[External shot of Galbraith Building, **Professor Steve Mann** chats with guests]

Professor Farid Najm: Thank you all for coming, I won't speak for long. Just three minutes. I am Farid Najm, I am the Department Chair in ECE Department and I'm very happy to welcome you back to the Department and to the University. I'm sure it's nice to be back without pressures of homework, exams, and midterms, and the like. This is the fourth of this type of event. It's a reception and a mini-lecture by a Professor from the ECE Department and we started this series in response to our survey of alumni that we did about five years ago to find out what alumni would be interested in engaging with us in. So we're not holding any dinners, we're holding only receptions and networking events and that seems to be working, I'm glad to see such a large group of you here today.

So the format will be that Professor Steve Mann will speak for about 20 minutes to half an hour, it's gonna be an accessible talk, hopefully, with some demonstrations I see, and then we'll have about 10 minutes of Q & A after that and then the food will start flowing in here so the networking session will continue after that. We have the room until 9 o'clock or until whenever the food runs out. As a Department this is an exciting time for us, and for the Faculty of Engineering. You may have heard that there is a new building under way, the plans for it are under way, I should say. The building itself will hopefully—the construction will start maybe next summer, maybe soon after that. It will be on the last available plot of land that can be built up on the St. George Campus, which is the parking lot next to Simcoe, and just across the street from Galbraith. And so Engineering was lucky enough to be able to secure approval for that and we are currently in fundraising mode. That building is called the Centre for Engineering, Innovation, and Entrepreneurship (CEIE). It's a tongue twister and future generations will thank us for that acronym. It's designed to encourage collaboration between all departments and divisions of the Faculty and to exemplify the Faculty's focus on training multi-talented inter-disciplinary engineers. So we're very much looking forward for that space. As you know we are all very tight, in this downtown campus. In the Department we are currently working on a major renovation of the Energy Systems Lab. This is the Power Labs, in the basement of Sandford Fleming, many of you will have taken courses there, you may have pushed shopping carts in their to move resistors around the room. So that lab needs upgrading, and we are currently reviewing bids for Phase 1 of 3 for the renovation of this lab. Phase 1 will cost about a $1 million and then subsequent phases will cost some other amounts that as of yet unknown. But this is long overdue, so this lab will be renovated and will be developed in a way that we can support modern power system education including Smart Grid and communication and power in the same network. So look forward to more news on that front. And if you're interested to hear more about any of this, talk to me after the lecture.

But now, it gives me great pleasure to introduce you to tonight's featured speaker, Professor Steve Mann. Steve is widely recognized as both 'the father of wearable computing' and the 'father of augmented reality.' Hopefully today I will understand what augmented reality means. Steve has spent more than 35 years at the forefront of this field of augmented and mediated reality, or *augmediated* reality as he calls it, an area which has recently exploded in the popular consciousness—you've all heard about Google Glass. Steve has a long and proven record of designing, creating and refining this type of technology, wearable technology. He built his first computer-mediated vision system called Eye Tap digital glass more than three decades ago. And so he has really been a pioneer in this field and he has been improving this technology ever since. He's also the inventor of a hydraulophone which is the world's first musical instrument that operates not on air but on liquid. So you make music with water. Mermaids would love this story wouldn't they?

By way of biography, Steve received his PhD from MIT in 1997 and is a member of our Computer Engineering Research Group. He has authored more than 200 publications, books, and patents, and his work and inventions have been shown at the Smithsonian Institute, the National Museum of American History, and the Museum of Modern Art, among many other places. You wouldn't normally associate these things with an engineer, let alone an electrical engineer, so it's really great to have Steve on the team to give us reach and impact in these various fields. Steve is much sought after as a consultant and has recently been working with METAinc on their new augmented reality space glasses, but I will let him tell you more. So please join me in welcoming Professor Steve Mann.

[Applause]

Professor Steve Mann: Ok, it's an honour to be here. A lot of fun to be here and presenting. So I'm going to be talking about my three research thrusts which are wearable computing, is the first thrust, you know, the digital eyeglass. The second thrust is Alethiometric Systems. Alethiometric, the Greek word for truth or sensing, otherwise known as surveillance systems or inverse surveillance. And the third thrust is Actional systems. Action, which is energy, is to power, as action is to energy.

When I was 4-years-old my grandfather taught me how to weld. And it was an experience that was at once exhilaratingly fun but at the same time it was frightening, terrifying in a way cause you wore this dark hood over your head and you see the world through this piece of dark glass. And seeing through the glass darkly, all you see is this little speck of really bright white light and everything else is almost completely black. And I thought, well there's got to be a better way and so that's what led me to the invention of HDR, High Dynamic Range Imaging. So with the HDR vision I had this idea of having a camera vision system—wearable camera imaging system that would allow me to see better, help see better. And we can see a dynamic range of more than a 100 million into 1 here from the tip of the tungsten electrode to the deepest darkest shadows in the background. This is a 1978, 35 years ago, digital eyeglass and it's a little glass that I put on this helmet so that I could see the computer screen and in my day-to-day life I started to play around with this. I even put rabbit ears on the glass so that I could transmit and receive voice, video and data at the same time, and be networked and connected as I'm walking around in this computer-mediated world. And around that same time other companies were playing in the same space as well, 3M bought up a company that made a product called Speed Glass. And SpeedGlas is an auto-darkening glass. You look through this piece of glass, both eyes are seeing the world through this glass, and the speed glass would be light, and when you start welding it would darken. But as soon as it darkened you're back to seeing this little point of really bright white light and everything else almost completely blacks out so it didn't really help that much. It just meant instead of flipping it up while you're adjusting the weld piece and flipping it down to start welding, you could leave it down all the time, but as soon as you start welding, you can't see much, except this little speck of bright white light and everything else completely black. So the glass that I envisioned was actually dynamically helping see better over the whole image.

