. That's actually something I love as well so we have developing different kinds of database technologies so one is where you have, you know Cassandra, what have you where you're storing everything and your regular vanilla kind of databases. But then if you want fast retrieval then I don't know about Cosmos. DB is Cosmos DB in memory.
Um? I mean, I think you are. Yeah, I think you can run it locally, but this one was developed mostly by Microsoft. It's geographically distributed, so you can write here, but also it's replicated world. Got it. Yeah, I've heard about it but I wasn't super shared by the architecture, but if you're looking for in memory databases where you want bleeding edge retrieval, then you can use something like Redis, right? So, readers will be much faster, but they are much more expensive. So, if you want to use cloud infrastructure if you're using Redis. Oops, I'm it's not coming to me, but whatever they read, this thing is if you use those, those are significantly more expensive than their regular virtual machine instances, so it will be much faster. Retrieval appear interested in that because it's in memory. Where where is

the others? Go to the hard disk. So, depending on how fast you want to retrieve it, I think that database angle is also a very nice handle.
So, I'll touch on it from a different angle. You know from a practicality perspective, from a true adoption in the field, people using this, there's probably data interoperability in solving. How will people communicate? Common data from company company sensor, sensor, business, business, whatever is probably more important right now. At least then the technical specifications of the type of database you're using or how you're storing or how you're processing. And I think we've seen. You know in other industries and we can look at the business industry. You know, as a good example or ERP systems big companies buy from big companies know humans talk and they all have different back end systems, but they at least came around long enough to say hey we have this real problem or I need to get my purchase orders to you without talking to people and they came up with a common model. It's not the best model but everyone sort, of supported it that allow data to flow from thing to thing and we're never going to get big adoption if. If I install sensor A and now I'm stuck with this product and I can't use this one over here because they just don't talk to each other, you know? I mean like if we're really going to get people adopt this stuff, there needs to be choice and it needs to be some flexibility and I think you see in a lot of other industries like that's that's like Rev two of most technology is more is focused on how do I make it work with other things so that I become more useful myself? You know more more extract interesting myself.
So I really think data interoperability is going to be. It's really important to find it's a very hard thing to define. You've seen things like at Gateway. Try and maybe they gone too far and got really specific in the weeds. There's probably some middle ground.
You know that that needs to the first step. It's like how do we identify the 90% most important data and just come up with formats for that? And everyone can implement however they

want, but now we have this common way of transferring data from entity to entity. So you had a common format for field polygons. Pass the machines take. Those things would be valuable, yes told you to flip the order.
I could have kept talking on this part, but anyhow, something else came to mind. Just related to what Andrew was saying about, you know interoperability of formats and everything, something that will happen as add data gets larger and larger is that you know you might want to go between different cloud environments so we have some technology that we are developing to do some of that not entirely pivoted to other, but multi cloud is for example Thing to do, it's kind of tangentially related to this, but there are some technologies like I think Splunk and Anthos. Google Xantus helps you migrate between different clouds, because all of these cloud technologies are proprietary, they make ingress egress very expensive, right? In general, like in in terms of. Get across bandwidth etc. So as you have more and more data it will be nice in different ways for these companies to cooperate in terms of data formats in terms of cloud usage etc. So I think that's another slightly less relevant dimension, but hopefully as add data gets bigger it'll be nice to migrate between clouds.

So, my last question is like, does the autonomous application and the monitoring application when we compare those, both in terms of data interoperability and the scale of data? Like do you say with some certainty that one of these are require more data or the other one require less data? And one of the applications that are monitoring thing have more sensors or a different type of sensors and in the autonomous data pipeline that will have more different type of sensors and have more amount of data that will ultimately relates to the. Come the power consumption and cost associated with different different players in the framework.
I, I'm not sure I I know exactly good answer, but or it may be this is off .2, but I think that. As a researcher, it pains me, but I think the reality is, is that you know big data and these types of processing ideas are going to make lots of cheap sensors. Then maybe aren't you know they're not scientific if you will, and they don't update every second. But there there are lots of them. A lot more valuable than than one or two really fancy ones. Or you know that meaning that oftentimes the cheap ones are also lower power, and you know, because you're not necessarily looking for the same type of tolerances and things. I think there's also a practical advantage there in that. Go out and visit a farm, right? Even if you're not a farmer, gotten in farming or you know this doesn't take very long to realize that things break. It's everything's are far apart, is very hard to maintain this stuff. You know you're a lot better having 1000 tons and letting under break than having two. And then when they both break having nothing you know, so I don't know if that's what you meant, but. There's that. (AB)
It's more about like the scale of data in terms of application. Like if we are using some sensors on farm machinery and the type of data we got from there, the scale of data we got from like from specially from. If we are working on autonomous applications like farm machinery and like smart irrigation, smart relation. On the other hand we have just a monitoring application there just more into the crops from images and all the data we have. So

like what do you think like from your experience? Like the scale of data, how it varies with the type of application.
OK, so in terms of yeah, so there there is a variation. Many times we're just looking for what what has changed, what's different in so in that instance, these cheap sensors that Andrew was alluding to, or they may not be calibrated and they don't give you a sense of actually what is the temperature right now to the nearest 100th of a degree. But whatever their calibration was, it doesn't shift too much, and so if you're just looking for the difference, well, it'll tell you it's different than it was yesterday. I don't, you know, maybe not that accurately, but at least you know it's different. So there is a very good application of lots of those kinds of sensors, which means a lot of 'em that are cheap and no one piece of data is that good. But if I compare now to yesterday and the day before, I get a good trend of something that's happening. But there's a different class of sensor that if you're going to use a sensor essentially to drive a biophysical model. Essentially calibrate that model from time to time. Then you don't just wanna know that well. Yes, the soil is whether it must have rained there, you might need to know. It rained and now how deep is the? How deep did the water flow into the soil? And so that takes sort of a different class of sensor, but you wouldn't have it all over the field. You might only have one or two of them, but you need really accurate data to drive models, and so I think there is a balance between the two. Uh, yeah.

Yeah, so by accuracy you mean
the more data, right?
No, just a lot of mediocre data suffices. Sometimes you need really good data and you can't afford a lot of it, so you just go with a couple, but
they're really good. Precision of the sensor
tolerance error rate, things like that.
OK, alright so I think for autonomous applications I think I like the question and thanks for clarifying that question so I don't go off track. So, for autonomous applications one of
the nice things is for you know if you're thinking of autonomous driving in terms of tractors or whatever, you can have a lot of data and you can offline train the model right. So if you can train the model offline using various kinds of temporal datasets that have been taken overtime, it's going to just enable decisions to be taken at real time faster and. Currently it right you don't want it to make bad decisions, especially for things related to autonomous driving, so I think things where latency, it's latency sensitive and plus the cost of a bad decision is high.
You want to make sure you have a model that has been trained overtime to see all the nuances, especially outliers, right? There might be a bottle or some quirky thing which is relevant
to a field, but it's very important that the model knows that, right? So, having sort of overfitting too appealed almost right. Like if you always running the tractor in that same field. So I think having all these nuances and for the biophysical model again right there, it might be important to have multi-dimensional data overtime to just have a richer model to give you a very intricate observation. So, so I think depending on whether it's an autonomous application or it's a by physical application and autonomous, alot of data will be good because you can take advantage of offline training the model and having model that is updated once in a while. Not necessarily always updating online.