Oral History of Ted Selker

Interviewed by:
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Steinbach: Today is June 12, 2017. I'm Günter Steinbach and I'm interviewing Dr. Ted Selker at the Computer History Museum in Mountain View. I started contact with you because you invented the TrackPoint that was, or is, in many laptops, especially by IBM. But this oral history interview is about all of your work and career, not just about that. So let's start with the beginning. Where did you grow up? What was your family background, your childhood hobbies, and so on?

Selker: Okay. Well, I was born to a Holocaust survivor. My mother came to this country and met my father in Washington, D.C., and they moved a couple of times. My dad was a chemical engineer. I was born in Spokane, Washington and spent all of my childhood in the state of Washington, beautiful place, and learned to love the outdoors. My father was extremely intellectually curious. All my grandparents were dead by the time I came along, but I was very intrigued by the fact that his father, my grandfather, had invented the shock absorber for cars, but I never got to meet him. Maybe that is the beginning of what became my lifelong love affair with innovation and invention. I lived in Seattle for six years and then Tacoma, and then Longview, Washington, where I went to high school.

Steinbach: And so I guess that background got you into engineering. I mean, you...

Selker: Oh, yeah.

Steinbach: You could be creative in other ways, too. But...

Selker: Well, when I was very, very small, I was just fascinated with electricity. What surprised me was that I could plug in a lamp to any outlet and it would always work. And that outlets are a standard is amazing, obviously. I was just more than a toddler at that time. So I started being interested in electricity and that's something that's been a lifelong interest. I tried to build things on my own and was discovered at an electronics parts store, when I was 11, by Alvin Nuganst, a TV repair person. He took me under his wing and taught me all about fixing televisions.

Steinbach: I had a time like that, too.

Selker: Yeah, it was so much fun.

Steinbach: Okay. So let's talk about your college degrees. Where did you get your college degrees?

Selker: Yeah, well, so when I was...

Steinbach: Not in Washington?

Selker: No.

Steinbach: Right.

Selker: Well, all my brothers went to Reed College, but because Reed saw the spelling errors in my application they weren't going to give me a scholarship. So my father wanted me to go to Reed anyway. So I decided to be an iconoclast, and I went to University of Washington one year. But, basically, when I was 16, my dad told me, "Well, you're interested in applied math, but Brown's the best school in the country. You couldn't get in." So I transferred there and got my degree from Brown in Applied Math. I was interested in how the mind works so I wrote an undergraduate thesis on how the brain focuses the eyes. I got interested in this idea of maybe if it could interpret the world, a camera could automatically frame things. There was this research project going on at UMass Amherst headed by Ed Risemean called VISIONS. He gave a talk at Brown in the spring of my senior year. I was intrigued with his project to make computers see, then he sent me this love letter, basically, saying, "Come to my university and we'll pay for your degree." So I went to work there and got a Master's degree. My MS thesis was again a neural net brain modelling thesis, “Paired Associative Memory.” I started wanting to make a difference beyond brain modelling. My UMass advisor, Dave McDonald, was going to Stanford for the summer, so I was pulled by my advisor to the excitement of the Stanford AI lab. I transferred to working for the Eye and Hand group at Stanford.

Steinbach: Okay.

Selker: Yeah, lots else happened.

Steinbach: But you did not get your PhD at Stanford?

Selker: No. I did not, and that's interesting. What happened was, instead of transferring to Stanford, I thought it would be easier to be a visiting student. But I was less and less happy with the advisors at UMass Amherst, and there was no user interface research going on, at any university, which fascinated me. I started a seminar series called "User System Ergonomics" at Stanford. Once a week I'd try to get people together and it was great. Vaughan Pratt and John McCarthy were the two faculty members who came. This was before Terry Winograd got interested in user interface, and all the people were coming from Atari, PARC, SRI. So I said, "You know what? I'm going to go work for the great Alan Kay at Atari, where the action is." And I quit graduate school and went to work for Atari's Silicon Valley Research Center. That was not a way to get a PhD at that moment, because Atari didn't last. So quite explicitly, a year and a half later, when I was working at Xerox PARC, I decided if I want to have impact at a place like PARC, I've got to get my PhD, and my dad had always pushed me to believe in its luster. He'd always wanted a PhD and hadn't got one. So I turned down all sorts of wonderful experiences to get my PhD, one of which was helping Bechtolsheim start Sun. I eventually went to IBM Research to work on my Adaptive Help system to get my PhD. They encouraged me to get my PhD and gave me freedom to do all sorts of stuff.

Steinbach: Oh, okay.

Selker: I thought it'd take three years at IBM. It took seven. But my PhD, then, is from City University of New York.

Steinbach: Okay.

Selker: A very dear colleague in the IBM Math group Ephraim Feig, made sure I could follow my dream and hooked me up with City University for my PhD work.

Steinbach: Okay. All right. So what did you work on at Atari, mainly?

Selker: Oh, my gosh, well, my Lisp machine's name was Intelligent Interface, and I dreamt of making AI-based teaching systems, and that's what I said I was going to do.

Steinbach: Oh, at Atari?

Selker: At Atari.

Steinbach: They made general purpose personal computers, too, right? Not just video games?

Selker: Yes, they made the Atari 400 and Atari 800 computers. This research center was something to behold. I mean, Alan Kay ran it. Doug Lenat, Marvin Minsky, Terry Winograd, and so many visionary computer scientists came around.

Steinbach: Oh, really?

Selker: It was such a party. Its first hires were the first graduates from Architecture Machine Group at MIT. We could do anything, supposedly. I made a Force Feedback ski boot, and I had this idea of teaching people with Cerebral Palsy to walk better, and maybe teaching people to ski. It was pneumatic. It ran off an Atari 800. I had this idea, Dream Writer. The idea was to make a computer interface that was a computer-controlled hand-held pen. In fact, it's the way I met Marvin in 1982. I showed him this mock-up I'd made of a pen that would draw in any font and draw anything on a piece of paper, and so you could rub it to print out …anything, say a picture of your wife. Or, if you took notes, they'd be collected, and if you wanted to address an envelope, it would come out in Helvetica 10 point. I did many experiments, explorations, about this at Atari, and before, but mostly at Atari, and I still kind of love this dream. Anyway, at Atari, it was shoot for the moon, and yeah, quite frankly, my intelligent interface work that turned into my PhD thesis was in my mind, but there wasn't much code written on that.

Steinbach: And then, Atari?

Selker: In March, I'd been at Atari nine months and it's so interesting to watch how businesses work. That company had gone from 1972, nothing to two billion dollars a year in 1983. That's such a climb. And then, going back down to one billion in 1984 killed it. So, it's funny that it's the trajectory-- I mean, a billion dollars is a lot of money. Basically, Coleco and TI and Sinclair and everybody wanted to make personal computers into game computers in 1984, but mostly they hoped to join the world in personal computers. But Atari depended on computer games for their revenue, and everybody else was just trying it out, and the market went down. In that year of the Coleco Cabbage Patch Doll success, Coleco's other big product failure was their "Adam" computer which almost sunk them. And Atari's demise that year was very, very sad. Because we had the most incredible organization, working on so many exciting things.

Steinbach: But the name still exists...

Selker: Atari.

Steinbach: ...as a...

Selker: Yeah, I should've worn my t-shirt.

Steinbach: But, of course.

Selker: Yeah, and quite frankly, I mean, one of the people that I think has been a lot of fun for me to get to know better over the years, the founder who was no longer there when I worked at Atari is Nolan

Bushnell. He is quite a visionary and showman and, really, guided all of that to happen, before he left before any of this, the badness...

Steinbach: Oh, really?

Selker: Oh, yeah, he hadn't been there in, at least, two or three years. He left, I think, in 1978.

Steinbach: Oh, okay. Okay. So when that blew up, when it-- what did you do then?

Selker: So that was a fascinating thing. There was this guy, Jim Dow, who started a company called Communications Intelligence Corporation.   He made a lot of the semiconductor industry's technology-- he made his millions by making Epitaxial, etching things, the very first generation. And he was really intrigued with this idea and interested in me going to work for him to make Dream Writer, and that's a sad non-direction because it was really exciting. But all at once Rod Brooks, who later ran the AI Lab at MIT, was leaving Stanford to go to MIT. He was supposed to teach the AI and Lisp class that fall, which is the same one that Udacity U was created out of, and I got offered the job. I saw it as a way to try out my ideas about AI and education. So I got to be the lecturer to teach AI and Lisp that fall, and instead of doing something reasonable, I made a whole new curriculum about AI in education, and I taught all of these modules. I made a windowing system for the DEC VT100 computer terminal that they were supposed to make, this intelligent tutoring system that taught Lisp. And since I had 120 students, half of them as far flung as Colorado, I teamed them up into groups of three, each of them made competing help systems, using Blackboard Architectures and rule-based systems and some learning, hopefully, and, taught these topics. And that, quite frankly, became where I learned some very exciting things about the problems of changing what a person sees when they do something. If you have an AI system that changes how it responds too much, it confuses people. So I really learned so much of what I needed to know to make my PhD work on AI and education, out of teaching that class.

Steinbach: Okay.

Selker: Which was really great fun, and very non-lucrative. I've never in my life, except for during that semester, borrowed money from my father.

Steinbach: <laughs>

Selker: It is a bad thing to try to make money as a lecturer at Stanford.

Steinbach: <laughs> Okay. So at what point did you go to PARC?

Selker: Well this course was, as I said, not lucrative, and so there were two things I did beyond the lecturing. One was get to know people at PARC, because I had always adored their work. They got interested in me because I had built a collaborative computing system at Stanford AI Lab when I was a graduate student there. I made this thing called NewDD, actually. It was the newData Disk (digital replacement for the buildings' computer monitors). And they were trying to make a COllaborative LABoratory. It was a room with special furniture, beautiful. Mark Stefik and Danny Bobrow had this COLAB dream. I got interested in them, and about a month after I finished my teaching at Stanford, I was working there. Also in that timeframe I got more involved with the Veterans Administration Hospital's research on people with disabilities, and I consulted for them on interfaces for people with disabilities. The funny thing about that is the first talk that I ever got paid to give was two or three years earlier, when I gave this talk about AI and disabilities, for some reason, and Larry Leifer, who is still a vibrant force and a professor at Stanford today, paid me to give a talk about intelligent interface. So that was the beginning of that direction.

Steinbach: Your speaking career?

Selker: Yeah, yeah, yeah.

Steinbach: Okay. But so you...

Selker: Mostly they have been paid like this interview, with an opportunity to share. <laughs>

Steinbach: <laughs> So I found one patent at PARC about a pen mouse.

Selker: Well, my patent on the standing pen was as an independent, not that I bothered to enforce it when Wacom used it.

Steinbach: Oh, okay.

Selker: There are lots of good things about a mouse. You can control a mouse with your arm for large movements and you control it with your fingers for smaller moments; if you put the heel of your hand down, you get even more accuracy. But your fingers are so far apart when holding its rock shape. So actually one thing I did make at PARC was a mouse where you could hold it with your fingers very close together like a pen. It improved pointing dexterity. I think Stuart Card still has that mouse. I just made it in my spare time. But what I had been dreaming of was a stylus that would not fall over. So many years later, I made this one I am showing you in a prototype ThinkPad keyboard. But at that time, that patent was about a stylus-shaped "mouse" that would not fall over. You see another reason mice are great is they don't move when you let go of them. Whereas when you are done with a pen you lay it down. And picking up a pen takes seconds and is kind of difficult. You've got, like, 45 muscles in your fingers all working together when you hold a stylus. We have trained them enlisting each other to work to move a pen smoothly. You've spent years learning how to be really dexterous with the pen “precision grip.” So this one, on a TrackPoint, I actually made and used this keyboard for many years and tried to get IBM to put a stylus in a ThinkPad. So there was going to be a pointing device in the middle and then you could grab the straw and wiggle it, and it'd fold down when you closed the laptop. It was always there, if you wanted to grab it to draw, or write, or sign something -- to do something really careful. But by being in a location that is recognizable and findable, you can save yourself a lot of energy and time, and I really believe that the several seconds that it takes to pick up a pen is the reason that mice are successful. So that was that patent and, sadly, I was at IBM and felt a little shy about pursuing litigation or business opportunities outside of IBM relating to my patent. So thank you for finding that patent. I'm very proud of that one, actually.

Steinbach: Okay. So you pretty soon-- you didn't stay at PARC very long?