So this is sort of a—I spent much of my childhood kind of as an inventor, amateur scientist exploring, tinkering, and trying to understand the world around me and so here's a little video. This video introduces a new way of seeing.

[VIDEO—Narrator: **Professor Steve Mann**]

The Quantigraphic Camera.

This Camera captures a visual dynamic range of a 100 million to 1. The goal is to capture, transmit or share welding video of molten metal, electric art and surrounding material, all very clearly.

So this is an Eye Tap device. It causes the eyes themselves to function as if they were both cameras in displays in effect in the sense that it captures eyeward boundaries, light, and those rays of light are re-synthesizing laser light to draw into the eye and so as a result it creates a mediated reality of the environment or a visual filter which is a proper superset of augmented reality.

Professor Steve Mann: I'm just going to fast forward a little bit here so you can see what it looks like.

[VIDEO—Narrator: **Professor Steve Mann**]: Here's an example from a quantigraphic camera mounted in a welding booth to show a group of students how to weld a hydraulophone pipe. Notice how we clearly see the weld craft cup, the tungsten electrode, including the tip, and the filler rod as well as the glow of the molten metal.

Now I have the quantigraphic camera on my helmet so that I can see the welding process on my head-op display. The special camera can be mounted on or in a welding helmet, or on a tripod, or on a special stand in the welding booth, or it can be handheld by an assistant. Notice how we see the details in the hydraulophone pipe such as the serial numbers on the pipe, at the same time as we can see the glow of the tungsten electrode, and the surrounding weld pedal formation. Each hyrdaulophone pipe has a unique serial number. You can even see the details of the smoke emerging from the mouth of the hydraulophone bulb.

This is welding aluminum so it's AC. You can hear the sound of the weld. The overlays happen in real time augmediated reality so it guides you, what you should be seeing. The arc length if you pull back too far it'll tell you that you've gone back too far. It kind of gives you some guidance as to what's going on there.

[End slides, **Professor Steve Mann** speaking to audience]

So the idea here is that it's augmediated reality, it's augmented, with overlays but it's also diminished. The bright areas are diminished, the dark areas are augmented and overall it's an augmediated vision that helps people see better.

So this is the invention of HDR. I have here the original scene is broken down into different—I have alternately dark, medium, light, in rapid succession. Dark, medium, light, dark, medium, light, dark, medium, light, exposures 120 times a second. In real time they're all stitched together photo-quantigraphically to reconstruct dynamic range of more than a 100 million to 1 in the head-up display and to help people see better in general. So if you're walking down a dark alley and there's headlights shining in your face you can still recognize the driver's face. Fast forward a little bit from my childhood experiences with tinkering and welding and all that sort of stuff to back in the early 1990s, I was accepted into MIT, Massachusetts Institute of Technology and I took this invention down there to found the MIT Wearable Computing Project, as its first member. And so this is a video of the Media Lab director kind of explaining how that came about.

[Video: Media Lab director speaking]

It's a very, very different time for us. Steve Mann was building wearable computers in high school, and I think it's a perfectly good example that here's a young man that brought with him an idea that was very much on the lunatic fringe, was very much something that people thought 'Well this is kind of weird' and doesn't really make sense, and when he arrived here a lot of people sort of said 'Wow this is very interesting,' and faculty became more interested and I think it's probably one of the best examples we have of where somebody brought with them an extraordinarily interesting seed, and then it sort of grew and there are many people now, so-called Cyborgs in the Media Lab and there are people working on wearable computers all over the place.

Steve Mann [in video]: What I've got is a computer screen in my glasses. I've been experimenting with something we might call wearable computing or personal computing. There real thing here is that it replaces a lot of the normal things that we carry such as a camcorder, a still camera, Walkman, pager, cellphone, all of those personal electronics items are subsumed into a single apparatus because I have a camera built into the glasses so that as I look around the algorithm that I've developed seamlessly stiches all of the pictures together and makes them into an image composite.

[End Video; back to **Professor Steve Mann** speaking]

So those konky eyeglasses are about 20 years old now, but I had all these different things. I had to build my own network because there was no wireless so I climbed up on the roof of the tallest building in the city and I put an antenna there with a microwave downlink to the roof of the building that I was in and then I ran a wire down the outside of the building into a 19-inch relay rack full of equipment that I built. And so I built this whole network and I applied to the New England spectrum management for a 100 kHz spectral allocation for my community of cyborgs, and so my call sign is November 1 November Lima Foxtrot, and I had my own station there. So this is kind of the evolution, I started with helmets, people thought it was crazy and walked across the street to avoid me, but then when I built in eyeglasses people came running over to say 'Hey those are cool eyeglasses. Where can I get them? I don't know what they do, but I want some.' So it was amazing, the change from just helmets to eyeglass. There's my 1995 passport – and that was an interesting adventure, 'take me as I am.' And then this is the digital eyeglass

