**Afternoon Discussion with Sunny Bains**

00:27 → 01:55

**Sunny Bains:** Ladies and gentlemen, would you take your seats for the upcoming performance of neomorphs? Moderated Live. Okay. Can everyone sit down, please? And if you can hear me outside, if you want to come in, come in. If you don't want to come in, have another friend. Okay. So, first of all, Brad, do you feel that you had enough time to be controversial earlier? Okay. But if there's so, if there's anything. Other medical things. Yes, all right. Why don't you start us off, Brad?

01:57 → 03:28

**Bradley Aimone:** Here's the provocative thing I was talking to Ralph about earlier as well as some other people. But I think that the thing that happens in AI that arguably has made it very successful over the last 15 years are benchmarks like image net and things like that. And often at the neuromorphic meetings that I go to, people are like, where are the benchmarks? Let's benchmark it. Let's lock it into place, and let's start benchmarking. And I will say I think that is the absolute worst possible idea you can possibly do. I think that this base of things that we as a community, I mean the problems I heard yesterday, especially in the clinical side are so broad.The impact is still to be determined. The needs and requirements are to be determined. We are hoping that the underlying neuroscience kind of underpinnings of these things will continue to evolve. Right? I mean, it's not. Neuroscience is stopping while these technologies are built. You know, we're going to learn more about the brain every 5Â min. Right? So there's nothing to do. If you benchmark and you lock into place a task today.I believe that we are making ourselves irrelevant, tomorrow, like not just tomorrow in the abstract future, I mean tomorrow, as in you know, Wednesday. So I, benchmarking is the absolute worst thing this community can do. That's my controversial statement.

03:33 → 03:44

**Audience:** We were having this discussion over lunch, and so I'll just continue on. So I think it depends on the time you are in. So, for example, in computer vision, which is what I did my PhD in in the 1980s. People used to write fantastic papers with a lot of nice math, but all the experiments were on 3 images. And they would say so many things. And when you try to apply that to actual real problems, nothing works. And so there was a call for making benchmark data sets.So then that happened. That was a great thing that was like all of us were on the same platform. But then that narrowed the whole problem. So people were writing papers that they could use the benchmark data sets on. And so there was no way to start a new area of computer vision problem.So it has its problems. So what the government can do is help create these areas for which there are data sets.If we don't do that then you'll be stuck in those ruts of whatever benchmark data sets are. So anyways, I'm just giving a history from computer vision.

03:45 → 05:31

**Sunny Bains:** So I think. But two things can be true at once, right? And data sets so it can be true that benchmarking in general is not a good idea, whereas, having data sets that that anyone can play with without having access to patients right can also be a very useful thing. So maybe, seeing as we're trying to put together a roadmap of things, to be able to do so, the obvious one that I believe that was discussed earlier in the last couple of days was EEG data. Can we talk about what other kinds of data sets would be useful? Or maybe you could suggest.

05:32 → 06:27

**Audience:** Yeah, so one of the data sets that was mentioned earlier in our programs was Mmlu, which is called a massively multilingual data set. It was actually created by Amazon. It was. It took 6 months.And that was very crucial for language machine translation. Here the corresponding thing is you should have eeg eog, or emg, all aligned on the same task as opposed to different tasks.Then, if you have a cross modal data set which seems missing. If I'm not mistaken, that would help us align, Eeg. And suppose somebody's working on non-invasive techniques like I'm interested in. You don't need to have the internal sensors, and you can press predict from the non-invasive sensors what the invasive sensors would have produced.

06:28 → 07:14

**Sunny Bains:** Okay, I'm going to just repeat the last 2, not for anyone here, but for my recording. So what we said was, benchmarking can be very narrowing in terms of people doing tasks based on narrow best benchmarks rather than really looking at the space and trying to solve real problems. But also that data sets can be useful in terms of giving people a way to understand whether their algorithms are working on a holistic problem. And you said, Eeg, eog, emg and sorry and ecog.

07:15 → 07:41

**Audience:** You can have all different modalities of measurements happening at the same time. If they're isolated, you cannot. It's called a parallel corpus in Nlp natural language processing. You need a parallel corpus here, where all the different sensors are simultaneously recording the action. Right? So that’s an expensive process. It's something that the government can actually enable.

07:42 → 07:46

**Sunny Bains:** Excellent do we have any more suggestions along those lines? Yes!

07:48 → 08:20

**Audience:** I just amplify that. I love what you just said. And along with that we need the parameters for the recordings. So what was used to record it? How was it used? You know the Co. The comments about the Hfos for epilepsy. We don't see them if we don't record them, and we need to know what bandwidth there is to record them? So you know just as an example. But we need to understand how the recordings are made and have them all time synchronized? I love that. That's something that I've been looking for.

08:21 → 08:29

**Audience:** Yeah. The critical thing is that they should be all aligned. If they are not aligned, you cannot extrapolate or infer different modalities.

08:30 → 08:44

**Sunny Bains:** Are there any other problems or sets of data that would help people trying to develop applications? I'm looking at you, Elisa. Do you have some ideas on that?