Selker: No. I was there nine months and loved it. I built something-- I made this automatic graphic design approach that was showing off some of the language features of Loops, and I was supporting, physically, making interfaces for this big collaborative space. So I've always had this dance that goes, mechanical, electrical, computer, AI. It's about me having a love for understanding all of technology, in order to use the useful techniques for a specific solution, and they liked that. But what they didn't like is I didn't have a PhD, and by not having a PhD at PARC, you mostly help other people do their research.

Steinbach: Oh.

Selker: And I believed, maybe, someday, I could do my own, so that was...

Steinbach: Okay. And so from there, you went to get your PhD, right?

Selker: That was my dream, yeah.

Steinbach: Yeah.

Selker: What happened was, one day, I was interviewing at IBM, and I thought the place was, kind of, dusty, and...

Steinbach: This was Almaden?

Selker: This was TJ Watson in Yorktown Heights, NY.

Steinbach: Oh, okay.

Selker: The building was literally gray, the offices are gray. Eero Saarinen built this great beautiful building; all the windows are on the hall connecting everything in the building; not one office has a window. But then I met this Vice President, a wonderful man, Abe Peled, who ran the research division, Computer Science Research Division, and I was, like, in the middle of my interview schedule. Suddenly, I'm in his fancy office talking to someone not on the schedule. He says, "Ted, your ideas, they're more interesting than what I see us doing now-- why don't you come do them here?" Now, I mean, there's nothing that can captivate a person-- I mean, that was quite a flirtatious thing to say. And that whole 1/3 mile wall was set with rocks that allowed you to rock climb indoors anywhere. But as soon as I came, they tried to get me to work on program development environments for scientific workstations, because that's what everyone was making: Sun, Xerox, Symbolics, and the like. But I said, "No, no, no. You told me I could follow my dreams here." So they did allow me to make my adaptive help system, which turned into my PhD.

Steinbach: Okay. And overall, you stayed 14.5 years?

Selker: Yeah, yeah, yeah, I should've stayed longer. IBM was fantastic. With 2000 researchers the depth and breadth of knowledge were astonishing. When I arrived, the guy in the office next to me was working on cosmic rays and how they affect memory chips. Down the hall they were making a “butterfly” network for distributed computing. This is in '85, but really, the place was extreme. The mathematicians were incredible. They were creating and contributing to fields of catastrophe theory, algebra, statistics, analysis of algorithms, cryptography, linguistics, etc. It was strange though, because most things the research division did for the company weren’t as much research as one would think, There seemed to be these consulting gigs people did for the “divisions” to be helpful to the company, like making a program-development environment that I was offered. And it's interesting because at the time when I went there, I thought, "Oh, IBM, what a crappy place. They use EBCDIC instead of QWERTY, and called pixels PELs just to be weird. They'll use SNA, instead of TCP/IP as some strange world domination idea over the world." But what I discovered was actually the place was quite flexible, and it was changing. I met a rock climbing friend in the Math Department that wanted to change to some new kind of work. He was a brilliant algebraist but hadn't written a paper in many years, Joe Rutledge. He had actually learned to program on the ENIAC. He was methodical and had the most amazing memory too. So I got him involved with this pointing device idea of mine. And I thought, "Oh, this is a six-week project. It'll be a fun project for him and me and keep me from going crazy while I write my AI and Education thesis." Oops, it took six years for us to make this thing and get it to market. And what really was fascinating was the way the organization actually wanted to embrace invention and innovation. They have this one-year review that's scary and then, do you get to be a Research Staff Member when you don't have a PhD? And then, you get to be a manager, and all-- it was a very slow corporate kind of feeling. But my goal was that-- my mom hated my dad changing jobs more than typical for his day- every five to seven years, which today is nothing, and I wanted to show people that I wasn't just a flake. I had gone there wanting to do my PhD while at IBM. I thought it would take 3 years, but did it in 7 anyway. So I wanted to stay there and accomplish something, and anyway, there's a lot to that story.

Steinbach: Things you did.

Selker: I did. And I also want to say, that the decision to go there instead of Apple was because Apple had a lot of people like me, people that wanted to improve graphical user interface and think about graphic design, think about better user interface, and IBM seemed like a desert . I thought, "If I made a difference and it came from IBM, people would know it was me." And also, yeah, I'd matter, and this is something I like to think about. I would much rather do something harder that would matter, that would be something that I only I could do, or wouldn't have happened without me, or may not have happened without me, than I would ever want to do the things that are easy but would have happened without me. I always want to do something special. I always want to do the new, not just keep on doing the things that I'm known for, not always doing the things that are easiest to get known by. So anyway, that was my idea, to go to IBM and do something unusual.

Steinbach: And I guess you did. You rose to Fellow, eventually.

Selker: So it's funny. In fact, one of the funniest things is John Sealy Brown himself, amazing guy, he was the boss at PARC. He came to me as I was leaving, when my belongings were actually in a truck going across the country, and he says, "Ted, why don't you stay and do great things here?"

Steinbach: Wow.

Selker: Wow, and I said, "Well, if I made a better pointing device--" because I was already thinking about this, "and it was used by IBM, it would be used by millions of people. And you guys, I'm not so sure." I actually said that. I didn't believe it at the time, but it turned out to be true.

Steinbach: Yeah. Wow. <laughs>

Selker: That was '85.

Steinbach: Okay. So Apple already had the Mac at that point, with a point-and-click interface. Right?

Selker: That's right. They did. And, in fact, we had the most amazing computing facilities at PARC. We had the homegrown $120,000 Xerox Dorado personal computer, and it had a Macintosh to boot it up. <laughs> And yeah, one funny aside, is when I went to IBM, they said, "You can buy any computer you want." So I said, "I want a Xerox Dorado." And an ignorant Xerox sales person said, "No, Dorado's not made by us. It's made by UNIVAC." Well, they were wrong. And finally, after weeks of trying to get them to sell me one, I called up Danny Bobrow----and I said, "I want to buy a Dorado. I can't get anybody to sell it to me." He got somebody on it. But after three months of paperwork, the vice president at IBM called me up and said, "Ted, would it be alright to just settle for a Symbolics Lisp machine?" <laughs> So

Xerox's paperwork was worse than IBM's. So that's a sad story. Sad, I bought an $85,000 Symbolics Lisp machine like I had used at Atari (costing much more than a salary). It was great, but it wasn't as good as the Interlisp-D with Loops that Bobrow, Stefik, and others had made for Xerox “D” machines. Loops was the most productive programming development environment that I've ever had my chance to use.

Steinbach: Really?

Selker: Yes, it was much, much better than the other AI development environments like Smalltalk or Zeta Lisp or SPE or KEE. All of them were responsive, interactive, extensible environments with dynamic binding that allowed people to explore more computing and prototyping capability than we could believe possible. But Interlisp-D with Loops was better, mostly because of its wonderful tools: visualization support for structure of object-oriented programs. It had Masterscope to see what called and what changed something and so on. It had Do What I Mean (DWIM) for finding variable and function spelling problems. It had a structure editor for writing programs that couldn’t have syntax errors. I really was honored to be able to work for the people that worked on it, and I guess, I also bring it up as I am thinking of the recent passing of Danny Bobrow who was so good— such an amazing guy that touched so many researchers, and was part of so much new technology creation.

Steinbach: Okay. Okay. So at IBM, did you start out with the TrackPoint?

Selker: No.

Steinbach: No?

Selker: In fact, I wrote it down on the list of things that I wasn't going to work on, because I had not--because I invented it before I came to IBM, and, indeed, there is a patent, which you didn't find. Before I went to IBM, I patented it.

Steinbach: Oh.

Selker: The idea of a pointing device reachable with an index finger in a keyboard, that would save the time of moving one’s hands to make graphical selections.

Steinbach: On your own?

Selker: On my own.

Steinbach: On your own, not associated with PARC or anything?

Selker: Yes, I paid for the patent out of my own pocket. I had the idea while reading the new Card and Moran Human Computer Interaction book in 1984. But at IBM what happened was that I started working on my intelligent user interface work and that went along. It was a lot of hard programming. I made a system that taught Lisp, and also taught HTML like syntax we called SGML back then. And very, very interesting, I remember my mentor, a man named Ashok Chandra, who really is responsible for me doing so well at IBM. He was never my manager. He was always my manager's manager, being interested in my work. Anyway, I remember, I went to him trying to test out my help system, which was on the standard command line, like a Lisp Listener. He said, "Ted, you must show that your help system, is not just succeeding because of your better user interface, but that the adaptive part is what is making the users learn better. " See, I had been comparing the typical help on a Lisp Listener to mine, which was a graphical user interface that decided when to put what kind of help where and put the stuff that's most important to you near you, and put the stuff that's about why stuff works, as the headline, when you never thought about it before. It started teaching something with examples. After a user showed mastery of the example, it showed the generalization of examples— syntax. It would do this at different levels, recognizing and supporting a person going from Novice to Intermediate, to Professional, to Expert levels of a particular teachable thing. So I had this AI system that did this stuff, and he said, "You know, if you really want to test this thing, you can't test if your help's better. You can't test with a graphical user interface that is better." This is not a user interface guy, but he hit the nail on the head. My job was to show that my AI system, not my better content or better user interface, improved teaching. He asked me to run my experiment, so I compared the same help on the same graphical user interface to the one with the AI system that decided when to put it up without being asked for it. And back then, the idea of things coming up without you asking for them, everybody hates inappropriate distracting popup stuff. Anything that customizes itself can surprise us and can be confusing to deal with. So the real big excitement was that people with the interface changing automatically liked the same help information better. They liked Lisp better. They liked the user interface better. But also, they got five times more exercises completed. So I say that this thing, this COACH adaptive help system that I started writing about in 1989 and was the basis of my PhD in '92, was the first demonstrated performance improvement for AI helping user interface, and there began a long battle with the productive user interface and visualization giant Ben Shneiderman, who believed direct manipulation was always better than AI . <laughs> So the educational merit of COACH and its demonstration that AI could improve user experience was really exciting. But the angst and difficulty of trying to get my PhD was ameliorated by the joy of working on the pointing device with Joe Rutledge for therapy.

When we first started working on it, I found a microscope that was broken in the hallway, and I fixed its front-surface mirror so we could use it, and found a bench that no one was using and we started making in-keyboard pointing devices. And by the time we were done, the same Ashok Chandra said, "Well, you say it works great, but why don't you make a hundred?" to show that to others. But as would happen, after I'd made three, I'd learn something and make the next three better. <laughs> So we made a hundred and learned a lot about how to improve it and its user experiences. But the most exciting thing, with Ashok Chandra at my side, was I went to Japan, where we compared this pointing device to a Trackball and a Touchpad.

Steinbach: Comparing, in terms of, user...

Selker: Comparing in terms of how fast you could make a selection.

Steinbach: ...tests?

Selker: Yes, with timed-performance user tests.

Steinbach: Okay.

Selker: So how fast could you make a selection? So I and Joe Rutledge, we wrote these experiments and we let people try out running the experiments, and there were people in Austin, Texas. There were people in Yamato, Japan. There were people in Boca Raton, Florida, and there was us. But the experiments in these different places gave people different lengths of time to make a selection with the device. Ashok helped me make the slide to show that all the experiments agreed if you assume a learning curve for the users.

Steinbach: So it was IBM people?

Selker: Yes, a group called IBM's PC Division's Entry Systems Technology (EST) group had been asked to evaluate the pointing stick. The manager in charge started by saying it had been studied to death and called the project "Castaway." The usability testing guy we were going to Japan to talk to about it was working closely with ALPS on a trackball for the ThinkPad. Yeah, IBM people only, yes. And quite frankly, they found different things, and Ashok had the foresight to point out that, "Look, if we put them all on one slide, it'll help make the comparison great." And that comparison was showing that it took 30 to 45 seconds for a pointing stick to get as good as a touch pad, so when you first started off with a pad or track ball, they were faster, and after about 35 seconds later, they weren't. And then, three minutes later, you actually could do text editing faster with a pointing stick . You know, with only three minutes of that exposure to this thing, you were as fast as a mouse doing point-and-type activities like text editing. After 45 minutes, you could actually do text editing significantly faster than with a mouse. And so that was really a big deal. But really, the big deal of getting it into product was showing that the data from the tests all over the world were consistent, And 'til I gave a talk about it, no one in EST or the product teams understood that there's a learning curve, and this learning curve was so short. Yamada-San gave a long talk about how his study found the pointing stick not as good for the first 45 seconds. I gave my talk praising the quality of his work but showing that that was the only condition in which the TrackPoint was worse than a trackball or trackpad. First the product manager Toshiuki Ikeda took Yamada and me to give our talks to 3 levels of management. Then the product manager said to me and to Yamada, who had done the study in Yamato, and who had a long-term relationship with the trackball manufacturer, he said, "For this to be used in our computers, you guys have one week to get rid of the learning curve so people walking into a computer store will want to buy our computers. You have to make it as fast as the track pad or ball, in the first 30 seconds." He is responsible for the ThinkPad being a success. This is the most incredibly flexible collaborative guy ever. And so my job was to help the guy in Yamato help me make the device better for Ikeda. And, indeed, Yamada-san had the very, very good idea, which was that if it moved a little bit, that you would feel that. And, indeed, you got a 15 percent performance improvement if the rubber top moved.