Generation 4, see it looks like I have a glass eye there. This glass is about 14, 15 years old now and there's a beam splitter here. Rays of eyeward bound light come in to this imaging system and go around, there's a computer controlled laser light source that repaints everything onto the retina exactly co-linear with the rays that come in. So we call it the glass, the glass eye because it looks like I—if you look up at my right eye, it looks like it's made of glass. It looks like I have a glass eye so people called it Digital Glass or Glass Eye or Eye Glass. And then if you look here 14 years later the Google Glass has a similar appearance. This is the glass that I built 15 years ago. Just one strip of metal curve, nice arc around the forehead and all one piece. No hinges or anything, just one piece of metal. And of course you can see on the right there there's a similarity. And the Google Glass, you'll notice that the camera's offset. The camera is not the eye itself, the camera's over to one side. This is what I call Generation 1 Glass; both of these are Generation 1, 35 years ago and today. Then I made Generation 2 which is, the eye itself is the camera, and then Generation 3—focus tracking so the other eye focuses the same eye. Generation 4 has infinite depth of focus with the laser Eye Tap. And if you want to find out more IEEE SPECTRUM, Vol. 50 No. 2 the article that I wrote on Digital Eye Glass. And so you can see the principal rays of eyeward bound light diverted through the system back to the rendering engine and into the eye causing the eye itself to in effect be both the camera, and the display.

Here's another invention, this is a neck-worn device, a pendant with a projector and a camera in it at the time there was no such thing as little projectors you could buy, so I had to build it with a laser scanning system, serval mechanisms to sweep the beam around to draw vectal graphics onto the world and so I could interact with the world. And I called it Synthetic Synesthesia of the Sixth Sense, if that's too much of a mouthful you can just call it 'Sixth Sense.'

Now we're a little bit further ahead here, the same sort of gesturing to the world, the idea of 'Sixth Sense,' is that you make gestures and control the world by self-gesturing in an interactive environment. Now I'm Chief Scientist of Meta View the makers of space glasses and my PhD student Raymond Lo is the CTO, the Chief Technical Officer. Here's a little demo video, product video.

[Video—Electronic music in the background. Back to **Professor Steve Mann** talking]

So back in the '90s I published the wearable face recognizer. It wasn't too accurate back then, but it's thousands of times more accurate now with a true 3D holographic vision system. So the idea here is to reach to a Generation 5 glass which is an actual true 3D vision, holographic vision-type system which is far beyond the Generation 1 system.

So many inventions come from research labs, that's kind of the norm. Inventions are done in labs. But WearComp, Digital Eye Glass, Sixth Sense, High Dynamic Range (HDR) and so on are inventions that came from my everyday life. These things came to me as part of my everyday life, whether I was welding something in my grandfather's garage, or whatever it was that I was doing, these were everyday life experiences for me. And so in this respect these technologies are very much in and of the real world.

So I'm reminded of the IEEE's tagline, very much I feel that describes my life. Advancing Technology for Humanity. The IEEE is the world's largest professional association, I think that this really captures the spirit of what it is that I'm trying to do.

So when I saw people hunched over these keyboards, wrapped up like pretzels, people wrapped up like pretzels around their computer. People serving their computer, you know, hunched over here I saw, there's got to be a better way. This is back in the 70s, I said, 'Well instead of wrapping us around the computer, let's wrap the computer around us.' So that was kind of my vision to take the computer and wrap it around our body so we can stand straight instead of hunched over a desktop metaphor.

Here's another, now not just wearable, I also, I use the term bearable computing because it can be handheld, carryable, wearable, or even implanted. So we develop this sort of eye vision system, the Eye Borg camera system for the blind, an eye that inserts in. We built this and here's the patent for it, that's my Canadian patent and this is sort of lower left there is kind of what it looks like and a group of us have been working on this kind of stuff.

In this 35 years of inventing, designing and building, wearing computers I've uncovered a lot of strange paradoxes about society. At the US consulate for example, picking up my daughter's passport, cause she was born in America, I was both required to enter, and forbidden from entering because you see electronic devices are not allowed in the US consulate. But I *am* an electronic device and so in this way I'm existential contraband by my mere existence. And so a lot of places say, 'Well cameras are not allowed,' or 'You're not allowed to have a seeing aid in our store.' Place like T&T Supermarket, they actually said I wasn't allowed to use a magnifying glass to read the small print on the labels. And of course my lawyer said, 'You should record that,' cause they're breaking the law by forbidding seeing aids. So I mean this opens, unravels a whole long rabbit-hole of experience, you know. You can go as far as you want down this avenue. But I started to say, 'Well, what is surveillance?' Because I would say, you know, they say, 'No cameras allowed in my store,' but I said, 'Well, there's a camera over there, there's another one over there, there's another one over there, there's another one over there…' And they said, 'Oh, but those are surveillance cameras, they're not cameras.' And I thought, 'Oh, ok. Surveillance cameras are not cameras. Suppose I take my seeing aid which doesn't actually record anything, it just processes the images locally and puts them into my eye to help me see better. Suppose I put a transmitter on there and transmit the images to the police station, so the police can look through my glass to identify suspects, that would turn my seeing aid into a surveillance camera, and by your logic, then it would no longer be a camera, and that would make it be allowed.

So I came up with this idea of a veillance contract, which is a contractual—you know when you sign a contract, both parties need to keep a copy of the contract, otherwise it's subject to the possibility of fraud. If you have to sign a contract and you're not allowed to keep a copy of it, it invites fraud. And so the veillance contract says that if A is going to record B, and B is not allowed to have a copy of the recording, then A's recording should be not valid as evidence in a court of law. That's kind of a construct I'm proposing. Very simple. So T&T, places like T&T that don't allow cameras, should not be allowed to use their surveillance video in court.