08:48 → 09:36

**Elisa Donati:** I mean, from what I did, yesterday, when I presented these mini prosthetic parts. So I want to say that it's kind of easy to get data from healthy subjects. But we should get also from, you know, some disease right, because we need to have both the healthy but also some pathology, because otherwise you don't have the ground truth and you don't have the data and unfortunately getting this data set of patients is not easy at all. So, starting from all the documents that you need to fill, I don't know about the United States. But in Switzerland it's crazy, believe me. So it's very difficult to get access to the subject to the patients, so we need help from the clinicians to get access to this.

09:37 → 10:47

**Sunny Bains:** Which actually raises another question. So one of the things that I tried to get us started on yesterday was the idea that there are different sorts of phases of this research. So we have the idea that there's a phase where you're just doing science. And you're collecting sensor data, and that may be all analyzed off Chip. And then you have the things that are actually being personalized or in the body. But if we focus on science because that seems to be where we are. Right with this discussion. So can the neuromorphic engineers help the medics to build better sensors that would allow them to do that? That would allow them to do that. Science likes to acquire the data sets that we can then figure out whether we can do analysis on it and then build better systems based on it and and to the medics, I would ask, what might those sensors be? You know, sensors that can acquire the data that we can then leverage to build new applications.

10:49 → 11:57

**Audience:** So I have a comment. It's on that yes. So I recently was privy to a talk at Hopkins by fantastic researchers. Parisa Rashidi. She's at University of Florida.She has instructed Icu and she's collecting data. She has collected a lot of data. So that's number one. And there is data available for analysis and neuromorphic people, but also in talking to her, for example, she was interested in seeing if we can get an event based camera in her Icu setting to actually augment the traditional cameras. To really collect data. So this community needs to go beyond themselves and a little bit more outward looking at the broader community. And there is a lot of opportunities there for collaboration. So data. There's plenty of data.

11:58 → 12:59

**Sunny Bains:** That's great. And what I was particularly thinking about. I'll bring it in a second. What I was particularly thinking of is, we were talking yesterday about the fact that there is insufficient data of people who are doing stuff right, that a lot of the data requires people being motionless in the using the tools that we have at the moment for interrogating what's going on in people. And I'm just wondering, are there specific areas where we could have some kind of interface. That was just sensing. Like, if we just focus on the sensing side, is there anything specific? Where if you could have people ambulant right. And like, I think, Tim, weren't you talking about this, that if you could, if you could measure these things while people were moving around at different times of day, because you were talking about the Circadian River. What did you do? I misremember?

13:00 → 13:43

**Tim Lewis:** No, that was part of it. I think one of it is to just get data sets more in the real lived experiences. Yeah, you know. So classical limitation, you gather, say epilepsy data with stereo Eeg, while you're in a very artificial environment. I think you know, we heard that from the panel. And then the same things happen in movement disorders. And actually neuropsych, where now we can gather more real world conditions and measure kind of characterize people over time. That's actually part of the new call coming out, exactly. Yeah. So actually, I'm going to defer. over because that's actually the new Nih initiative that's starting us. Then marry up those measurements with other sensors just to get a much deeper profile of people, but getting it, getting it out of the clinic.

13:44 → 13:57

**Sunny Bains:** So basically if we can create wearable sensors, even if they're not doing anything actively in the body, then that can give us data to work on and potentially give everyone data.

13:58 → 16:00

**Dana Schloser:** Yes, so sorry. I'm Dana Schloser nih brain initiative. Obssr, so I'm going to just address what Tim just said very briefly. And then I'm going to bring up a panelist. I mean a question from Zoom as well. So yes. The Bbqs or brain behavior quantification synchronization program which I just slaughtered presenting about yesterday. I think my brain was at the end of the day, but it is very much focused on getting real time, natural or naturalistic, as close as you can capture of behavior and neural patterns and capturing the environment that these are happening in at the same time and having those synchronized. So what I would do. I mean, in fact, I was chatting stuff to Grace as you guys were talking. I would encourage you guys to reach out to me or Grace. If this is something, you know, we're going to be collecting and having this consortium that are going to be collecting this, not just from humans, but from clinical populations, nonclinical populations, and a variety of animal models as well. So I'm hoping to have this very great resource by the end of this. Or as this program moves forward. So I'm just going to shift really quickly. And ask, it's not shifting subjects. It's going back to the same one. Okay, it's not. It's just that I'm behind because of. Well, it's hard to get the remote people in. So the other question or the other thing is that Stephen Hollis? Thank you, said the opposite opinion. Benchmarks can be very useful, such as those discussed multimodal data streams and funding for creation of such benchmarks can be very helpful. Yes, benchmarks can be overused, but they are an integral part of the research platform. Okay?

16:01 → 16:48

**Audience:** I just wanted to mention. All the newer moths know this, but the medical, not. A real big achievement in the neuromorphic community has been the vision sensor, an event based vision sensor that runs low power and that actually has found impact. For example, there's a company that can now do really low power, fast eye tracking, which even impressed matter. Also, in my lab. I have been looking at this and doing action recognition. We have set up and calibrated with multiple other sensors, including motion capture. And eg, if there is interest in multimodal processing with this neuromorphic sensing.