Steinbach: That's feedback, I guess?

Selker: Yeah, and that proprioceptive feedback helped people when they were just learning. We have these porcinian and marcusian cells in our fingers that sense your lateral movement. By the way, once you get to learn to point well, the proprioceptive feedback no longer helps. So it's like throwing a ball, I think. At the beginning you have to pay a lot of attention, but eventually you learn to throw it perfectly without so much thought. But for the beginning, a soft top that moved some made a huge difference for novice performance. It took us a week to get 15% improvement in selection speed for these early users. I made, probably, 50 different tops. I went to a ping pong rubber store, and every hardware store I could find. The Toku Hands, a maker-oriented department store, was where I bought a lot of my materials, and I kept making them on the subway, on the way to and from IBM Yamato, and working with Dr. Rutledge and my Japanese counterpart to test them, and it was really great fun. That was a very special week, yeah.

Steinbach: Only the top matters, I guess, right? It doesn't stick much up from the keys...

Selker: Oh, everything matters...

Steinbach: ...and so it's only the top that you have. You don't grab it?

Selker: At the beginning, we had a metal rod and you could grab it, but I wanted you to put your finger on top of it, so you would be able to use it without taking your fingers off the home keys. We had initially thought that the connection between that rod and your finger, it was a cup-shaped top thing that had sharp edges so it'd grab your finger. We thought that the sharp cup and stiffness were really important as we had gotten better performance by making it hard for your finger to slip. But the soft top with motion feedback was better. The stiffness, it actually hurts your finger, and a wonderful product manager named Arimasa Naitoh looked at it. Anyway, he is a hardass. <laughs> But I remember he pointed with this thing and he showed me his finger. He said, "Look at this. You made a dent in my finger." And so getting rid of those two problems was the goal of that week. We found that a compliant soft top could hold the finger while allowing it to move laterally a little. In testing everything from cork to sorbothane rubber, to sandpaper, to Styrofoam, we found that 55-durometer rubber for motion and a latex Ping-Pong paddle material with all those little standoff posts inside that would press in a millimeter or so, were great for letting the finger sink in and hold in place. The other thing that's really interesting is that the first pointing sticks were between the G and H keys, not below them as we improved them to be.

Steinbach: I have a pen.

Selker: So the first place we put it was between the G and the H and -- I thought it was good because the fingers from the left hand go over to the J, and the right hand over to the H. But in fact, that's where your finger tip is broadest and most likely to touch it from the side. And it was then, after making those hundred keyboards, that I began to realize that moving it down below the G and the H is much farther from the center of a finger touching a key, and it's between the hands. To this day, I'm shocked that people don't have trouble running into it when they type. But we worked hard at that and there's lots of other places that I've found in the keyboard where you could put a joystick and not run into it. For example, I might have it with me, we tried putting things between the space bar and the keys. Your thumb comes down to the space bar, fingers go up to the keys; they never mix. So this is a microcosm of how I try to build mechanical things to test out conceptual things.

I think that understanding how to work with people is really the center of making technology. I say “technology” is something like “listening”, a complete tool that works where “techniques” are something like voice recognition, which is a system that breaks at times but could be part of a complete tool that works. Voice recognition systems might be part of listening, but don’t do so many things we do to understand someone that is talking to us. Listening includes disambiguating words and sounds with context and feedback. When we are listening we will say, uh huh, yea, nod our head, look down, look up, all to help the speaker know if we need more detail, understand what they are saying, etc. We have to get the feedback. We have to understand the other person. We have to work with them. And I have always been excited about people and making things to help people, and so what you'll find in all the things I build is a love of solving problems that helps people do things. So is it user interface? Is it technology? It's about solving problems that help people.

Steinbach: How many hours of tests do you think you ran?

Selker: <laughs>

Steinbach: User tests of this.

Selker: On the TrackPoint?

Steinbach: Of the TrackPoint-- well, yeah.

Selker: We tested it differently than the hundred years of people trying to make great control devices did before us. Typically, people had made a device and then tested it. So what we did differently in our tests is that we made an interactive suite, where you would make a transfer function. That's how hard you pressed, how fast it goes. And then, you'd run through a little maze. We had a little racetrack, and we'd run through that little racetrack and see how fast you went. And just Joe Rutledge and me, in less than two weeks, we discovered, one day, that we made a version of the TrackPoint that was so painful to use that you couldn't do it very long. But using this transfer function the user was 25 percent faster than any of the reported literature on making selections for a rate-control device. And it's really interesting because in the 1890s people were trying to use rate-control devices in gas pedals, trying to understand, and they always reported overshoot. If you make these rate-control devices responsive, the operator overshoots; you go too far and you come back. And that was what our painful pointing stick had gotten rid of. I thought, it's all about dynamic range. Were we pressing so hard, that we got lots more control of dynamic range? So we ran another experiment, where we had a circle and we had to hold the cursor inside the circle with the pointing stick. We would then make the circle smaller and see if you could still hold it inside. We found that you only have 5 or 6 bits of repeatable control for force. The dynamic range kind of topped out at 200 to 300 grams. In other words, you don't get more dynamic range by pressing harder. So then, I was really curious. Why was it that I thought that when I pressed really hard, I could make selections faster? And what I discovered is that if the cursor moves too fast, you're losing the tracker with your eye. So the pain of pressing hard had worked by stopping us from moving the cursor too fast. So, we made a funny transfer function that never let you go faster than your eyes could track. Voila. A 25% more productive pointing device than had ever been shown with rate control ---that everyone hated because it felt sluggish. So what I think had happened to everybody else's rate control experiments, that concluded that rate control couldn't compete with position sensing, is they did experiments where they made something that felt good, and then they passed it over the wall to somebody else to test it. And what we did is we made things that tested well, by an interactive process. That software rate-control experimenting program, JoyTest and JoyPoint, allowed us to iterate towards solutions without giving up. We would change the transfer function and try a new one, in two minutes. It would take less than a minute to run an experiment with the new transfer function on our 16 selectable item Fitts Law test. You make another transfer function, try it again. So that iterative cycle, that went so quickly, allowed us to discover this first eye-tracking thing.

We didn't discover why people hated transfer function that made you move the cursor at a controllable speed for another six months. What we did to get rid of the hating of the slow speed was to make it so when you pressed hard, the cursor went really fast, “turbo”. We didn't understand why people wanted to go really fast, because we knew it didn't make selections well. So we made it so you'd press and you could never go faster than your eyes could track, until you pressed really hard, and then it would zoom. And then we learned that it was because our experimental data was all about making selections, Fitts Law selections on a screen. But what people liked going fast for was to change context; for example to change windows on the screen. So context switching is really important to people. Zoom back over to another window, to do my text editing. Zoom, I go over to another window and do my email, and that's what we realized made people like “turbo” for the fast section of our transfer function graph.

Steinbach: And that does not require precision? Because the window is large.

Selker: Exactly. There's much more to say about this. And I'm hoping I’m not too detailed, still trying to explain how many experiments it took to make TrackPoint. The answer is that we worked with inadequate tools for something like a year, then made the programs which allowed us to make an initial insight in a couple weeks or something of playing with it ourselves. But there were so many more steps and things to test and learn over the years. The answer is thousands of hours, probably. And yes, there were refinements and improvements. I mean, for example, we came up with this idea that if the cursor was moving in one direction it should keep going in that direction, but Rob Barrett made this. Well, he took this bad idea that hysteresis would improve selection and improved upon it. But through testing hysteresis we came to an insight. The really cool idea is called negative inertia. People could make selections better when we amplify slowing down or speeding up. So it's like, ABS brakes and ideal Tesla-like acceleration for a car. There were many other things like improving single-pixel selection for things like editing a picture, we had a special algorithm to make that work, which came from my circle experiment. Initially the pointing stick was optimized for staying on lines of text. But then, the very famous Richard Sapper, who designed ThinkPads and also many other wonderful things said, "I can't draw a circle." So I had to make it so you could draw a circle: a very important thing to be able to do if you are drawing. All these things combined, and that last experiment was two or three years after product announcement. So we kept improving it. Running experiments, coming up with new ideas. I've got a long list of ideas I would like to do, if anyone would want me to improve the TrackPoint. There's no reason why we couldn’t do things great for text, do things great for circles, and do things great for spreadsheets too. We tried so many things that never got to product. For example, I made an adaptive TrackPoint that actually showed that, for some 19 year olds, the plateau of eye tracking speed could be much faster.

Steinbach: I was just going to ask you, isn't that an individual-- isn't there an individual difference about how fast you can track?

Selker: So in my experiments, in general, I have found that individual differences exist and can improve results for some by like 20%, but helping everyone is the hardest and most important part. First you get the big picture right for the general person, and usually making it work special for an individual makes it possible to make it worse, too. In this case, I believe that Dan Kellem could have improved his pointing speed from 0.9 seconds, which was his all-time great, to 0.8.

Steinbach: It's more than 10 percent.

Selker: Yeah, that's more than 10 percent, with a higher tracking-speed plateau. He could also handle a faster single-pixel speed selection. I think we have other ideas of what we could do for the fast twitch crowd too. Yes, I am willing go back to it for anybody that's watching this. Let's go make better pointing devices together soon!

Steinbach: If you know what you're doing, you mean?

Selker: Yeah, yeah, if I know what I'm doing as the designer, I can put those into the driver. But we were so focused on making it reliably useful, that we put off the exciting ideas of improving it for individuals or special support for different uses of the device.

Steinbach: For example, the device driver should know I'm doing text editing, right?

Selker: Yes.

Steinbach: "And now, I'm drawing a circle. I mean, I want to draw?"

Selker: Yes.

Steinbach: Okay.

Selker: And in fact, track pads do have different algorithms, depending on what you're doing, somewhat. But we developed a tremendous library of exciting goals of this sort that would still be fun to implement, and those experiments got done, too. So I had a dream team in Barton Smith, Joe Rutledge, Steve Ihde, Ron Barber, Rob Barrett, and a few other people, working continuously on improving the pointing device. The easiest changes to get into each product revision were ones that came with cost reduction. These were fun because we only did this when we could change technology to also improve robustness and quality. So we made capacitive, optical, plastic, cement, and constantan strain-beam sensors in so many configurations.

Steinbach: I did find those, yes.

Selker: <laughs> One fun innovation that made the big difference in quality and price through sales was, one day a guy at Phillips Corporation called me up and said, "You know, you're our biggest buyer of these processors. What can we do to get more of them to you?" I said, "Look, almost half the cost of the circuit is this dang analog-to-digital converter which has to sit outside your processor chip. I can't give you more money, unless we get rid of the 16-bit A-to-D converter." He said, "Well, but there's only space for 8 bits on the chip dye." I said, "Yes, I knew that. But I only need 8 bits of it fast. What if we use a comparator and a charging capacitor to make the slow changing bits of the A-to-D, we would then have a 16-bit converter with a slow 8 bits and a fast 8 bits?" And he says, "That's a great idea." And I said, "All right." So, we patented my idea, and out of that phone conversation came a multimillion dollar collaboration between IBM and Phillips. They actually built into their chips that algorithm I just described, an external capacitor, and it basically halved the amount of silicon we needed for the TrackPoint. It cemented their position and no one could touch what they did for joysticks in laptops for several years. They actually made a full-page advertisement with a picture of me and my friend Joe Rutledge in Wired Magazine in celebration of our mutual work together. That was one of the best moments ever. <laughs>

Steinbach: Great.