So surveillance is simply defined as a watch kept over someone or something, especially over a suspect, prisoner. For example: The suspects were under police surveillance. That's Random House dictionary. So surveillance means watching from above. 'Sur' means over and above, as in surtax or surcharge, and 'veillance' means watching, as in *veiller*, the French word 'to watch.' Now my six-year-old had an interesting take on all of this and she drew here 'surveillance,' and of course the opposite of surveillance is 'sousveillance,' *sous* meaning under, as in *sous chef*. And so we have surveillance and sousveillance. Over watching and underwatching. Sousveillance is the opposite of surveillance.

Now we've all seen these QR codes, usually they're in product information. Before you buy the watermelons you can scan them to see whether or not you want to buy them. So on the big, there's a big huge carton of watermelons, with a 'Scan me,' on the box and you scan it, and if you like what you see, you buy the watermelon. Gives you a little bit of pre-purchase product information. Well of course right next to a lot these signs there are signs that say, 'No cameras allowed.' We have signs like, 'No cellphone in store please.' 'No video or photo taking,' 'No cameras.' So there's a kind of hypocrisy here that says we're going to record you but you're not allowed to record us. Surveillance is the veillance of hypocrisy. The opposite of surveillance is sousveillance. Sousveillance is the veillance of what? What is the opposite of hypocrisy? [Audience offers responses] Uh close. Transparency. Truth. Give me another word. Integrity, yes! The opposite of hypocrisy is integrity. So sousveillance is the veillance of integrity and surveillance is the veillance of hypocrisy. Just a simple lesson in opposites.

Now integrity is a very interesting thing because we can also talk about data integrity. As an example, recently in the London Underground, London Police in the subway shot someone. A case of mistaken identity, they got the wrong guy and they shot him, eight times. But they had mistaken and got the wrong guy, he wasn't really a terrorist. And so then they seized the surveillance video, and there were four separate surveillance systems and the police seized all four of these hard drives and they said that all four hard drives were blank even though the subway guards had watched the video and seen it before. Before the police seized it. So this was in the news, 'Row over 'blank' CCTV tapes,' 'Riddle of Lost CCTV.' And so centralized storage leads to potential data corruption, 'Whoops the hard drive fell on the floor and maybe it got damaged.' And so if the data's centralized, it can be lost. We know what a RAID is—Redundant Array of Independent or Inexpensive Discs and we spread it around and then that's more –it protects the integrity of the data. The opposite of human integrity is hypocrisy; the opposite of data integrity is corruption.

So, in this sense compare that with Sammy Yatim here in Toronto who was shot in the subway and bystanders happened to record it and it demanded a public outcry and resulted in some social change. So if you do this chart here it's very simple. Surveillance is the veillance of hypocrisy, it's centralized, it operates with secrecy, and it's the veillance of corruption. Sousveillance is the veillance of integrity, it's distributed, it tends to be more open in nature through social networking like Sammy Yatim. The justice was brought because it was distributed and spread around, and not concentrated. And it's honesty in terms of humans and integrity in terms of data.

Now this takes me to Research Thrust 2: Alethiometric Systems. The wearable camera is an alethiometer in a sense. Alethia is the Greek word for 'unclosedness' or truth, it's a broad word that means unclosed nature or a truthful nature, or a self-evident nature. And so alethiometric systems are systems that are self-evident and comprehensible and easy to understand. So we see here as an example we had this project in collaboration with University Health Network where we looked at reducing hospital infections through using sousveillance. Presently doctors are not really accountable to anybody above them and so we thought well, we'll make them accountable to the patients below them and make their hand-washing protocols evident in protection of the patients' interests. So this system that we did in a research project was simply to reduce in a transplant ward, where hand washing could mean somebody's life or death, to equip the hand wash stations as sousveillance to monitor hand-washing among the doctors. And the idea is to make the patients able to know if the doctors wash their hands and the patients can then say 'Oh would you please wash your hands before you do that surgery on me.' And so we found this was quite an interesting outcome of the Hawthorne Effect. The Hawthorne Effect is normally studied in surveillance theory but here we studied it for the first time, the Hawthorne Effect in sousveillance theory. Here's another example, back in 2000, back in 1998 actually, I built the world's first wristwatch computer—videoconferencing wristwatch telephone. And it was on the cover of Linux Journal back in 2000. This is the patent. So if we take that wristwatch computer, and we put stock quotes on it, or BitCoin or something in our field of view, when we look at it with our eyeglasses it will show that timestamp. And this prevents us from falsifying the date of the video. It's kind of an inverse time stamp. You can time-stamp your video but you can't—to time-stamp it the other way, there previously was no method of time-stamping it the other way. So now we've developed for the first time in history a bi-directional time-stamping system that puts a forward-bound and a backward-bound and when that date is. So you have today's news displayed as a hash MD5 hash function, or the current price of BitCoins, stock quotes and everything. It's very hard to fake that cause you can see the glare on the watch here. Very hard to fake all that video in real time. So it's alethiometric, it's like a truth-meter. So this is an example of an alethiometric system.