16:50 → 16:55

**Sunny Bains:** Okay, sorry. Sorry about the confusion there. I understand Syd Cash wants to speak.

16:56 → 18:11

**Syd Cash:** Yeah. Hi, Hi, everybody. Sorry I'm not there in person right now. I just want to go back to some of the people who were talking about the benchmarks, and so on. Before you go too much further. There is a fair amount of data out there coming from people like myself that are on various databases, including ones supported by the Nih, like Dabby and Dandy and other ones. And some of those are very large data sets of intracranial recordings, including recordings with simultaneous emg and other features in them. And there's other ways that data is shared. For example, Kegel. Competitions have been a mainstay, not a mainstay. But they're an important part of, for example, seizure prediction and seizure detection algorithm development. So if the question is about developing algorithms, I think there's actually a fair amount of data out there for particular problems, not for all problems, but for particular problems. And if the community wanted to make that more aligned with some of the questions that we've covered over the last day. You could imagine a competition or a data set specifically focused on asking whether or not. A neuromorphic approach from an algorithm or a chip point of view is beneficial compared to other approaches. I can imagine something like that. But people researchers should know that there are quite a few data sets out there to pursue algorithm development and testing.

18:12 → 19:03

**Audience:** I just wanted to pop in on the preclinical side. My last job was in industry and I worked for Tucker Davis technologies, Tdt and their systems. They have electrophysiology, fiber, photometry, auditory, they added on a behavior system before I left. Now, this is all preclinical in animals. But if you want multimodal data sets, there are folks who are collecting this stuff for neuroscientists as part of their experiments. So it's definitely already out there. And like with the Tdt system. It was all going through its own processor. So everything was on a single clock. But yeah, definitely on the preclinical side. And we saw that too earlier today with adding in in vivo microscopy. And yeah, and ifiz data, there's a lot of stuff coming out now that I'm sure people can develop algorithms on.

19:08 → 20:08

**Audience:** So I had a quick thought on what Sid said about competition. This is mainly for Brad. Because, you know, we know what these competitions are like. As you say, you know, you, you end up developing a particular algorithm or a particular chip that does that algorithm that does that competition really, really, really? Well, and nothing right. And that's, I think, what Brad is worried about, right in the sense that we do not.If we are too focused on just benchmarking, and then we go. And you know Stefan is a friend of mine, and we disagree here that you know, we don't get the chance to do almost what you know, what someone an economist once called useless science. There is such a thing as science for the sake of exploring, for understanding what else is possible without being focused on just trying to meet that benchmark trying to replicate that. You know that, you know, chaotic spike train, or whatever.

20:09 → 21:52

**Sunny Bains:** I'd like to before we move on to the FDA questions. I'd like to move on to something else that I raised yesterday, and we didn't get too far on. But actually, I think it was really well discussed today, and I'd like to crystallize it, which has to do with specs. So today, we talked a lot about stretchable things, adhesive things. We talked about biocompatibility. We talked about potentially ambient powered devices that could go in the body. And all of these things that are very specific to medical devices. And I wanted to make sure that we had actually a really nice list of what these things were, and maybe some of the more specialized ones. So, for instance, what's adhesive on skin is not going to be adhesive on the heart. So maybe we could talk about some of the places in the body where we would like to put sensors, and maybe just to mention those so that engineers can go out and investigate. Well, well, the stomach is very acidic. And so there's specific materials we're going to have to use if we're going to put something in the stomach and all that kind of saying so again. So I'm 1st going to ask the people who are more on the medical side. Would you like to volunteer at a place where you'd love to have a nice low power sensor, or implant or stimulator, and why it might require a little bit of thought in terms of materials and specs to put something there. Yes.

21:58 → 23:24

**Audience:** So that's a great question. And in fact, we commonly think about, you know, placing sensors in solid organs. You know, like in the heart, or maybe in the blood vessels, which is very interesting, target the brain. But there, there is actually a sort of an organ that is hugely important in determining our interaction with the environment. Which is very difficult to actually track and monitor. You know, and especially on a continuous real time basis. And that's the immune system, right? So we have really very limited means to interrogate the immune system, you know, in a continuous fashion. It doesn't exist, you know, and yet immune inflammatory responses are involved in almost every disease, you know, and they're instrumental in determining not just the amount of, you know, injury, but also the recovery, you know. So the immune system has many different aspects, and so I'm a rheumatoid arthritis sufferer. So I very much like it. I mean you know, if there was a way to, you know, sensorize immune cells or immune molecules and be able to track them and understand exactly what they're doing. They're also, of course, as everybody knows, their immune cells are involved, not just in fighting infection, but also fighting cancer. And you know, determining all sorts of responses that we have to different sort of aggressions. I think that there's a huge unmet need.

23:25 → 23:52

**Sunny Bains:** Okay so let me turn that back to you and ask you where in the body is the place where you would put a sensor if you were going to look for that. And are there biomarkers that we would look for? I mean, are there existing biomarkers? Or because if it's if you guys haven't figured out what the biomarker would be, it's going to be very hard for engineers to help you out to solve that problem of a sensor there.

23:53 → 24:18

**Audience:** You're right. Because when we say immune system, we're talking about actually an array of different systems that are involved in. You know, responding to internal or external threats, right? So that can be cells, lymphocytes or neutrophils, macrophages, you know, monocytes. That kind of thing can also be signaling molecules,

24:19 → 24:34

**Sunny Bains:** You know, like pick one that you think would be a no, no, seriously, because low hanging fruit is where we start right, and then we get more advanced. So is there one obvious biomarker in one obvious part of the body that somebody here could start working on to try and build a sensor?