Selker: But, I mean, that's a weird thing. How do you end up designing an algorithm or changing the design of an analog-to-digital converter, when you think you're a user interface designer? Well, I realized, all of a sudden, if I did that I could make an impact on the stuff mattering. But there are probably a dozen stories where things that I made made an impact by just trying to pay attention to what would make success. I'll leave you with one. So there's a bisection sort that happens to calibrate, auto-calibrate, the strain gauges when you power up this pointing device. Product people had put a capacitor in the strain-gauge amplifier feedback to quiet noise. This capacitor had longer hysteresis than the settling time of the bisection-sorting algorithm. So the voltage would be still settling when the search was deciding not to go above 128. On many keyboards it wouldn't calibrate correctly. Anyway, it was the moment of announcing the product. I was wearing a suit at IBM's Madison Avenue 44th Story office. We're going to start delivering these computers to the customers, and I hadn't had my hands on the actual product yet. And I'm standing there and everyone's trying to schmooze. But first I go over and I start playing with them, and a third of them went fast to the left and not so fast to the right. YIKES! So I quickly took the bad ones away from the demo room and put out some that did work. It just had to do with where that settling time happened in the calibration of that particular post, and no one in the world knew, except for me and Joe Rutledge. I got a telephone in my hands, right before the announcement speeches. I called him up and we talked about how we were going to fix this, and we had the short-term and the long-term, and that's how a lot of these things can happen. Things that are subtle can be delicate. Sometimes things get through testing; sometimes you catch them before the press trashes your mistakes. Sometimes you are just alert enough to fix catastrophes. Had I not taken a minute to assure myself that everything worked correctly, the product would have immediately bombed. I could tell you stories that went on for years. While the product was being sold, there were big problems being solved that kept it from not failing completely.

Steinbach: <laughs> Okay. I think that's a great story about TrackPoint. Now, you also, at one point, showed me a lot of other stuff you did around the keyboard.

Selker: Oh, yeah.

Steinbach: Like mouse buttons, because your TrackPoint, of course, is just typically for cursor control, you also want to say, "Now, I'm here." Right?

Selker: Yeah. So one of the interesting things about this pointing device is that the heel of your hand has to be supported for best control. I was fighting to get this keyboard pushed back so your hand would be resting on a wrist rest. Because if it isn't, your hand is in the air with more tremor or uncomfortably on the desk below, and we could get selection improvements by putting a wrist rest on it. And the coup de grace, my very favorite one, was a snap-on wrist rest that stowed between all the keys and was half a millimeter thick of plastic, and the structure was the waffle-y shape of the keys and then it snapped on the front of this ledge at the front of the laptop computer and gave you a wrist-rest surface. But instead of making something so exotic, after a couple years of discussion, they simply moved the keyboard closer to the display, giving me the 2 ¾ inch rest that I wanted. This, of course, was the solution I hoped for. You can see that there's space in front of this pointing device that was the wrist rest, and now, all computers have wrist rests, or are thin, allowing the desk to be a good wrist rest. The other thing that's interesting about these buttons is this blue button is literally a way of turning a TrackPoint from being a pointing device into a scrolling device. I did a whole lot of experiments on two pointing devices in a keyboard, and why two pointing devices? Well, two pointing devices because you have two hands. An artist will often move things into place with one hand and do the detailed work on them with the other; handing things from the non-dominant hand to the dominant hand. We wrote papers about six-degrees-of-freedom control with two pointing devices being great. But what we got into the product, in the end, was that third button. That third blue button changes the function of the pointing device, making a second pointing device, and lots more could be done with that. But the other thing that was interesting is these little triangles of tape you can feel on this prototype keyboard. Those triangles were me showing the product people how to allow a person to distinguish which pointing button they were about to press. Without them, people made mistakes. The product team finally put these raised dots on the buttons to differentiate the buttons enough and keep people from making mistakes about which ones they press on. The buttons on some of the first ThinkPad 750 notebook computers were too stiff. At that time mouse buttons tended to be too stiff too, and if they're too stiff people are slower at pressing them, it really wastes time and degrades pointing performance. No mice that I know of have buttons that are stiff, but Dell makes this mistake, to this day, even though they've been told of the problem often. Maybe they don't want people to use their pointing sticks. We could help improve their pointing device easily.

Steinbach: You didn't accidentally press it if it's easy?

Selker: Good question. People do well if they have anticipatory and confirmation feedback. Keyboard keys take like 60 to 90 grams to press, people are well used to that pressure and don't accidentally press them. Buttons in a car are stiff so you don't make mistakes when reaching in a moving vehicle, for example, to raise the window. So it's important to get good feedback when you activate a button. You don't want to accidentally activate something in a car. But when you are on a keyboard and one of the buttons is four times as difficult to press as the keys, you're going to be surprised and slow down. The shape matters too, as you don't need to put all the pressure on a small place and dent the thumb hitting it.

So this wide locking button I am showing you was my first strange innovation for a button. I push it and it locks it on, brush it and it unlocks, on the ThinkPad 755. And that, believe it or not, was the way I got a chance to design the shape and pressure of the buttons to improve them. The locking key was for people that have disabilities. They're using a mouth stick or have one functioning digit or something, so they can go into drag mode and wiggle it and then go back and turn off drag mode. IBM was very good about disabilities, and I've found, throughout my career, that often a lot of my favorite ways of getting interesting ideas into product is to see how I could help people with disabilities. Universal design is the statement that often, things that help people with disabilities, if done right, can actually help everyone. The locking button invention allowed me to fix several problems with buttons: size, feeling, feedback, and pressure. And I just told you all those reasons that the buttons can make a big difference in performance. The button design being bad can reduce performance as much as a bad transfer function.

Steinbach: And from the beginning, the buttons were below the spacebar? I guess, they have to be...

Selker: Yes. Well, the first thing I made was pressing on the key as a joystick and using other keys as buttons. Finding the buttons was a problem for teaching people to want to use the pointing device. But even before that I tried putting a joystick below the spacebar, and had buttons below the space bar too.

Steinbach: Oh, on the...

Selker: The big departure with the key being a joystick was that it was a bit confusing to users, was overloading keys as pointing joysticks and button keys.

Steinbach: Any key? Or…

Selker: The J key became a joystick when you pressed down on it.

Steinbach: Okay.

Selker: And then you press on that key. We started with the F or J keys because they are the home positions for your index fingers and when you pressed on that and made a selection, then you'd use the keyboard as the buttons, and it was really lovely and very elegant and, unfortunately, hard to teach and people would get confused. It was better to make a separate pointing device. Now, I could go back and, maybe, make that one better, too. But anyway, that's, for me, a very interesting point. The buttons below turned out to be an almost universally easy-to-notice idea. Getting people to see and think about the pointing stick was important to getting them to try using it. The first pointing stick I ever made-- well, I put a joystick in the thumb position.

I first contemplated and tried making the joystick in a keyboard in 1983 or so. Later, when trying to really put it into laptop computers, the track ball being in that place in the Macintosh 160, 165, 170, could be used with hands on the keyboard. Below the spacebar, if you used your thumb on those track balls, you didn't lose the time of leaving the keyboard to go to the pointing device. In fact, the thumb has more representation on your brain's precentral gyrus than anything on your body except your tongue. Theoretically, the thumb could be great at pointing. However, people aren't as used to pointing with their thumbs. I went into stores and I'd watch; everyone took their hands off the keys and used their index finger on the ball, silly users. Even though it would have been more efficient to use their thumbs on the trackball below the spacebar, invariably, they would take their hand off of the keyboard and go down and use the track ball with the index finger that they were used to pointing with. So a pointing device in the thumb position could be a good idea, but hard to teach. A large number of people have TrackPoints in their keyboard, but they're used to taking their hands off the keyboard to use the Trackpad instead of trying the TrackPoint while typing. People don't bother to learn a new thing if they don't need to, and I think that people are busy and they have their goals and they are going to use the thing that they're used to. Losing traction to Trackpads started with IBM realizing what an advantage the TrackPoint was. Their downfall was opting to try to make it proprietary to ThinkPad. They realized the danger of that too late for TrackPoint to become the dominant type and point input device… so far....

Steinbach: And it's just a tool. You don't want to necessarily...

Selker: It's more than a tool. It's a religion.

<laughter>

Steinbach: Right. Okay. Anything more you want to say about pointing devices?

Selker: I can always talk about pointing devices. Anyway, you were asking me, "What drives Ted?" And it's an invention for people. And so I'm going to tell a little story about pointing devices that took me on a different excursion. So the General Manager of IBM's huge PC company, a guy named Jim Cannavino, who started his illustrious career fixing teletypes at IBM, said, "Ted, you got rid of this big dangly wire in this thing (the mouse) that bugs me in my laptop. But I still have this power supply, a big dangly wire and thing." This cord-shaped transformer I am showing actually was one of several alternative solutions I invented around his provocation. So the power cords were those big heavy wires with a standard end, like we use to plug in a server. Such a standard cord has to be able to plug into a standard 15 amp; it has to be big enough to power anything with that kind of a socket. So you'd have these big-ass wires, which when coiled up were actually bigger than the power supply. So I wanted to get rid of that wire, and my first idea of how to get rid of that wire was to invent a new kind of a transformer that would fit in the cord, and that was this. I'm kinda surprised to have this patented transformer in the 1990s.

Steinbach: I saw that patent.

Selker: This one is a bit crazy. Because my first idea of how to do this was patented in 1947, which was to make the transformer magnetic core that was the length of the cord. It turns out its efficiencies are in the 0.1 percent. But by making the cores go around the cord, not the length of it, they get small. Since, the 'μ', the magnetic resistance, goes up with the square of the length, this is actually quite an efficient transformer.

Steinbach: Okay. I was going to ask, where is the iron?

Selker: The iron is these little shiny bands.

Steinbach: Okay.

Selker: It is a soft iron alloy tape. It is wound around the cord to look like rings. The rings are wound in layers to reduce eddy currents. The power cord itself being a place that could hide the power supply excited me. But then I tried other ideas too. Actually, my first idea of how to get rid of the massive power supply came to me earlier as I was contemplating what Cannavino eventually asked. I thought that if I just used the battery as the capacitor in the computer and just snipped off part of the raising lowering parts of the 110 Volt standard-power sine wave, I could just dump some charge into this battery, and I'd use two batteries. One would be offline so we could have the physical separation between wall power and computer power required by law. So, the whole power supply had no storage capacitors or inductors, just a really fast switch to grab pieces of the sine wave that were suitable to charge the battery. It also had a relay to change which battery to charge and which to draw power from. I told this idea to this vice president, and he said, "Make this for me." And I was so busy working on adaptive help for his operating system and on the pointing device for his laptops that I didn't get to it immediately. He called the head of IBM research, Jim McGroddy, the most extraordinary research manager possible. He was responsible for the 3000 people in IBM's research division but had not lost his facility to be deeply technical. So, Dr. McGroddy calls me up, and he says, " I heard from Cannavino that you had this idea about how to make a better power supply." I said, "Well, I'm going to snip off the voltage above 20 volts on a standard AC line. I'm going to use a TRIAC." He says, "Ted, a TRIAC won't do that. You're going to have to reform the silicon in a different way." "The way I'd design it"—he continued. And he just dives right into designing this special transistor for me. So that's what an amazing guy he is.

So now I was on the hook for the idea and I made that power supply. There's a video about this on my *tselker* YouTube channel, which talks about parallel design. Well, such a scheme of taking only part of the sine wave has a power factor problem, putting noise on the power line snipping off, the high voltage peaks. It could be difficult to get it through UL approval. Anyway, those were two of the many ideas we tried to get rid of the power supply on the ThinkPad. We also tried to find existing better, smaller power supply technology. I found some chip sets that would halve the size of the power supply our supplier was creating. I also tried industrial design solutions. For example, the strain reliefs and EMC core on the cord take a lot of space. I tried to get rid of the strain relief that made the power supply big. This strain relief I am showing is made by creating an EMC core you find on most cords anyway, that has a bell-shaped hole in one end. This combines the place to hold the end of the cord, the EMC-reducing core, and the strain relief in a much smaller package. This smaller EMC core/strain relief with a thin winding power cord that I brought to show you actually did go to product.