Here's another example, the space glasses project onto the shirt today's news and then it captures a video. So everywhere you go it's projecting the news either in infrared secretly so that it doesn't bother anybody, or if you don't mind bothering people, or if they want to have fun and share in the experience you can make it visible and project the news headlines together with a BitCoin hash of the current price of BitCoin which would be very hard to predict or any of these things like stock prices and stock tickers all MD-5 onto subject matter. And the camera sees it so it's very hard to fake and this produces evidence of where you were when.

We had a conference, I was the General Chair of the IEEE ISTAS conference on Veillance and so this kind of brought to light many of this concept of Alethiometric systems as a venue for this field of research.

"Insanity is defined as doing the same thing over and over again and expecting different results." That quote is often misattributed to Albert Einstein as well as Benjamin Franklin. It's actually from Narcotics Anonymous 1981. The idea here is that insanity, but you know, you see my system manager, when I was using a computer in a lab told me 'Oh, your program didn't work. Run it again.' That was the advice, run it again. Just try it again, do the same thing again and you might expect different results. So in other words, it's please be insane. Everybody is telling us to be insane. The software engineers who are making reliable computers are not only causing insanity, but actually requiring insanity. In this way modern computing requires a certain amount of insanity and I wanted to write a paper with the title 'Optimum Insanity.' How insane should we become in order to function in the software world? The optimum amount of insanity, like often times I double click everything cause usually the first click doesn't work, it wakes up x windows and the second-click actually…So you get in the habit of double clicking everything. Sometimes you triple-click or quadruple click. One click should be enough but times two insanity is when you double click everything and I think I tend to think maybe the optimum amount of insanity is maybe 300% or triple-click everything. And obviously if you quintuple-click it might be too insane and it may download, you get three or four copies of the thing pop up. So there's a certain stochastic and randomness that asks this question, 'what is the optimum amount of insanity required to use modern software?'

That brings me to Thrust 3: Actional Systems. So Thrust 2 is Alethiometric Systems, systems that are self-evident and we did things like a USB cable that has a switch to turn off the data so that when you charge your phone it can't, on an untrusted laptop, it can't suck data out of your phone or try to hack your phone. So it disconnects you know, and just different things like that that are transparent to the user and obvious so that you can see how they understand. I want to see how things work. I want to know how computers and everything work. And Actional Systems is that third thrust that's also closely related.

Actional Systems I talk about Power, Energy, Action. We all know what power is, 100 watt light bulb, 100 watts uses a certain amount of power watts. This is a flashlight, flash lamp and it's measured in watt seconds. It's just because photographers don't know the concept of joules, but they know what watts are. So it'll say 400ws, 400 watt seconds. And the switch is here for condense or max capacity 200 watt seconds and 100. So this goes 100, 200, and 400 watt seconds. It has a certain amount of energy it flashes briefly, maybe for one millisecond, and during that time it's about—if it's a 1000 joules for one millisecond, it's a megawatt or so when it's on. But it's on very briefly so it approximates the direct delta measure of light. It's approximately infinitely right for a zero duration, approximately so to a first order of approximation wattage is not really a very good model to describe it so we describe it as energy, joules. Watts, joules, and if we integrate again, over time we get action. The integral of t – v d t is action, Lagrangian action. The integral of Lagrangian, kinetic – potential.

But let me, I want to introduce a new concept, what I call 'total action' which is the integral of t + v d t and I call that 'total action.' And that just means the amount of the integrated total energy. So we have watts, watt seconds, and watt seconds squared, and this is action then. So I want to build this concept around Lagrangian Modeling of Electric Circuits, let me say Hamiltonian Modeling of Electric Circuits, integral of t + v d t and I want to talk about a third new thing I called Absement.

This all started in my kindergarten class. And over the years I came up with some new concepts as a result of this and a lot of people laughed at it and said it was a stupid idea. Now there's a paper, 'Lagrangian Modeling of Electric Circuits,' it's building on this work. So the theory here is that my kindergarten teacher said there's three kinds of instruments—string, percussion, and wind. And it kind of bothered me because strings and percussion seem more similar to each other than either was to wind. Something really bothered me about that ontology or taxonomy. What bothered me is that strings and percussion, I thought about it for a moment, there's a piano that she played on every morning, and strings and percussion both make their sound from solid matter. And wind makes sound from gas. So I thought that what bothered me about that ontology is that solid, solid, gas. I thought strings, percussion, wind, solid, solid, gas. The three states of matter. Repeat after me: solid, solid, gas. The three states of matter. And there's something that really bothered me about that. And so I said, how about a musical instrument that made sound from vibrations and liquid? And she said, 'Well don't be silly, you know.' And I talked to some engineers and physicists, and they all said well you can't do that cause liquid's not compressible, it's impossible. You could never make a musical instrument that made sound from vibrations in liquid. And so I did just that, over the years of course. And so I built this instrument, with the help of a team of about 30 of us and a bunch of architects and engineers, and here it is as the main centre piece in front of the Ontario Science Centre. What's most remarkable and interesting about it I think is it's kind of a new physics or a new kind of physical concept. A piano responds to velocity, how hard you hit the key, and an organ in a church you know, responds to displacement, how far down you push the keys, gets louder as you push the keys down further. And this new instrument that I invented responds to something new that hadn't been observed before and it responds to the integral of displacement over time because the keys are flowing. The keys are continuous; water is continuously flowing so it's an endless key flowing past your fingers. Something new and remarkable and interesting happened here. I'll just play a short video of it so you can hear what it sounds like first and then I'll explain why it has to do with electrical engineering.