24:35 → 25:31

**Audience:** But you know I mean. So if you just take the example of the lymphocytes, I mean, there's many different subsets right? There are regulatory lymphocytes. There's a you know, T. Lymphocytes B. Lymphocytes. But I mean there, there's some, you know, if you think about all the different components of the immune system as a kind of interactome, you know, and they're all kind of linked together in this kind of big network of signaling. You know, there's some that are clearly hubs for signaling within the immune system. And so, for example, in the early phase of the inflammatory immune response, the neutrophils play a huge role, and they're often associated with bad outcomes, you know. And then the lymphocytes come in. And they, you know. So if you, for example, if you could put a little camera on one of the cells. You'd really want to be able to see what the neutrophils are doing, you know, in the acute phase you'd want to see what the macrophages are doing and what the lymphocytes are doing. Those are sort of 3.

25:32 → 25:42

**Sunny Bains:** Okay, maybe that will inspire someone. So I just wanted to ask you, so what about detecting cytokines or phosphatidylserine, or something like, could you think about that? Could you pose that question in a metabolic fashion?

25:43 → 26:38

**Audience:** There's clearly, you know, a lot of non-cellular actors in the immune inflammatory response. And so cytokines and other signaling molecules, chemokines, cytokines. I think you know, those are generally produced by immune cells. Right? So I think if you track one, you can sort of track the other, so you can easily measure cytokines. I can be with any one of my patients. I can send a panel and get il 6 tnf. Alpha, and whatever it usually takes about a week to get the results, you know. So I mean what we really lack, you know. And this is striking. I'm a critical care physician. Every single one of my patients has this massively revved up immune response to their illness, and we have absolutely no way of monitoring that response. We have no way. But you're getting like one measurement in a week.

26:39 → 26:41

**Sunny Bains:** I think this is a conversation that you guys should have but not necessarily in front of all of us.

26:42 → 27:31

**Audience:** Okay, yeah. Just just very quickly. I mean, for example, Tim has shown us that if you want to deliver a treatment, that's 1 thing right. But if you're actually looking for biomarkers. This puts you in the wonderful world of outcome measures and I have a startup company on outcome measures. And the very difficult thing that you have to do is you change your mindset from that of a scientist to try to help the clinicians, because I can't tell you how many times I've heard “I love technology. This is all great math whatever. I just want a number. I want actionable information and just keep it simple. Just a number.” I know that a lot of the clinicians here are of a different mindset where they want to know what's under their hood.

27:32 → 28:02

**Sunny Bains:** But that's interesting, right? So. So if you do, you need a little bit. But you are so strict so if you're doing data gathering right, and you just want to develop applications. Then you might want a lot of data. But if you're just as you say, looking at outcomes. You might want a little bit of signal processing on the chip, and then it just to output, you know, high or low, or medium or something,

28:03 → 28:16

**Audience:** Whatever, at the end of the day, if you don't have a sit cache that you're talking to, for example, because they want to know a single number. Thank you.

28:22 → 28:28

**Sunny Bains:** Okay, over here. And then I have another subject along these lines that I'd like to go into.

28:29 → 28:48

**Audience:** I was just going to say, for an analyte sweat is something that people are looking into with wearables, especially if you're talking about cytokines. And then there's a lot of work going on right now in the wound, healing space with having. So that's a little bit more invasive. But yeah, especially if you're talking cytokines. There's a lot of work happening there.

28:49 → 28:51

**Sunny Bains:** Thank you. Okay, Tim. And then we really are good.

28:52 → 29:32

**Tim Lewis:** Oh, yeah, this is just very brief, but it's before you were to launch. And you probably do this. Anyway, there's a lot of people have been looking at this for quite some time, especially in, you know, immunization, so set point medical Galvani. They both have trials ongoing, and so I would. I would also go. I won't call it benchmarking to respect Brad's, you know, Flag. But say, I'd certainly be aware of what's already out there before you launch into it, because a lot of people have already been looking at this very, very deeply for many years. I'm just saying as we're starting. No, but I'm listening to us all kind of going through and and like, let's make sure we're not reinventing the wheel.

29:33 → 30:22

**Sunny Bains:** I'll take that just so I can pass it on. Okay. So I'd like to make sure of that. So we talked about a number of different things that we need our technology to be. As I said, we talked about biocompatibility, stretchability, adhesiveness. We talked about the electrical properties that we might want it to have. We talked about whether it should or shouldn't dissolve in the body, which can be a good thing or a bad thing, depending on the application right? So I want to make sure that at some point today, everything that you think is important in terms of these implants, you know, in terms of like the properties of these implants has been mentioned. So we've also talked about low power. We've talked about latency a little bit. What other things have we missed?

30:27 → 30:51

**Audience:** I'm just gonna say, quick, from yesterday it's just to reinforce. There are regulations on physiologic control systems. The FDA has been very active and giving guidance documents out for 6 0 6 0 1 10. And so I just want to capture that, for when we start thinking about closed loop control, they basically map out all the considerations that you should check off as part of your submission.