My pushing for nonstandard thin power cords that wound around the power supply got it into the product I brought here to show you. I had this other idea too, which is to be able to plug in the cord that way or this way or this way, by bending the plug at a hinge just outside the power supply. It allows you to plug it in near other devices in plug strips; you end up doing a much better job of plugging it in anywhere. And unfortunately for my hinged-plug idea, at the same time I showed the product managers, Naitoh-san and Ikeda-san, a few-inch long cord that will twist in any way to fit a power strip or wall socket. And we went to market with this. And why did they pick this? They picked this because it's no change to the price. Right? They don't have to design molds to do this. They don't have to go and become a power supply company that makes my high-power factor thing. Apple went ahead with a hard plug that snaps onto a power supply. So IBM took the simple design changes easily. To make the new power supplies I had shown would have been easier if they wanted to become a power supply company or a transformer company that makes a new kind of cord power supply. Right? All they have to do is buy a short cord, and it basically makes the power supply half the size. Then, by doing this cable management, they get rid of almost another quarter of the size. Then by including my funky strain relief approach, they get rid of another bit of it. And so for no money at all they showed progress solving the unwieldy power supply problem that this vice president talked about. I was sad, because while I had invented all this breadth of stuff, they had chosen the cheapest, not the best. And we could have eliminated the power supply as Cannavino wanted, but didn't.

It is my style to try many solutions. The power supply story I think of as a microcosm of this. What are the parts you might change to solve a problem? How do you solve a problem? You might do it electrically, physically, ergonomically, and in many problems you can solve it with software, or even with training. And my power supply product manager went with the simplest solution to implement. Now I will show another plug I designed in this effort that everyone loves, but seemed too fancy too. Today, there are pretty good plugs that'll plug in anywhere in the world. But this one I have a patent on, so I'm proud of it because it selects the prongs by nature of what holes are in the outlet to plug into. You see all these prongs when you shake it, they all pop out, and when you go into the wall, whichever ones don't push in from the wall become the power adapter. So this is an adaptive power adapter. You can plug it in, and in this configuration it is British, and if you don't have the British ground, then it goes in and a light on the back turns on to show you don't have a ground. If you happen to be going to Europe, the two thin prongs will find their way into the wall, for the US, Japan and so on the blade prongs will find their way into the wall. So this was great. Every executive wanted one— for themselves. None of them wanted to take it to market. AMP, the best-known connector company, wanted to license it from IBM, and that was kind of a special moment. It didn't work out because AMP finally decided not to get into the consumer market after all. But it was a lot of fun to try to do that. By the way, today, still, I would be so delighted to get rid of the power supply, and anyone that wants to do it, Dell, come find me. <laughs> Because it's still possible to get rid of it.

Steinbach: Well, you could put it into the machine, right?

Selker: There's a good idea.

Steinbach: But, of course, Apple kind of started this with the super-thin machines, right?

Selker: NEC made 2 lb. laptops from the beginning. And the Radio Shack TRS80 laptop I had in 1985 lasted two weeks on AA batteries. But for full featured laptops Toshiba made the full featured Windows notebook computer that had the power supply inside as you describe. For some reason it wasn't a big changer for their sales in 1995. And since it didn't make an impact at that moment, everyone said, "Why bother getting rid of the power supply?" And I think it's just crazy sad. Because, it could really simplify use of laptops. And I still want the power cable to be the strap to hold the computer on my shoulder too. And the strap could also have an antenna in it, and it could be used for other things. It could let me hold the computer as a wearable computer. I used to like positioning my laptop like a concession vendor at a ball game, in front of me where I can type on it while standing around.

So I'm going to show one other example of getting to put all sorts of innovation into the ThinkPad. Once you start doing it, people like that. I had this idea of a laptop display you could shine light through to project onto a wall. The backlight would come off and let you put your laptop on top of an overhead projector. The laptop computer then becomes the projector and this was really wonderful, because it cost the price of a projector and was a computer too. We made the ThinkPad 755 a projecting laptop. It was the highest-quality color projector of its time. It had the biggest profit margin of any computer that IBM sold. And also, you could open the display to let the sun come into the back and illuminate it, giving 20 percent more battery time when outside. A lot of power goes into the backlight of a computer.

Steinbach: Yeah, a back light.

Selker: So this laptop display I am showing you would capture the sun and you could use it out in the sunshine at a café, or even at the beach. We used it to help run Wimbledon in 1996. We, IBM, did make computers with this removable backlight for a year, and I was very, very proud of this because it shows how, again, you can solve lots of problems in lots of different ways, and often there are technology confluences. The strap was the way of holding it onto the overhead projector. But as I'm showing you here, I used it often to type on my computer while standing when I didn't have a table, right before I gave a talk or something like that.

Steinbach: It's pretty close to your face.

Selker: Oh. That's only because I want you to see it and me in the video thing, and I would make this strap whatever length I need to make it with this adjustment strap... Now, it's down at my waist.

Steinbach: Okay.

Selker: And I'm touch typing comfortably, without a surface to put my laptop on. As I said, I still miss the strap in new computers. <laughs> By the way, making this strap that could be attached to the computer frame securely took me six months to come up with. I had a big box of straps that didn't work. The overhead projector (OHP) computer was not going to go to market if the strap required any change to the computer. So after trying many ways to attach a strap to a computer, it ended up that I was able to make a mechanism that connects the strap to the holes designed to hold a docking station. The magic is the plastic on the outside of the case being curved to press up against and reinforce the computer's case, utilizing the strength of the internal hinge that holds up the display. So this little curve in a piece of plastic made it possible to make a product..

Steinbach: And it simply slips in and...comes out?

Selker: Yeah.

Selker: It slips in. You turn a lever to pull it tight to the computer case. And it's… strong enough to sling the computer off your shoulder. After so many inadequate proposals for how to do it, in the end, this thing was very simple. Without a great way of securing the laptop onto an overhead projector, the product would have never happened. Without this curved mechanical connection this wonderful product would not have been made.

Steinbach: <laughs>

Selker: Customers and press loved the product. IBM stopped making it because they were stopping all unusual laptops at that time, and it's a long story. But it also had to do with Ikeda-san trying to simplify product development and save money. By using an off-brand display for this we simplified procurement and saved money, probably false economy. We would've had to give a million bucks for tooling to another part of IBM (DTI) to make the display for all ThinkPads. This was the part of the company that made most of the ThinkPad displays. The product manager of displays had been very skeptical of my projection computer all along. So we were maybe skeptical about if he would come through anyway. And we were also reluctant to have to go find the money to give to him to tool up to make the removable back display. Maybe we should have paid him so the feature could have been on all laptops. Ikeda called Hoisiden, another display manufacturer. They were willing to give us displays with the mechanical frame and removable backlight design for the same price as we were paying internally for DTI displays. It was a great deal and saved the company a lot of money. But had we supported the IBM/DTI folks, every ThinkPad would've been a projector. And so I'm sorry we missed that opportunity.

Steinbach: <laughs>

Selker: And because we don't have a use for them, overhead projectors sit dusty in the corner of classrooms or are gone, now.

Steinbach: That is right.

Selker: You never had a video connector problem. You'd walk up, put the ThinkPad on the overhead projector and it worked. I was at so many venues where the guy before me would have an Apple laptop, and they'd try the connector, and the projector wouldn't figure out how to project through the system, and they'd spend all this time fiddling with it. And I'd just walk up and flap the display on the overhead projector (OHP) and everyone would see my display on the screen. And then, I would point at something on the display by placing my finger on top of the display pointing at something. The audience would naturally see the shadow of your finger as the pointer.

Steinbach: Yeah. Now, about straps and taking the ThinkPad along, I did read that, at one point, you took a bunch of networked ThinkPads up on Mount Everest.

Selker: <laughs> That was great fun. Yeah, and thank you for knowing about that. I joined the expedition about three months before the climb. I'm a mountaineer, but I did not climb Mount Everest, because a few months is not enough time to prepare.,

Steinbach: Now, this was not an IBM project?

Selker: Yes, it was. IBM allowed me to design special notebook computers and to go support the American Scientific Expedition.

Steinbach: Oh, it was an IBM?

Selker: IBM paid me to do this, which was really quite awesome. And I went and modified a bunch of ThinkPads to work at high altitude. So it's hard to know what's going to matter for a computer working in this dusty/cold/high altitude situation. I put in heaters to keep the displays warm, if I wanted to. I put in dust seals and made dust-relief covers for the keyboards, now a product many make. And here's the wonderful thing about working at a place like IBM Research. The guys that invented disks were in the next aisle over. So, I went and I sat with them and said, "What do we need to do to use a ThinkPad at 20,000 feet?" And they said, "Disk drives wouldn't work reliably above 10,000, unless--" and we sat there and we started drawing wings on the head so they'd fly differently and thought about the different viscosity in the air. But then, I said, "and the expedition is in three months." And they said, "Oh, my. We can't reinvent the disk that fast." But we did some calculations, and there was a certain group of disk drives that if we picked them, they were really out of spec for sea level and couldn't be sold, but they would work at 20,000 feet. So we called up the guys at IBM Fujisawa, who made the disks, and had these new pressure chambers to test them. The pressure chambers were new because of earlier problems with high-density disks in high altitude places like Denver or on airplanes. Within a week they had identified five disks that would work at 20,000 feet. Surprisingly, it turned out they were actually able to work at sea level. They weren't supposed to, but it sure simplified provisioning the computers to not have to run the computers in a vacuum chamber to set them up.

So I brought all these adapted laptops to Nepal. All the other teams at base camp had worse equipment. They had troubles with computers and generators that they were running their computers off of, and their computers were all breaking. But we had a whole network of these small, light laptops that I designed that had a little solar cell system to power them. So I was really proud of this. But many things work differently at Everest than the way they work at sea level. For example, inkjet printers can have trouble with their droplets. I discovered that the liquid crystal displays would get this funny little pattern all over them. And I thought, "This is really interesting. I'll show this to people when I get back." Well, when we got off the mountain the patterns disappeared from the displays. I believe that the patterns were caused by the LCD not being pressed on by atmosphere. A little bit of internal gas is showing up, and when it gets compressed it disappears again. We could still use the displays, but that's how technology was at Everest. Everything broke. And I had so much fun there helping all sorts of teams improve their systems to get them working.

Steinbach: So what kind of an event was it that there are multiple teams with computers?

Selker: Well, the teams I worked with were people working on the American Scientific Expedition to Everest. We had a medical team from Yale, and the biometrics team from MIT, and the mountain surveying team including equipment from Trimble, etc. The team from Yale had brought a computer with an ultrasound transducer for evaluating artery dilation. They were having troubles with the computer that I got to fix. There was the team from Trimble who had donated a very fancy GPS, to make the best mapping of the mountain ever. Their representative had gotten altitude sickness and couldn't get all the way to base camp. The connector had been broken off of the circuit board. I had to fashion a way of soldering on a surface-mount board, a little wire hanging off a cheap soldering iron, to fix it. There was the doctor that wrote that book "Into Thin Air," about the problems the year before on our team. So it was a fairly large expedition. We had this network. MIT's Rob Poor made this network of I-squared-C microcomputers that went on the chest, and at the last minute, we were up there and it was all made by students from MIT. I helped students, Rob Poor, Matt Lau and Maria Redding, debug hardware and software stuff. They had planned to put this blood oximeter on a mountain climber's finger. The climbers did not want to encumber their hands by wearing something in their glove to measure their blood oxygen. So I put a sensor on the sternum and there's a photograph of me, being very happy when we got that working. I had a lot of fun at Everest.

Steinbach: So you said you didn't go up, but...

Selker: No.

Steinbach: ...how high did you go?

Selker: Without a permit you are not allowed to go above base camp. Well, I will not confirm or deny that I went above base camp a little ways. And I climbed several mountains that were not Everest, along the way. Twenty thousand feet is about as high as I went and as I ever want to go. Because there's actually a tap response that now I'm old enough that, probably, it's gone, anyway, but when you go above 22,000 feet, people seem to lose this fast tap response. So that's the only neurological thing we know of that's for sure lost going above that. I've climbed to twenty thousand five hundred feet in Ecuador as well.

Steinbach: That's with oxygen?

Selker: No, I have never used oxygen on climbs yet.

Steinbach: Hard physical exertion...

Selker: Oh, yeah.

Steinbach: ...without oxygen?

Selker: Yeah, yeah. It's extreme. You try to remember to breathe. It's not always possible to drive away the headaches, stomach aches, and feeling of generalized stress.

Steinbach: <laughs>

Selker: It's exertive and takes vigilance and concentration just to be there without getting sick. You have to work at it to feel that it is fun. I definitely felt that it was an honor to be there. It felt like it could be useful and who knows, even historic.