[Video plays. Demonstration of the sound of hydraulophone]

Professor Steve Mann: Now what could this possibly have to do with electrical engineering? And what am I doing as an electrical engineer building public art sculptures? And it's done some good for the world. We built one for the CNIB, the Canadian National Institute for the Blind. I was part of the outdoor classroom project there and it's used for tactile, for the deaf-blind, as well we have deaf musicians playing it because water, the sound comes from vibrations in water and when a deaf person touches it the sound vibrates their fingers and it carries through their body because the human body's mostly made of water. So obviously when you vibrate water it goes right into the body and it gives you a non-cochlear sense of sound. So it has been immensely helpful for the deaf and it's also helpful for the blind because it's used for rehab, rehabilitation of children, special needs children, used all over Canada at the CNIBs, Canadian National Institute for the Blind, and all over the world in fact. And it's created a lot of interesting research on how it works. It's an 'out-strument,' not an instrument. An instrument normally fluid flows in, you blow into a flute. This thing, the fluid flows out of it, when you stop the fluid it makes sounds. So it's the opposite of an instrument so we call it an 'out-strument.' And this is all about 'out-struments,' there's a whole flow and all the Navier-Stokes equations mathematical modelling which is kind of related to electrical engineering but you're saying 'Wait a minute, what exactly does that have to do with electrical engineering?' So absement, the integral, what it responds to is very interesting because there's a paper that you should all read that's called Lagrangian Modelling of Electric Circuits, and it's built on this theory that I developed for this instrument. So it comes right back to electrical engineering. Here's one we sold to LegoLand in California, it's in the shape of a giant Lego block, here's one, you can see the individual hydraulophone pumps that were welded in. You saw the weld video, here's the pipes, what they look like. And here's a 14-year-old high school student who did a project on absement, the integral of displacement which exactly is the way a hydraulophone responds so this is another example of hydraulophone in outreach engineering education.

Here I want you to look at this figure. A piano responds to velocity, how fast you hit the keys. An organ responds to displacement, and if you take the derivative, you go that way. Take the derivative again, you get acceleration. What's the derivative of acceleration? Time derivative of acceleration? Jerk. Go one more. Jounce. And then you can go snap, crackle, and pop. [Laughter] I like to say snap, crackle, and poppy cock because it's poppy cock, codswallop, and flapdoodle should be the next ones after that. Because I start to wonder what meaning it has when you go that high. But nobody's ever, and you come down, take the integral of acceleration, you get velocity, you integrate again, you get displacement, but nobody seems to have gone down the other way. Everybody seems afraid of negative number here. So I said, 'Ok a hydraulophone responds to absement which is the integral of displacement, when you press down on the hydraulophone key you hit it, nothing happens, hold it down, you have to hold it down, it builds up the water. And so absement models the flow of water or the flow of electricity, and of course the one at the Science Centre is actually a two-stage hydraulophone. There's a hydraulophonic mechanism on the consul that activates the organ pipes so it actually integrates once when you play it on the consul and once when again when you play it on the organ pipes so it responds to the double integral of displacement. And so that instrument responds to what I call absity, these are what I call words I made up. Absement, Absity, Abseleration, Abserk, Absounce, and so on. And so we have a complete negative kinematic systems. And that brings me back to here, power. The Power Lab changed its name to the Energy Systems Lab, I've drawn an X through both of those, and I'm calling our research, this hydraulophone lab is called the Actional Systems Lab. And the idea I think Action is really what matters. Power, energy is the ability to store power. Action is the ability to store energy. Total action, not Lagrangian action, I'm using this new kind of action. Hamiltonian action you could call it because it's the integral of t + vdt.

So in concluding, what I've tried to do here is to create three new fields of research that are all very inextricably intertwined. One is wearable computing, intelligent image processing, high dynamic range imaging, wear cam, wear comp, wearable cameras, wearable vision systems, seeing aids for the blind, all of those things, is the first thrust. The second thrust came out of that.

The second thrust, alethiometric systems really happened because I was physically assaulted by a security guard while wearing a vision system. And so I realized there's got to be a connection to the real world. It's a truth meter. The camera's a truth meter. It's funny, I was, I'm trying to go to different schools to find a school for my daughter so I went to all these different schools to their open houses and one school really objected to my camera and became really angry at me. All the others were ok. So in a sense it's an alethiometer. Now I have a suspect of the, you have a person of interest who's a suspect, now I have a place of interest that's suspect in my mind, 'Why are they so scared of the camera?' So this inverse surveillance, sousveillance systems or alethiometric systems, systems of truth, integrity, the opposite of hypocrisy. We've got surveillance studies, there's all kinds of surveillance studies programs which are funded with huge amounts of money, we need some sousveillance studies programs that are also funded because sousveillance is the new veillance. We have as many wearable cameras now, there's as many people carrying cameras around with them now as there are cameras mounted on lampposts. So we're really into a sousveillance world, or a veillance society.

And the third thing is actional systems, integrating over time. We go from the power lab to the energy lab, to the action lab. We're integrating over time, absement. Total action, energy storage. Why does that matter? Well batteries, batteries store energy. That's important. Action is important for batteries. Action is important for the human body. We store energy in the body as fat. And so I'm working on a project collaborating with a Department of Nutrition on analyzing fat using the eyeglass to see what I eat every day and it documents automatically whatever I eat, and it sees how much exercise I'm getting and it figures out my diet. And that's all about action, it's action-based research. It's not power, it's not energy but it's action. Action is what matters to us. The most fundamental concept is Planck's constant. Planck's constant is the smallest amount of action that you can have. Think about that. What could be more fundamental than Planck's constant? Very fundamental. Action systems.