31:00 → 31:30

**Audience:** And then there's a second set of guidance documents for things to think about for AI, and that's both with FDA as well as for ideas. Look at the Mhra in England also has put out similar guidance documents like thinking about AI as part of your algorithm.

31:33 → 35:37

**Audience:** So I will give you specifics of what I want. And unfortunately, they're not specific. So, in neurology and psychiatry. I think we have similar desires, which is, we would like to have an arbitrary number of electrodes placed anywhere we want that have fully customizable sampling rate and bandwidth. Possibly up to 4,000 Hertz down to some people would want higher than that. I'd be willing to let a thousand slide. Maybe a thousand is about as low as I would go, and on the bottom I would like it down at maximum point 5 hertz. So there are many solutions now. They're nowhere near this. I would like to be able to put in many electrodes and then record continuously and save the data continuously. So there are devices that record that they don't record continuously. They record little tiny snippets of data. Then I would like to be able to stimulate with an arbitrary stimulus. Any way I like with a controller that is any controller that I. You asked what I want. This is what we want. And so what you get. What you get with this tool is the entire brain, rehab the entire psychiatry and the entire neuromodulation, for every neurological disease will grab this device and use it immediately. So there are. The neuropace device now has tremendous limitations and they're finding ways to hack into it and try to get it to stream data. There's a woman in Ucla that has done this. She has to build this with pieces that she's putting together. She has to jailbreak the device to get it to work. But the data is remarkable, even just using the data that they have with the limitations, because they record for so long they're able to get tremendous statistics and show some interesting things. But as soon as there's a device, people will start using it. The problem is that in clinical research, researchers end up having to reverse engineer so many things too. And then we're cutting so many corners because the devices that are approved by the FDA have tremendous limitations. So I said yesterday, I don't really care what structure you give me that in. I think maybe what I've asked for is a lot. And if neuromorphic, the word is what is necessary to get closer to that. Then that's great. But that would be great. Now, one that's the ambulatory thing. A second thing on the more research side, something that we've wanted for a while, and people keep touching on this, but never really doing. It is to have multimodal recording where you can record potentially with very high spatial and temporal resolution, electricity, but also to be able to record other things. Potassium, oxygen, sodium, various neurotransmitters, all simultaneously. People get one piece at a time. They choose their neurotransmitter du jour. They choose their one thing and they say, Look, I got this one answer, but we actually did a study where it looked at 27 neurotransmitters at a time. And the answer was not what people thought it was. They are different. There's complex things going on. And you never know, because you look at one thing. It's kind of the blind man and the elephant tail is where we're living. So we'd like true multimodal for an inpatient acute setting.

35:38 → 35:53

**Sunny Bains:** So it sounds like also, just from the last two, that the chemical sensors are really, I mean, we know that the electrical sensors are needed, but also the chemical sensors are a really important part.

35:54 → 36:03

**Audience:** Who knows what we would see if we had a combination of three or four things at a time. We've been looking at this one dimension and to be able to truly have multimodal

36:04 → 36:54

**Sunny Bains:** Great. Thank you very much. That was good. No, I'd like to move quickly to some of these questions that were sent by the FDA. Now, I'm not sure about this question whether it's advanced enough for this to be a meaningful question. So it's about the risks. What new risks or uncertainties do. Neuromorphic designs include relative to existing alternatives, including traditional and AI, ml, I don't think neuromorphic is really outside of that bubble in terms of risks. But maybe I'm wrong. Does anyone want to take that question on? Does anyone see that there are any new risks related to neuromorphic Andreas?

37:04 → 37:38

**Andreas Andreou:** Well, if we take one example of what is considered neuromorphic, which is spike based or event based processing algorithms which are spike or events-based processing may have deficiencies, which traditional algorithms don't have, you know. And so then, I mean to be fair. I can't just take an event base or a spike base or a time base algorithm and apply it to a system without really testing extensively to see.

37:39 → 37:42

**Sunny Bains:** But we're not imagining using anything without text testing it extensively.

37:43 → 38:03

**Andreas Andreou:** I know, but I think this is a question about an algorithm which applies value hardware. I mean, I think this is really, I'm talking about the hardware spike based hardware, not the algorithms, because the algorithm you can test. But the hardware. You really. How do you validate your hardware? Okay, I see what you're saying is doing the right thing. Right?

38:04 → 38:19

**Sunny Bains:** So it's having some system to do sort of pre testing precalibration of each validation of the individual chips as opposed to validation. Thank you. That's helpful. Did anyone else have anything before we move on to the next? Tim.

38:21 → 39:23

**Tim Lewis:** This is long term, but I am touched on it. In the presentation there's some real practical stuff that eventually needs to be dealt with like design for manufacturing and like. So I'll use the example of you. Do a memristor array. And so if you were to say, rely on prior data sets to preset your memristor. How easy is that to manufacture? Do the test in line and things like that, and what you have to do this gets back. I will call it benchmarking in terms of just some of the manufacturing methods. We have scan logic. So if I build a digital chip, I have the complete infrastructure to very quickly verify that every chip coming off the manufacturing line is ready to go, and so eventually, depending on some of them. You know the physical architectures that were used. We have to think about some of the manufacturing, testing and qualification that will be needed and any susceptibility to drift. So there are some manufacturing or liabilities.