Steinbach: Wow.

Selker: Yeah.

Steinbach: Okay. But the ThinkPad was only one of the things you worked on at IBM.

Selker: At IBM—among other things, I worked on a lot of wearables. So this was a wallet that I wanted so badly to make, that was going to be a four ounce telephone that also had a scanner in it to scan your receipts, and it had an electronic-- what do you call it? Credit card that would become *any* kind of credit card you wanted. It had a way to get on the World Wide Web on it.

Steinbach: With a display?

Selker: Yes, it had 3 displays. One display that allowed you to show pictures and user interfaces. Another had a cover with key depressions in it for also displaying a keyboard or a graphical user interface. It had another display on the outside that showed important things, a message or the time, without opening the wallet. So I made mockups of this fancy electronic wallet. Even 12 years later after I left MIT, I went to IBM, and they were talking about making the electronic wallet, and I said, "I'd like to make it." But it wasn't to be. But this was a lot of fun. People loved it. Lou Gerstner, the CEO, wanted me to make this wallet, What's interesting about companies is that even the CEO can't make some kinds of decisions. He started a task force on the topic, but in the end, the electronic wrist watch won out. I was mostly the dissenting part of that task force wanting to make a wallet, but we decided to make a computer in a watch. My reasoning was that a wallet represents identity and finance. Identity is most commonly associated with government issued IDs, and finances are most commonly associated by banks— two of our largest customer bases. And smart watches are still a big, exciting idea. We had a Linux watch in '97 or '98 with silicon on a chip and packaging and an OLED (organic light emitting diode) display and everything. The technology was eventually sold to Citizen watch company.

Steinbach: So this was before that?

Selker: Oh, yeah.

Steinbach: Okay. So probably, it was a bit short on computing power at that time?

Selker: Not so bad, the watch ran Unix, even then.

Selker: I still think that the smart wallet was a fabulous idea. One way it came out during that time was this electronic boarding pass my group made and deployed in 1996 or 1997 for Ansette, an airline that's now actually defunct in New Zealand. We made a PDA and an operating system for it and we had this idea that if you were a fancy traveler you wouldn't have to go to the counter to check in. Your boarding pass would recognize when and where you were at the airport, check you in and help you get to your plane. As you walked down the ramp to the airplane, it would show your picture and the flight attendant would recognize that you were the person associated with the boarding pass and security system. So if the gate changed maybe the boarding pass would tell you of the change. But maybe too it would offer a free coffee as you walked by a coffee shop. Now, of course, everybody uses electronic boarding passes on their phones. As we hoped, they reduce waiting and offer some of the security we envisioned.

Steinbach: And now, it's in your phone.

Selker: That's right. Your boarding pass in your phone means it doesn't have to be printed, and can update itself as needed.

Steinbach: Right?

Selker: It also is harder to lose and easier for the attendants to verify.

Steinbach: Everybody has a phone ...and it's not a special purpose...

Selker: Indeed, and our boarding pass pretty much looked like today's phones.

Selker: No, that's right. But we literally deployed this to high net worth customers of this airline, in '96 or 97. That was one of the things that we were going to do with that. Actually, we had a couple ideas in the boarding pass that could be added to today's boarding systems and improve them still.

Steinbach: Okay. And even at IBM, you worked on user interface, in terms of, like, gaze tracking and things like that.

Selker: Oh, yeah. I was sure that gaze tracking could improve interfaces a lot.

Steinbach: You had some ideas for the computer... knowing what you want?

Selker: Yes, Intention is what I care about. My group made the Blue-Eyes structured eye approach to eye tracking that Tobii now uses. Myron Flickner headed up that effort. One of the first successful projects around that was Simple User Interest TRacker (SUITR). The motivational insights for SUITR started with the literature on text editing with eyes. Using the eye to target characters and words for text editing is difficult and slow.

Steinbach: Too high resolution?

Selker: The eyes have to keep moving to keep the chemicals working to see. They also move in complex ways. People's' eyes can't stand focusing on something besides "the tiger that's in the periphery and going to come after you." So, when you're staring at something, your eyes are fiddling around, and want to glance here and there. Eyes are always moving with dither, tremor, smooth pursuit, and ballistic movements. The problem is you don't like staring at something for long, and people can't do it well-- even when we try really hard to keep our eyes on the characters we might want to select. As well, it feels scary not to be checking the periphery for danger. The eyes can only type like four to sixteen characters a minute.

So what I said is, "Let's use the eye for what it's good for, and what the eye likes to do." The eye jumps around and stares at things you think are cool. And so we put a news ticker going across the bottom of your screen. By the way, we had AI to decide what to put there, and we can talk about that. But if it attracted your attention, you could read it. If you stared at it a little longer we could tell if you were really interested. So you could read it, no problem. If you stared at it for a third of a second, up pops the article. Well, it takes almost a second to select something with a mouse. So this is a lot faster than you can even select with a mouse. People loved this system, Simple User Interest Tracker, that I built with Paul Maglio, Rob Barrett, and Chris Campbell, and got on ABC Nightline. Nobody's used it yet in a product. Shuman Zhai and Steve Ihde also demonstrated a related idea of taking where your eye is alighting as a good place to let your mouse do the accurate work. And so we came up with this thing called Magic Pointing, where when you looked "over there" and started to move the mouse, the mouse would be where your eyes were looking, right when you wanted to work with it. And that made mouse selections significantly faster -- so very exciting. I wanted to do lots more with eye tracking and cameras in the computers. Back then, I was trying to get an origami camera to fit into the laptop that would fold out when you opened the laptop lid. The first camera on a ThinkPad came from a snap-on camera / CD player demonstration I made that was at the top of the display. This was simplified to the snap-on you may have seen in the ThinkPad T40 line of computers in the late 1990s. Cameras are tremendously exciting.

When I went off to MIT, I continued working on the value of cameras in human-computer interfaces. I used the IBM Blue-Eyes camera in the E-Bed to notice whether you'd woken up or gone to sleep. If you were attending to the radio or TV, it would notice whether you were nervously blinking your eyes when it put on some media to know to change the program. If you were staring at something, it would attribute your interest to present more stuff like that to the you. Instead of eye position per se as a control, we used natural eye gestures: dwell time, eyes closed, eyes open, blink, wink, as user interface commands, to decide what to do for you. With this eye-gesture language the E-Bed worked well and with almost no instruction. People would walk into my lab, lay down on the bed and gaze up at the ceiling display, play educational games about constellations, read email and books, control a TV or radio, etc. They enjoyed it enough that we often let members of a visit run the demonstrations for each other.

Now, why did I pick a bed as a place to further demonstrate languages of eye gesture for computer interface? Holding your head stable was one of the big problems of eye tracking for the longest time. And so what I'm always looking for, is the confluence of where would this be useful, where we wouldn't have to deeply change what people do easily. The bed demo solved stabilizing the head problem in a natural way. People responded to it so much that I left the demo running in my lab for a decade. It got on "Good Morning America." It got lots of other recognition. One of the first things I did when I went to MIT was to start showing that eye gestures can be recognized with even simpler techniques. My students, Andrea Lockerd, Winslow Burlseson, Jorge Martinez, and Ernesto Arroyo, etc., worked with me to make this is one-photodiode-- no camera, eye-gesture recognizer. So all it does is it looks at how bright your iris and your pupil is, and it can tell if it's visible and it can tell if it's moving. It can tell when it's closed because it's dark. It can count blinks and winks. And so with a cheap microprocessor that's, like, a dollar, I was able to do almost everything that I found useful for social eye-gesture recognition with eye tracking by the IBM Blue-Eyes. This had an infrared for communicating with other devices and it used infrared for illuminating the eye-- it's called EyeR. See, there's the eyebrow and eye as part and here's the R in the shape of the circuit board that attaches to the arms of your glasses. The Infra-Red (IR) beacon is something like 18 degrees, and if I looked at a robotic dog with an EyeR transducer on it it and started staring at it, as I did on "Good Morning America," it starts barking. If I stare at somebody that's attractive to me, then it will send them my contact information though their EyeR system. I don't necessarily get their business card, they get mine. If I look at a demo I'm interested in, it'll email me the demo. I made this to support social communication for MIT consortium parties. You can go around MIT Media Lab and whatever demos you are interested in, it'll email you about those demos. And whatever people you were interested in, it'd email them about you. And it got used by Saab to look at eye dwell time of people that were flying fighter planes. A student made a version, so if you started falling asleep while you were studying, it would wake you up with a buzzer. So what I'm excited about is this idea of making really cheap eye controlled interfaces that are driven off your eye's natural social communication gestures, instead of the expensive eye trackers of the time costing tens of thousands of dollars. I was showing that you could make an eye-gesture tracker for ten dollars that would solve the problems that people actually could solve naturally with an eye tracker.

Steinbach: Now, did this actually know where you were looking? Or did it just...

Selker: It used visibility of its 18 degree IR beacon to "see" which computer or EyeR you were looking at.

Steinbach: Does it know you're not moving right now, you are kind of fixed?

Selker: So the trick about knowing where it had a cone of infrared communication is this 18 degree-wide IR beam coming from EyeR. Another EyeR would then see it if they were in this beam. The beam is narrow enough to easily distinguish which person you were looking at.

Steinbach: Eyes fixed to your head...I guess?

Selker: Right, the beacon was directed by head pose from the arm of your glasses.

Steinbach: Okay.

Selker: So I'm looking at you. I'm looking at a laptop. I'm looking at that other person. I'm looking at this demo over here. So it can tell, within a foot or so at reasonable distances, which device or person with an EyeR beacon you are looking at.

Steinbach: If that item cooperates?

Selker: Yeah, if it had one of these circuits on it

Steinbach: Okay.

Selker: EyeR was made to show that one simple Light Emitting Diode (LED) *in context* could capture people's' intentions as part of useful scenarios. Technology works when it is fit to a scenario. You think about the whole story of interaction with a person in context to design sensors and feedback. How will it work? So instead of trying to fight so hard to recognize eye position, my eye-tracking explorations celebrate ways we communicate easily with ways we open and close our eyes, and variation in eye movement. The ancillary responses people make with eye movement and small sounds are central to real communication.

I tried so hard at IBM to get the guys that ran the speech recognition to think about feedback. To this day, I don't think speech reco designers think of guiding the reco with listener feedback like " yea", "um," "uh," "Mm-hmm," "Yeah, yeah." All the signal analysis we do on low signal-to-noise input media (like eye tracking, voice reco, or handwriting reco) makes understanding a person much easier, but we don't always really think about the whole scenario, including feedback, to interpret ambiguous input. We think about the techniques we're working on that will decode a signal. We try to interpret or infer the signal even when, beyond incomplete, it is intentionally or unintentionally left ambiguous.

This is back to my technology-versus-techniques thing. Think about the whole problem, be courageous enough to try building a piece of hardware or software to make things easier instead of just writing some Open CV software sometimes. I made lots of other eye tracking stuff at MIT. For example, we made Face Interface, where we could attach facial gestures to characters on a web browser so that you could control your computer with your expressions. Open/closed mouth, head turn, nod, and eyebrow movements were not hard to attach to Windows commands. We went off to Taiwan to work with design students. My prolific student Jackie Lee and I ran these workshops using webcam cameras to create a whole cave experience. They'd use the camera to watch the users watching imagery projected on a wall. The camera could tell how many people were there, how many were clapping, how many were moving to the music and so on. We used Flash programs to turn their actions into changed projecte- animated environments. It could tell who was looking at it. Then Jackie Lee, Matthew Hockenberry, Conner Dickie, and other students helped me make various context-aware interactive vending machines. They could tell how many people were at the vending machine, to create a personal or collaborative interaction game. It could tell if you're paying attention, and then put up the news instead of turning into a vending machine. They could provide specialized graphics for what you were contemplating buying, give you Wi-Fi, and had a femtocell for phones. My student, Mike Lee, made the Invision-This system that used Blue-Eyes to tell what your pattern of eye movements showed you were interested in on the screen. It would move those things that your eye motions related together closer together on the screen. In our case, we were interested in what sponsors of the Media Lab you were interested in. The system would cluster names of Media Lab sponsors relative to the relationships the eye tracker picked up in the way you looked at them.