So I've tried to create three new fields of research that are all intertwined, actional systems, sousveillance systems or alethiometric systems, and wearable computing. And they're all related to one another. So here I have a hydraulophone, and I just want to finish off by showing it so that you can see one. When I push water through those holes here and the way you push water through the holes in the hydraulophone, you can pump it with one hand and play with the other but what's nice about this is I'm collaborating with Pete here and developing some actional systems here. So as I pedal, if I pedal faster of course it'll go faster. And each of these holes when I block it [demonstrates playing], and if I block more holes at the same time I'll get a chord [playing hydraulophone]. And as I play a little slower…

[Applause]

Professor Farid Najm: Thank you Steve, that was great. We will take a few minutes, maybe five minutes for questions and answers. If anybody has a question, I can pass the mic so that you can be heard on video.

Audience member: Thank you. It's a fascinating presentation and my first question is, what's next? And what do you think of the concept of singularity? This is the advancing the computer to higher levels.

Professor Steve Mann: Yeah, I'll say about the singularity, what's very interesting about the singularity is at my conference I had Marvin Minsky, the father of AI, and I also had Ray Kurzweil, the Chief Engineer of Google come to the ISTASS conference for the keynote. And Ray Kurzweil and Marv Minsky and I, the three of us wrote a paper called 'The Sensularity,' and the hypothesis we said is the sensing singularity, the sensularity, is nearer than the computational singularity. Singularity may be near, but what's even nearer is sensularity. And we said there's going to come a point where sensors become more profound and more ubiquitous than human sensing. If you think about all the sensors there are in the world, there's sensors in every appliance almost. It's more and more sensors, more and more machines have vision in them. Machines that see. And so you have these new street lights that have cameras in the street light that see how fast the cars are moving and adjust the lights. So if you're heading north slowly it'll light up a few lights ahead. But if you head faster, it'll light up more lights ahead of you and a couple behind you and detects the difference between pedestrians and so on. And even the things like the automatic flush toilets, the old ones were only 128 pixels of which about 64 of them, light fell on them because it went off the end of the array. The new ones are 1024 pixels so they can recognize the difference of whether you're standing to urinate or sitting to defecate and flush more or less depending on whether you do a number 1 or a number 2. So what we see is that the sensors around us are becoming more intelligent. And I don't think, I think it's going to be a long time before we get to the singularity. I think that it's a long time coming before the devices that are around us will—that computers will become more intelligent people. But already I think sensing is becoming the main thing. I think that's what really matters and so if you look at that paper that 'Sensularity,' if you just search for 'sensularity' you'll find it, by Minsky, Kurzweill, and Mann, 2013. It will give you a sense of where I stand on the singularity and no offense to Ray Kurzweill or any of the others, even as a co-author now, but I think the singularity is blown out of proportion beyond what it really is and we should really focus on sensing, that's here and now.

Audience member: Just a simple question. You're obviously a creative genius, are you able to sort of encourage that in others, in students? That sort of spark of creativity, of jump to sort of the genius level. I'm not expressing myself well, but can you, are you what you are alone, or can you sort of push others to be more like you?

Professor Steve Mann: Well thank you for the compliment, what I'm trying to do is I've got a teaching method that I call 'tinquiry,' which is inquiry through tinkering. And what I believe is that if we look at—I also call it praxistemology, the praxis of existential epistemology. What we need is—you see, at MIT I learned this thing called 'learn by doing' or constructionism, Seymour Papert and Marvin Minsky, you know the learning idea, problem-based learning, PBL. There's these theories so instead of lecture-based learning, we have learn by doing. And I thought well that doesn't go far enough. So I want to invent something that I call 'learn by being,' existential education. It's a praxis of learning by being.

There's an element, there's two things—three things about existentiality. Well one, there's like many facets to existentiality, but one is existence before essence. You know, in other words, create something for its own sake without necessarily needing to have a goal or a problem in mind. I put in my plan file a goal—a plan is a prison and a goal is its guard. And I think we spend a lot of time in engineering with Gantt charts and planning, and we should spend more time with tinkering as a form of inquiry. And the other element is authenticity, existentiality is about authenticity. It's what I call Type A integrity. Type A integrity is the artist's integrity, the academic integrity as opposed to Type B integrity that you might find among a bookie who will shake hands and you don't need to sign any papers cause they'll just break your legs if you don't pay the bill. But the sort of business, bookie-type integrity is not quite what I had in mind but by integrity I mean the authentic, artistic, academic kind of integrity that is at the existentiality notion. And so, this combination of integrity and self-exploration I think is what's missing from the engineering education and that's why I think the stroke of genius is often crushed behind Gantt charts and planning and structure that I tend to find the true lateral thinkers, the modern day Leonardo da Vinci-type thinkers are crushed by planning and filling out forms and they often don't get things. You know there's too much procedure and not enough individual exploration and authenticity. People are doing things because they want to get a good job, not because of natural passion. And so we need to create a world in which people are naturally driven to their passions, and that's what I think I mean by 'tinquiry' or 'tin*quiry*' is to play, to reach into a dumpster and pull something out and tinker with it and play and see where it might take you.

Audience member: Does it work?