39:26 → 39:57

**Ralph Etienne-Cummings:** But also the body is a very, you know, extreme environment, right? I mean, you know, there's all kinds of, you know, changing temperatures. You know, scarring all these things going on. So how does that affect the devices that you're putting in there? So yeah, so it may not just be at the time that it comes off the manufacturing line.

39:58 → 42:00

**Sunny Bains:** Yeah, I had a student. Actually. So I don't. As you may know I'm not research active. I'm a journalist, but I teach a lot of Phd students. One of my students was talking about exactly this problem that there were these devices that they were using to fix the heart. But there was a calcification that happens on these devices? Over time, and then there's scar tissue left, and so it's not so easy to implant the next one. And how do you avoid that building up? So yeah, that's an important thing. Okay, anything else that people want to raise before we move on to benefits? So does anyone want to talk about the specific benefits of neuromorphic or, oh, sorry. We yeah, specific benefits of neuromorphic. I don't want to sort of belabor potential computational complexity within the same small package that you would have lesser complexity. We've talked about power. We've talked about latency. Is there anything else in particular? Oh, and we've talked. And actually Ralph and I, when we had our long argument in the car because we had to go back to Washington last night, we're talking about the fact that one of the nice things about neuromorphic technology is, it speaks the same language as the nervous system, which means it's sort of more inherently compatible with the brain or with the nerves. So are there any other benefits that we want to discuss that I haven't just captured there. Okay, I guess we've been talking about the benefits all day. So okay. And then, finally, the barriers, what have you experienced as barriers to translational development of neuromorphic engineering technologies. Andreas, you're a translational kind of person. You're doing sort of research and then applying it to real problems.

42:10 → 43:11

**Andreas Andreou:** I think we need to make sure that we have the regulatory processes in place, and if we want the ecosystem to expand, we need to build an ecosystem which is resilient, which is robust and scalable. And so this is really a long process. So it takes time. SoI don't know. How might FDA be of help if they can accelerate the process of approving cube devices in similar categories. I know they've been doing it. For example, in electronic stethoscopes and stuff like that that include AI and Whatnot. But it is really the barrier that I see is really time. It will take time to actually do that. And so companies that really want to do something. Now it just it's not going to work out. So I think this is really a trade-off.

43:12 → 43:27

**Sunny Bains:** Okay, thank you. Any other barriers that these funding agencies can help with or maybe that industry can help with, or maybe that we can help each other with? Yes, Pam.

43:31 → 44:56

**Pam Abshire:** So there's I think, inherent in a lot of the ideas that we have about neuromorphic. There's the notion of feedback. There's the notion that I think these things would be learning or might not necessarily be completely fixed. Once deployed. Having worked in the area of adaptive circuits somewhat earlier in my career, I can say, like, if we have a system, and we introduce local storage. We introduce the capability to tune performance generally. You can do better in an application when compared to non adapting systems. But if you compare the ideal system to the ideal system with adaptation, like to assist, you know? Like, if you can. Okay, I'm not saying this very well. If you have a system that has capability for adaptation. There's some aspect of its performance that's mismatched. It's not looking at the right range. It's not looking, you know, like there's something that needs to be adapted in order to tune in the behavior. If you compare that to the ideal system, you always lose. Right? You can always make a better system. And so if you're comparing an adaptive system to the best system, you're never gonna get there. You're like you're never gonna win. And so we don't have good ways of quantifying the value of an adaptive system. I think that that's fundamental.

44:57 → 45:04

**Sunny Bains:** But what about a system that's required to be adaptive? Because what's the ideal system today at 3 o'clock is not the ideal system

45:05 → 45:17

**Pam Abshire:** The notion of regulation of an adaptive system is going to be real hard. Okay? Right? Okay, right? And then quantifying the benefit of the adaptation is going to be another hard part.

45:18 → 45:19

**Sunny Bains:** Thank you. Ralph?

45:31 → 45:58

**Ralph Etienne-Cummings:** So it also goes back to like different having fail safe mechanisms, because you can have something which is novel. But in case and this happens in any autonomous vehicle like there are different levels of autonomy. So here also you can have these several different layers of security or fail set mechanisms. So you can always go back and revert back to the original architecture. If you can detect failures.

45:59 → 46:03

**Sunny Bains:** That's yeah. That makes sense.Yeah, yeah.

46:04 → 46:26

**Audience:** So what about resilience to adverse hacking? That's another thing that, you know? Are there things about neuromorphics that make it more resilient or make it less resilient? You know, what do people think about that, you know? Is it? Yeah, is it easier to?

46:28 → 47:43

**Bradley Aimone:** Yeah. So one thing that, you know, our brains have. I mean, I don't know if this is for security, but I think it is for resilience. In general, I think it probably does affect security. Right is, you know, our brains are sarcastic right? And the circuits are not incredibly precise. Right? I mean, there's a lot of variability. There's a lot of noise. It not only works in spite of the noise it works with the noise right? And all of the sort of reasoning is is likely very probabilistic, and I think that that basis of computation and provides a level of resiliency, and it's not necessarily gonna like, protect you from having someone hack into it, although it, you know, pulling off an individual sample when the solution is across, a lot of samples will. But also, it's, gonna you know, that resilience means that if someone wants to break something right like disrupt it by breaking our electronics today. Right? You know, you flip a trend. We flip a bit. And bad things can happen right or may or may not happen depending which bit you flip for the brain, you know. Synapse doesn't, doesn't communicate. It's no big deal, because that's what happens. So I do think that neuromorphic can inherently provide that resilience.