The eyes say so much. So, I think that lots of eye tracking work has trouble sometimes where they don't recognize that there are lots of things we do with our eyes that are about saying, "I'm paying attention to this. I'm focusing on that. I'm doing the other." And those things are quite useful. Whereas, the first eye-tracking product that came out with near universal appeal was in the IOS Canon Cameras. The eyecup stabilized where your eye was. It watched where you were looking in the viewfinder to decide where to focus and what part of the image to set for best exposure . The Canon cameras would meter light and focus a camera where your eye was showing interest in the viewfinder.

Steinbach: Oh, okay.

Selker: Very simple little thing, right? It's not trying to do the difficult act of target practice. It just notices something your eye shows in its attention to what it wants to do. It notices the area that something's going on for this person. “Well, what if I focus there?" And it was delicious. And that's what you want. You want to make interfaces that add no extra work and solve problems and, of course, feel delicious.

Steinbach: Okay, one thing that struck me as, well, unexpected--I don't want to say strange--at IBM, I found that you did a digital living room at IBM. And I thought, "IBM? <laughs> Living room?"

Selker: Thank you for noticing that my work was designed to be stretching the ideas of what IBM was exploring. It was fantastic that I could do that there. It became my job to do the unusual, and it was so much fun too. Thank you, Ashok Chandra. So my first foray into that area was I had this idea that people don't naturally read a wall, they naturally attend to things held in their hands. So what would it be like to make a wall display that worked with a tablet you hold? I should look to the projected wall shelves to see a book I wanted to read. I would point with the tablet book, and I'd have it on my tablet. Or I'd point at that spreadsheet and I'd have it. Or I'd point at my email and I'd have it. So there'd be a picture of a bunch of mail on the shelf and I'd grab it by pointing at it. And so I made that scenario. We made this gorgeous table at that point that had five computers, a projector and all these tethered displays. This Room With A View could make any room with things on the wall that you could interact with on a tablet. So your boss walks into the room and you've got a room that's all full of management PERT charts and all the people that work for you and their progress reports and stuff. Your colleague walks in and the room's walls fill with the project documents and the technology and the procurement that you two are working on. So, I made this RWAV system and showed it off at the Olympics, by the way. Dan Rather refused to video it because it was too futuristic. But it got on ABC and got a lot of news play. I probably didn't write enough articles. But the idea was you like to read at the distance your arms are at and you get oriented out there.

And so user interface is two things: being focused and oriented. And who wants to go over to that old office that we used to have with all those papers and stuff? Going into that office, you can look at what photo-galleries and other materials are on the walls to get to know a person. Wouldn't it be great if you could have that in a hotel room too? But if anyone wants to make this product, let's do it. RWAV demos were presented at the 50th Anniversary of Computers. RWAV got invited for a month-long demonstration called "Living Room of the Future." The scenario is where mom's reading the news, dad's playing Sudoku, the kids are doing their homework, and we're all sitting there together in the kitchen. What I used to say at that time, everyone went off to their office or their bedroom to play with their computers and they aren't spending time together. I hoped that this shared platform would bring a family together. The kid could have a big pile of papers all over the table while mom's making dinner and when it's time for dinner, poof, they're gone, right? The mess of a partially completed project is virtual and retrievable with RWAV. And so this idea of bringing people together through shared use of an orienting computer-cave projection with personal-focus devices allows the whole wall being your organizational scheme about your paper you're writing, while allowing you to have several coordinated focus tablets opened at a time.

Steinbach: So that's also a display, on the wall.

Selker: Yeah, the walls are displays that look like the interesting offices full of the wall-hangings and bookshelves we love. And all of these projected on the wall can be transferred to a tablet just by pointing them to get detailed interactions with it.

Selker: And too, RWAV was a piece of furniture, it was a computer, it was a pile of coordinated tablets, it decorated the walls of a room and even included a massaging chair that it would control. Displaying walls were presented as a low-resolution selecting orienting interface. The tablets were the high-resolution control, edit and compare, focusing part of the interface. It's hard to turn something new, like RWAV, from something that many people, even at conservative IBM, thought was a great idea, to one that actually gets produced. No one would actually make it. Three different parts of IBM considered getting into the furniture business with RWAV but didn't. Jeff Allison designed it with me to give social alternatives for people sitting at it. The table was designed so if you were talking to somebody in a difficult decision you sit across the pointy part of it. If you're collaborating on one thing you're sitting next to each other to look at it on the curved part of the table. If you're working adjacently with two displays there is an oblique angle between two curved areas.

This table shape was also used as part of "Living Room of the Future," explorations too. This was a plug-in-and-turn-on computer media center and high-tech coffee table; and it would've been a great product-- —you might buy this thing at Best Buy. Instead of having this big complicated sound system, by having these different sides to it we could direct the sound every direction, as well as use it for a subwoofer to create a high quality sound system that uses one wire, plug it in. It worked with every kind of media; You could put in CDs, DVDs, video and cassette tapes, or stream internet back then. You can pull out the keyboard and use it as a computer with a wireless internet.

Steinbach: Did it have a display too?

Steinbach: In the table.

Selker: It used a projector, <laughs> Yeah.

Steinbach: In the table.

Selker: It projected on a wall.

Steinbach: Okay.

Selker: It could project on the ceiling or use a periscope-like mirror to project on the wall. So for watching movies you watch those on the wall. The table included a foldout keyboard. Though I made this 20 years ago, I still think it's still a plausible way to set up a media center in a living space.

Steinbach: Although now you have a lot of speakers that use Bluetooth.

Selker: Yeah.

Steinbach: So they don't have wires anymore.

Selker: That's right. Except that where do they get their power?

Steinbach: Yeah, well.

Selker: You have to plug in somehow.

Steinbach: Right. <laughs> Yeah.

Selker: And they can be charged.

Steinbach: And they have very efficient amplifiers now.

Selker: Yeah. They still have to be charged now and then. But, maybe some ideas are better for a time. Still, I am nostalgic for this simple-to-setup computer media system. We are still wrestling with what will happen in the living room. And I helped kick off and work on a living room project at Amazon many years ago, too, which eventually lead to the Echo. I still feel there are many opportunities on how to help people in their living spaces.

Steinbach: Yeah. Right. Right. And, yeah, another-- last thing that I-- that struck me from your IBM time from one of those articles is the Emotion Mouse. <laughs> I heard Emotion Mouse? <laughs> You didn't bring one by any chance?

Selker: Measuring emotions is interesting. Galvanic skin response is one way people try to do it. A galvanic-skin-response measuring mouse was made by Roslyn Picard's group at MIT Media Lab. And I had a small part in helping her design her famous Galvactavator glove. My students, Andrea Lockerd and Ernesto Arroyo, demonstrated and published papers about recognizing what you were doing by the way you move your mouse. We showed that cursor movement around a website could compete with eye tracking for knowing what you are thinking. We can measure so much physiologically. Recently I published a paper showing that the tremor in the way you hold your phone (before having coffee or a cigarette in the morning) indicates how well you have slept in the last 2 weeks. But my most recent paper, on the sensing of affect, describes a new physiological metric that can recognize cognitive overload quickly enough to allow reduction of it before it causes control mistakes in a driving simulator.

I love to think of how computer interface could impact everything we do. It's exciting to see that some of these things are now happening; I made an exercise machine that remembered and helped you work out at IBM. I made a smart couch. If you sat down it would recognize you and what was on your schedule and talk to you or play music. My group made about 40 prototypes a year in that lab and about three of them became part of a product success. I felt that was doing poorly; it turns out we were doing great. I'll show you one of my strangest mice. This, at a time when I want, shows value in a more capable scrolling system that could go any direction on the screen in response to the wheel that would only go up and down a screen. Well, we did a study and found out that people preferred, and could get more done, with a scrolling stick that allowed you to scroll in any direction instead of just one, with different speeds by pressure, something like a track point on a mouse. You'll see that there were some IBM products that went that way. When the product people said, "Well, we can't spend any money on this," I made this one where there is this button, which turns this mouse into a scrolling mouse; actually all it does is it presses a piece of rubber down to keep this roller from moving. So that the motion of that mouse simply flexes that rubber inside and makes the mouse into a screen-scrolling joystick.

Steinbach: Ah.

Steinbach: Great control again.

Selker: This is the prototype. Simply pressing on the scroll button reused the sensors that already are in the product for measuring mouse motion to become a rate-control joystick. I was able to make them measure motion of the mouse as a joystick, which was interpreted as a scrollable mouse, without adding any electronics. Reusing sensors that way was a fun trick that could have saved a lot of money in manufacture and produced a 2D scrolling mouse.

I have collaborated some with Rosalyn's famous Affective Computing group, but I have always studied focus and engagement. Focus, whether I'm interested, whether I'm bored, whether I can be made interested, all of that's really the heart of much of the work that I've done. And a really hard part is figuring out when to bother a person. A lot of my best students' work was around that topic. Ernesto Arroyo, for example, made something called Disruption Manager. It mediates instant messages relative to its topic and timing relative to other things that you are attending to. So if you're typing or actively browsing material it will wait a moment to present a message. If the message that's coming in is different than the one that's coming next, it might clump some together that are on the same topic. In an experiment of online order taking, the system reduced time per order by 30 percent. With Disruption Manager mediating messages, orders could also be filled out with some 25% fewer errors. We increased people's' performance dramatically by varying the interruptions and understanding the difference, as he called it, between disruption and interruption. Disruptions are when you stop what you're doing because of an interruption. Interruption's something trying to get your attention; disruption is when you stop what you're doing to do something else. And often these things happen around a notification. My most recent PhD student, Rahul Rajan, did a wonderful piece using audio notifications in a conference call to improve it. We watched an audio stream and we are able-- we took all of the things that people know that they hate about conference calls — and used automatic notifications to ameliorate them. We figured out how to make people better at not taking over a meeting, better at speaking up when they should, make people more aware of who's spoken, getting rid of noises in the background. So we used some AI to recognize communication impeding problems in the meeting and reduce them. The communication frustrations are a level above the emotional responses in the meeting. I am more interested in recognizing and trying to solve the problem that caused the emotion than just recognizing the emotion. And this is actually something that I am trying to take to product.

Steinbach: This is just audio or using the video as a key?

Selker: I have been using the audio as the key, but am currently creating a video system as well.

Steinbach: So just based on audio you will--

Selker: Just based on audio, we can recognize communication needs that are not being addressed. I can decide some way to interject some audio to help. So my question was, I can make human computer interactions better, but can I make human-human communications better too? And okay, let's choose a really small communication path, which is audio, and I'm going to add noise to that. Can I add noise and sound to the audio and improve the communications with it? And so that's back to my AI and user interface theme, which has been a focus throughout my career,

Steinbach: I would've thought you really need to see the person to know when to speak or such.

Selker: I would have thought that you needed to be in the room to recognize people's' communication needs too, but we have been able to interpret and react to audio cues to speak to improving communication between people.

Steinbach: Okay.

Selker: At first we found that it was very easy to disrupt the meeting and make it worse. You start putting noise behind somebody that's speaking and then everyone's unhappy. But identifying a disruptive external sound, like a barking dog or television in the background, and someone on the call has to say "who's not on mute?" So we found in our studies that when people had to say "who has the TV on?" while it gets the person making the sound to stop, it also raises the stress in the whole meeting, reducing the focus of everyone. We found that people would avoid saying anything the second time the TV was turned on. On the other hand, when the computer noted the problem, the resolution of the noise was better, didn't raise the meeting's stress, and people made fewer communication errors in collaboration.

Steinbach: Yeah.

Selker: Learning when and how to recognize people's needs is so interesting to me. In another example, my students, Andrea Lockerd and Floyd Mueller, did a piece of work where, now-Professor Lockerd walked around Harvard Square taking videos with one of the video microphones listening to her audio reactions to the video she was making. We could pretty reliably find her noises of interest while videoing. These markers could effectively edit the important part of the video. And once you know that making a little annotative noise will be noted later, you do it as a way of tagging it intentionally. I love overlaying something people naturally do with something that's going to be a controlled sequence, so that people could remember it better and do it easier. I found many examples throughout a lot of the work I'm talking about, about using small changes to natural behavior that can be effective user input for computer control. In a one-hour segment of videotaping that she took, her audio remarks identified 4 significant video segments she was really interested in.

Steinbach: And that's not too personal in terms of somebody else would have some other--

Selker: Well, she's the one that's making the video. It's her video. I would love to spend the time to see if we could make it as easy to learn and use for everyone as it was natural for her.