Professor Steve Mann: I find it works, I mean this is how I taught. I did this for, I've been teaching that way for 14 years now. Years ago I gave everybody a card-reader that I got at Active Surplus for $2, mag stripe reader, and I said, 'OK I want you to hook it up to your computer. I want you to figure out what voltage it needs, what wires—there's four wires coming out of it, I want you to figure out what they probably are. I want you to try to figure out what voltage it needs, I want you to figure out the protocol and I want you to write a device driver in Linux that will read from that device. And I taught all these third-year undergrads how to figure—how to reverse engineer something, how to write a device driver for it, how to extend the operating system to get it to work, basically how to figure it out. And that's the kind of thing that I think we need more of. And it does work.

Professor Farid Najm: We'll take one more question…

Audience member: Oh, perfect. Firstly, Professor Mann amazing presentation, I have two questions for you. The first question you said that, you stated that you learnt strings, percussions in kindergarten…

Professor Steve Mann: Strings, percussion, and wind.

Audience member: …and wind, in kindergarten…Which school was that? [Laughter] Secondly, the question is, I see that you made something very similar to Google Glass which is today, what do you see the future of Google Glass in the next ten years, five years, and what is the limit of variable computing which you see today?

Professor Steve Mann: Well I would say, I went to school in Hamilton and I was born in Hamilton. And the limit, the Google Glass is very much—it does what my 1978 machine did. 35 years ago. I've tried it on, and it looks the same, pretty much like what I saw in 1978. It kind of—that sense of, you know, the camera is not your eye, imagine your eye is outside over here somewhere. Kind of makes you feel dizzy. And yes, so I went through several generations past that and I think the future is going to be something that's a Generation 5 Glass of some kind. The Space Glasses concept is I think where the future is.

Professor Farid Najm: Thank you very much Steve. Thank you all. We still have the room for another hour or more, and we have food coming now on trays, will be served. And let's continue the networking session, and thanks Steve again.

Professor Steve Mann: Thank you, it's been an honour to speak. And by the way if anybody wants to try the instrument, feel free to. Just don't pedal too hard cause we don't want to spray water on the floor.

So the water comes out of the hole more easily and so I'll just—I'll unplug this for a second, and so we can just hear it. See if I plug in the amplifier you can hear it louder but if I just go [playing instrument]. So there's basically a flow past something and it goes easier past here and when you block it here it pushes it through a little whistle. There's a side thing here and the water comes out through the side.

Audience member: Is this like an organ that…?

Professor Steve Mann: There's a T-fitting and when you block it, it pushes it out the side of the T-fitting into another pipe.

Audience member: Oh okay.

Professor Steve Mann: And so when you obstruct it, it's easier to go straight out. It draws a vacuum by the Bernoulli principal and when you stop it from coming out it pushes it out through the—And then it depends on how the volume, the volume level depends on how much the water can vibrate so this one is electrically amplified so there's a small vibration which is picked up with a listening device. If you're willing to pedal a little harder you can make a system that produces the sound entirely acoustically. And then it vibrates the water—

Audience member: So you manage this for the right vibrations like 256 cycles UC or—

Professor Steve Mann: This is a, right here, that's 110. D, E, F, G, A—that's 220. And that's 330.

Audience member: So you could get a whole range of vibrations. You've just chosen to select those specific—

Professor Steve Mann: This is simple. The other one at the Science Centre has 45 jets on it. So it goes from 55 all the way up to 660.

Audience member: But you have to tune it such that it's an accurate C, D, E, or F. Cause you could have vibrations, frequencies between those that would be--

Professor Steve Mann: Yeah.

Audience member: So you've tuned it to the right frequencies. Fascinating.

Audience member: How do you tune this?

Professor Steve Mann: It's manufactured. It stays in tune. I mean if you want to change the tuning you can put whisky in there or some other liquid that's different.

Audience member: Oh so it's different density.

Audience member: There's a certain breathiness to it, where does that come from? You can hear the wind.

Professor Steve Mann: Well it's just like wind. It sounds a lot like an organ because it is an organ.

Audience member: Where can I hear it?

Professor Steve Mann: You have to put your head in the water to hear it if you don't amplify it. The easiest thing is to put your head under water to hear it. The first ones I built, you had to play them underwater. So all of my concerts were underwater concerts originally. But I've built some that are loud enough, acoustically that you can hear it above the water. You need a lot of energy to get it to vibrate so loud.

Audience member: Do you have a patent on this as well?

Professor Steve Mann: Yes I do.

Audience member: It's amazing.

Professor Steve Mann: It's a matter of getting enough volume to hear it.

Audience member: So you need a lot of horse power, a lot of

Professor Steve Mann: Well, right now I'm pedalling, I'm powering the pump and an audio amplifier as well is coming from the pedal power. But it's also—the one's that are entirely acoustic, you know they tend to be—

Audience member: Now is it a pure note like a flute, a pure sign wave, or is there harmonics? Where do the harmonics come from?

Professor Steve Mann: Well there's different. It depends on the pipes, you know, like an organ pipe can have different harmonics.

Audience member: Ok.

Professor Steve Mann: So there's different pipe work like I can make, you know, it's just like a pipe organ, I can have different, many different kinds of sound.

Audience member: The pipes are down behind this thing?

Professor Steve Mann: Yeah.

Audience member: Ok, I'll let somebody else come around.

Professor Steve Mann: Yeah, you can try it if you want.