47:44 → 48:34

**Francisco Valero-Cuevas:** Yeah, we had an overview in the nature of machine intelligence about what biology should be. And shouldn't we copy into engineering right? And one of the things is this question of resilience, etc. robustness. But that is squarely the domain of the stability, plasticity, dilemma. It's a dilemma. and in biology it can get solved or not solved, and it can happen in, you know. So so then you will never be able to have guarantees, because if you want your system to be able to learn, ie. Exhibit plasticity. Then it may not be stable either. And so there are lots of checks and balances in biology. But it is a dilemma. So let's just remember it will always be with us.

48:39 → 49:03

**Grace Hwang:** So how? How would this be regulated through the FDA? If we have a dilemma? Given this dilemma, it sounds like this could be like a double edged sword. If you can't regulate your device and prevent it from going to a region of instability. You know, what strategies are in place for FDA to regulate these kinds of devices.

49:05 → 49:46

**Francisco Valero-Cuevas:** Yeah, I'm speaking out of term, because people who stimulate right? They have bounds and all of that. So that's manageable. Yeah, yeah, that's one. So when neuropace rns was 1st coming out, that was one of the concerns is, it might actually end up overstimulating, giving excess dose, inducing, kindling, actually kindling epilepsy, making it worse. So they actually put dose limits. And so the device still actually gives a maximum number of stimulations per day. So you can put guardrails in and work with the FDA that actually say, yes, we have upper and lower limit bounds that limit the potential risk for patients for some reason.

49:47 → 50:10

**Sunny Bains:** Okay, I want to keep us more or less on time, right? So we have a couple of minutes left, and I'm just wondering if there are important issues that we have overlooked over the last couple of days, or that have been underplayed, that anyone wants to highlight.

50:12 → 51:05

**Audience:** So this was a topic I was talking to Jennifer about. So what we forgot. Actually, there's a lot of overlap between the biomedical and neuromorphic community. Because a lot of us have worked in similar areas. What I think we forgot is the legacy part .Like some of the neurotechnologies they were originally tested and manufactured using these old Moses runs that you know, we still remember you would send out chips every month, so some of Reed Harrison's you know, the intent amplifiers were designed in those fundamental processes. So I think as a community, we haven't sold like, what was the impact of getting access to that free run. Right where we could send those chips. So I think we need to make that case again that if the community needs to move forward you need access to free Fabs.

51:06 → 51:56

**Audience:** Yeah. Oh, I would argue that the whole reason, at least I got into Vlsi. Because these runs were free. Right? When I was a grad student, we could essentially send chips out on a regular basis. You know, it was whatever, you know, a few $1,000, maybe even a few 100 bucks to get a chip, Fab, or whatever it was, right. And over the last few years this whole thing has gone away right, especially as it became harder and harder and harder to design these chips. Now, Andreas would argue that it's not about designing chips anymore. It's about putting systems together. Fine. But you got to put a system of something, and that something is, you know, maybe maybe just. But yes, I would love to see more accessible, you know, small nodes you know, design capabilities being made.

51:57 → 52:42

**Sunny Bains:** But I thought I actually thought Andreas's point that he made earlier about packaging is really important. And one of the criticisms I've often heard is that you know, someone will show off their neuromorphic chip. And they'll say how power efficient it is. And then you look at all the electronics around it. Right? Is that exactly true? So it’s about the system. And it's about being able to do that whole piece efficiently in terms of power whatever is important to you, not just the chip itself. Were there any other issues that people wanted to raise before I celebrated being the only person to finish anything on time today?

53:02 → 54:08

**Andreas Andrea:** I want to go back to something that Jennifer said about the structural complexity of the things that she is doing, the cartoons and whatnot. I think we need to go beyond silicon chips. I think we need to incorporate some of the materials and new materials in standard platforms. We've seen fantastic work from at least 2 people playing the speaker this morning, Professor Bao from Stanford. And so, yes, and this afternoon. So I think that's another. It's kind of the equivalent of Moses for the structural complexity of modern devices. Because I think we need more of those than actually real silicon chip design.If you're a student and you want to, or a professor, you want to send a chip, you used to write like a page of proposal, and you send your chip, and 3 weeks later, a month later, your chip comes back. You design it and you send it in, and it comes back and it's free. We need something similar that includes the new materials and structures of the complexity that we have seen today.

54:16 --> 55:04

**Sunny Bains:** You were talking earlier about the fact that you were sick of having to invent everything from scratch. And I thought that what that raised for me was the idea that you need a really good information Hub, so that you can find recipes. And I remember this from back in the day when I started. I did holography stuff, and people would share recipes for holographic photopolymers and other kinds of materials, but it seems to me that that kind of idea of. You know, not having to go to the broad, wide range of literature and hope you could find things, but things that were tried and tested and known in the community that I think that could be a really nice project for someone.

55:13 → 56:10

**Audience:** Of course, we acknowledge the importance of the future on five.So as we send it. Okay. Okay. I just wanted to add to yours this design tools in general, some still missing from the neuromorphic community that exist in Vlsi design from designing asynchronous circuits automatically to even running one spiking neural network designed for one hardware on another hardware. So when that comes, then it will all be easy, and of course going. Then also to the one.

56:20 → 56:30

**Audience:** I have a question, or Cornelia, when she brought up design tools, it made me think, is neuromorphic, in fact, scalable today?

56:32 → 57:07

**Audience:** If we are there to design medical devices. But higher level up definitely. So the tool chain exists. No, it doesn't exist yet. I think we need to start it right too. If Moran, now you one algorithm runs on a spinnaker and another one on another chip, just to unify that, for example. And then, next thing to design tools that can run on a synchronous hardware to automatically design. So that's really essential. Yeah, to drive it faster ahead.

57:10 → 57:20

**Grace Hwang:** So just so the state of the art neuromorphic compared to digital signal processing is a huge gap. Just to be clear that those design tools still need to be created? Thank you.

00:20 → 7:34

**Ralph Etienne Cummings:** Alright, well it's been 2 grueling days of a lot of discussion and agreements and disagreements and various jokes as well. It's always good to be, you know, to keep it light and you know, to be able to agree and disagree agreeably, so that you know that's important and our next step is essentially to try to synthesize everything that we could do right. And I, you can imagine there's a lot right? Luckily, we live in the age of AI, right breaking of the data and trying to understand this stuff. What would happen next is the following, so Sonia and I will take a stab at putting together a document not too long. We'll try to summarize what we've heard. So yeah, we'll put together a document that will try to summarize everything that we did today and yesterday. At which point, then we'll circulate it to the Organizing Committee and the technical committee to get the pass, clean it up, and then we'll pass it over to everybody who's here to try to get you guys to. Also, if we miss something edit, add it, you know, to basically try to contribute to the overall document. Ultimately, we want to publish a position paper on this on this you know, on this topic, so that we will hopefully move the hands of those who signed papers and put out funding in the right way, you know, in the right place to try to, you know. Make this community, you know, prime medical research. So that's the step forward. We really appreciate everybody who came and talked, and, you know, made their voice heard. I mean, yeah. It's, you know, for me. At any rate, I don't know about you guys. It was an incredible, you know, set of talks and discussions. And you know, I really learned a lot, and I appreciate it so much. Thank you, Sunny, for being the gladiator, because that's what that's what you were. You know you had to, you know, deal with a lot of questions ato manage it, and so on. So thank you so much for that. Thank you to Conference Catalysts for putting together. You know the infrastructure to make it possible. I see Hannah over there. So let's thank Hannah for all the hard work for putting it all together, and the websites, and so on. And there's, Oh, there's still some more stuff that you know. You'll be getting emails from us like, there's 1 important thing which is a Post conference survey. You know, you may have gotten an email about it from a Conference Catalyst recently. Please do fill it out because it gives us information that we can use to try to improve things as we go forward. So very critical. So thank you so much for that. So in terms of the funders, I can. You can imagine this would not be remotely possible without grace, without Jessica, without David for putting, you know, from nih for helping us. So this is an Ib. Iv. And an Inds for helping us put together, but large funding came from the Nsf. And this is from, you know, from ale. If I'm saying it correctly. Portfolio she was. She's been extremely helpful and extremely supportive for us to continue to do this. So with that in mind, and of course all the Organizing Committee. You know Jennifer and Luke, you know. And where am I forgetting myself? No, Jessica and Luke? Oh, Francisco, yes. You know Robert and Shantanu. And what am I missing? I'm sorry people online, Sid Cash is still online. Yes, Sid. And well, I got to see the list, but unfortunately, I don't have this. Anyway, Yeah, it's late afternoon, and I'm forgetting everyone. But I'm sorry if I forget you. But thank you so much for everyone who contributed to this, and I also want to thank Steven vendor. The Dare program also supported this workshop with Amanda in the room. Amanda stand up and Stephanie Gage also co-funded this program as well. So I also want to make sure we spread the thanks around the sponsors. Oh, Margaret Kim. So it's special thanks to Dana and Joe. Monica also helped us with this chat. Thank you. Travel from across the world. Oh, we have to thank our keynote speaker who travels in Oxford.You traveled from the West Coast. It's a simple gallery, right from our work, from our hopefully, you do from here, with a lot to think about, and that's what we need to. I'll get some feedback. And can I also just suggest that if any of you do have ideas about what manifesto to come up with that sooner is better in terms of feeding it in, because then it becomes more whole thing rather than adding, trying to add in new additions at a later stage, I am really easy to find. I'm sunny like a sunny day bathed without any. And you are absolutely welcome to just drop me a line and say what you think should be in here, and I will make sure to kind of gather what I have, and collect it with great, with Ralph. So, I think I do want to make one final mention of the Misha Howard award for trainees on the line. There's, I think, a $2,000 prize, and for investigators is a $10,000 prize and I believe the due date is the end of October. It's coming up really soon. And we've had former winners here. The fish in the back. So yeah, so it's possible. Wonderful. Thank you.