Steinbach: Okay. Well, but that means the software that deals with it--

Selker: Yes, it’s such an exciting time for that collaboration between our behavior and software working with it.

Steinbach: -- has to learn her idiosyncrasies.

Selker: Yes, we used a hidden Markov model, which we trained to recognize how she easily presented her interest with audio reactions.

Steinbach: Okay.

Selker: And the training was on her, but that's kind of appropriate, in that it is her reaction to her work that defines what she is focusing on. Still, we showed that asking someone to indicate with a noise when they like what they are recording worked great. So for the purpose of mom taking pictures of the kid, it's kind of right.

Steinbach: Yeah.

Selker: Professor Lockerd, who I think of as a serious scientist/ engineer, used giggling to indicate the segments. Maybe some more camera-shy people would just say “this,” <laughs>. But I noticed that even you giggled a little bit just now about something. Encouraging people to giggle might be good for them anyway.

Steinbach: Yes. <laughs>

Selker: So maybe your affect will help.

Steinbach: <laughs> Yeah, maybe. Okay. So there are two more things I want to ask about IBM. One was you started out at TJ Watson.

Selker: Yes. I worked in Yorktown Heights, New York for 7 years and at Almaden Research Center in San Jose for 7 years.

Steinbach: But you're here again now.

Selker: Yes, I love the energy of Silicon Valley and have come back to it again and again.

Steinbach: So you split your time-- or at some point you decided to come here within the IBM--

Selker: Well, there's a funny story. Ashok Chandra, my big mentor, again falls into this story. So I—my sweetheart was living in Seattle and I was at that time willing to leave IBM, go be with her in Seattle. That's how I felt about getting together with this girl. And she's, "No, I want to live in New York with you," so she comes to New York. "We're going to stay there until you get your PhD and you get this other thing done, but I don't want to live there forever." And so we're going to live there for two or three years. So, after something like 4 more years and getting my PhD done and getting the TrackPoint launched, it was time. October 1992, we had just launched the TrackPoint, and had just had our first child. I said to Ashok, I said, "I'm going to leave IBM to move to California." And he says, "Well, turns out I just took the job at IBM's Almaden Research Center. Why don't you come and start a group there?" <laughter>

Selker: We decided to move and left in less than a month. It came out that fast. And so he just made a place for me and let me build a laboratory here. And it's what I wanted to do. And he let me do so many fun things. Like I wanted to put IBM on the map in human-computer interaction. So I ran a workshop called New Paradigms for Using Computers that we ran every year at Almaden, and continued for more than 15 years, so people could recognize that IBM was not just a closed academic tower in the sky. We had such amazing speakers and attendees; it was only and most of the people that made the ideas that changed the world of computer use. James Gosling gave a talk about hot Java, "a new web browser," before he had exposed the Java language. Within a few months of when Mosaic came out Terry Winograd gave the talk "Hacking the Internet Superhighway," where he was talking about the kinds of tools one needed to find your way in the internet: WAIS, Archie and Veronica, and his metaphorical descriptions of how machetes and chainsaws had different, complementary uses in hacking through a jungle. We had amazing talks from Marvin Minsky, John McCarthy, Douglas Engelbart, Danny Bobrow, Richard Sapper, fabulous people who are all gone now. David Kelly, Bill Buxton, Martin Eberhard, Todd Rundgren, and Marc Davis gave talks about the relevance of design, music, and personal production of media to a world just readying itself to think about those needs. Many talks were so forward thinking; for example, Ed Fredkin talking about the "Internet Of Things" in 1994. He may have coined the term there, actually. And it was about the stuff that happens now. I mean he was talking about how if you have an earthquake you could have a train that would stop before the earthquake derailed it. That's what they do in Japan. I exposed new collaborative experiments every year there. One of my favorite moments came when the great industrial designer, Sapper, was talking uncomfortably about genetic engineering instead of his design; I gave the tablet that let the audience comment on talks to a great cartoonist, Mike Moser, who began drawing sheep that appeared above Sapper on the wall, Sapper riffed off the cartoon, and in the conversation that ensued the talk became amazing.

IBM Almaden was a fantastic home for me. It's a place where every research member has their own view out over a mountainscape and state park without seeing any other buildings. And the place has incredible resources. It's a great place to work, but a bit of a drive from Palo Alto.

Steinbach: Yeah, I visited there once for a talk.

Selker: It's 22 miles from Palo Alto, where I lived, an architectural triumph, worth the 35-minute commute.

Steinbach: Mm-hm. Okay. And the last thing was IBM is-- went totally out of the consumer space, right? And what you're-- I mean your focus was on people--

Selker: Yes, I relish forays into people-oriented solutions and mourn their departures to middleware and backend solutions,

Steinbach: -- if not to say consumers, right?

Selker: Yeah, consumers are the people that matter in my mind and work.

Steinbach: So do you feel like you left at the right time or?

Selker: The focus on services and the reluctance to pursue consumers was on my mind at the time. Actually, I was rebuffed from my grand proposal to the C-level executives to consider being a source of user-focused innovation for the industry, beyond products IBM could deliver.

Steinbach: Really?

Selker: Oh yeah.

Steinbach: And you saw the writing on the wall somehow?

Selker: Well, at first I was going to continue running my group from MIT. I hired the extremely talented and wonderful James Spohrer to manage it and came back every few weeks to work with everyone. Yeah, I still had contact with the CEO and general manager of research after I left. And I had a big argument about them selling the ThinkPad brand. Yes, some things aren't there that were.

But I'm still a little sad that I left. I did continue consulting with them for many years and enjoyed that. There's always an opportunity to help users of all computer systems. Global Services is IBM's huge consulting arm. I think that I would have loved working on fancy tools to help their people do their jobs. My most recent thing that I tried to encourage them to do is to work on great program-development environments for cognitive and systolic computing. So they've made these amazing new paradigms for programming, but how do we visualize their architectural performance, how do we debug them? How do we build them? I've always had a soft spot for working on program-development tools. But they have to have people using them to become good. Actually, one of the guys that used to work for me, Myron Flickner, worked on the programming tools for these new strange computers, last I checked. I think there's always a chance to work on things that help people.

Steinbach: Right.

Selker: I was really unhappy about IBM getting rid of the ThinkPad products. And they thought it made sense because of the commoditization of that industry. I thought it didn't make sense because it was a very important branding statement. People appreciated the ThinkPad's specialness and still do. But anyway, a lot of the same people that worked on it at IBM are at Lenovo even now, continuing to work on it. So maybe it was okay for IBM to move on from the PC business.

Steinbach: After IBM you went to MIT.

Selker: Yes, which was also so much fun.

Steinbach: All right. What made you leave and go to MIT?

Selker: Well, my father had always wanted to be a professor but he didn't end up getting his PhD. He had seven kids when he was trying to get it. <laughs> And he did teach at Seattle University for a few years, but he always valued the role. I also saw what my mother saw, that for him industrial laboratories seemed unstable over time. And that weighed on me. In fact, that's why I turned down many of my early opportunities to be part of entrepreneurial experiences. I sadly even turned down going to Google in 1998 to go to MIT Media Lab. They were just starting and I'd been working with Larry and Sergey at Stanford and they wanted me to come. But I always wanted to be a professor. MIT was a very big, exciting thing. The director of the Media Lab said, "Well, it's the third time we're asking." <laughs> And he was saying, basically, this is your last chance. Yeah. So it was a life goal. Tremendous students, incredible faculty, the most interesting people you can name came to visit, and over a hundred sponsors all interested in innovation in different areas. I always wanted to innovate for more than just the computer industry. So at MIT, I was so lucky. I got to work with the cell phone companies, the auto industry, the furniture industry, and even the food industry, a lot. I ran something called Counter Intelligence, about food and kitchens of the future. I worked with Chrysler, Ford, Lear, Motorola, Sanyang, and the US Postal Service on vehicles of the future. With MasterCard, I got to design physical security for a credit card that they almost produced.

One of the things I'd worked on at IBM, with Steve Ihde as the lead programmer and Jeff Allison the lead physical designer, was what I called eSlate. This was a working computer that was supposed to be $100 and replace books for young children in school. It had hypertext links, it had authoring tools for making something that was going to be cheaper than books. A hundred dollars and you'd be able to teach kids with it and had a little button on it to call for help if some bully picked on you. Denmark considered buying it from IBM for all K-12 students. So when I got to the Media Lab we started talking about it. I'd given a lecture as part of visiting the Media Lab long before, as keynote speaker at their Wearable Symposium. At their Wearable Symposium I showed eSlate at these talks and Nicholas got interested and started the One Laptop Per Child initiative. So as I started presenting design ideas for the OLPC, this was the wildest design approach for the One Laptop per Child. This handle is the cable. The cable in a laptop, going between the display and the keyboard is one of the most difficult, expensive things, so I made it into an external carrying handle/cable so it wasn't trying to be compacted inside. The idea was that you could make the keyboard fold out and Velcro the display on the base or anywhere, just a fun exploration. I made a whole bunch of different industrial design ideas for that, One Laptop per Child. Should it look like a book, a purse, or a laptop computer?

Steinbach: Okay, that was during the MIT time, right?

Selker: Yeah, I was at MIT at the time. We built the One Laptop per Child. I was involved at the beginning and then later on I solved some technical problems in the keyboard. There's such an untethered way that you do things at the Media Lab. Those untethered openings and resources for creating things with students that would be noticed by the world is special about the Media Lab, still. And still there is a roughness to everything there. What I used to say is at IBM I worked with professionals and at MIT I worked with pre-professionals <laughs>. Because if they become professionals they leave, right?

Steinbach: Yes.

Selker: So that even in deciding how to go forward with something like One Laptop per Child, that was really not done with the kind of support and infrastructure that you would do it in industry.

Steinbach: So that was an MIT project?

Selker: Oh, yeah, Nicholas wanted to get everyone to contribute, as we could.

Steinbach: I didn't know that. I thought it was some-- well, I didn't know where it was.

Steinbach: At the time, I read about it, but yeah.

Selker: Nicholas Negroponte leveraged the Media Lab to create first prototypes, then took people over to the new organization as it grew. Yes, it came out of MIT. I taught the first course on programming it with Henry Holtzman at the Media Lab. Michael Bove did a lot of the engineering, he's a professor there. I helped and Nicholas stepped aside from his other duties to run it. Walter Bender, who was the executive director of the Media Lab, finally took on being President of it and still works on the software for it.

Steinbach: So it is still out there, the One Laptop per Child? Now you can buy hundred dollar laptops, right, for the kind of Chromebooks and so on.

Selker: Yeah, I believe the organization still works with people in need.

Steinbach: But you don't hear that. I don't hear about One Laptop per Child anymore.

Selker: I know, you'll have to ask somebody else about that.

Steinbach: Okay.

Selker: But there's follow-on stories and software upgrades, and there's still curriculum running on it. But I think that, yes, I think it's not its special time anymore. But at the beginning, the OLPC attracted great students from the Media Lab, MIT Computer Science, the Harvard Education program, and companies that wanted to program it too.

Steinbach: When was the beginning?

Selker: Well, that's a question. I gave the first talk about it-- with this in my talk at the Media Lab in 1995 or six. But in 1998, I and the great Professor Joe Jacobson, ran a course called "The $5 PC" which was really aspirational. Then about two years later, Nicholas started having these meetings about it. They were amazing meetings; I went to this first meeting and there's Seymour Papert, Alan Kay, Marvin Minsky, Nicholas Negroponte, talking about this One Laptop per Child <laughs>. It was, I mean, well, maybe even too much horsepower, but we all had a great time <laughs>.

Steinbach: Yeah.

Selker: But that was part of my transition to MIT. Another was wearable computers I made at IBM and talked about as the keynote for the Wearables meetings at MIT. This is the shape, I had a couple working ones, a wearable that would have a head-mounted display. We — I actually designed and built an actual platform that the companies making virtual reality could use. Cybernaut and VIO were the two companies, as I recall, that wanted to buy them from us. They had big money, V.C. funding. What shocked me is when I said all right, I can give you the computer platform for one-fifteenth the cost of what you're paying now. So they were paying something like $20,000 for their belt computers that they hooked up to their VR headset. But between the two companies you'd have to create orders for 10,000 or IBM won't make it. They said, "Oh, we can't do that." That's when I really questioned the viability of the VR/AR industry at that time. By the way, I work as a contractor for Magic Leap now. I'm not going to talk about that.

My main goal at MIT was to build my research group called Context-Aware Computing. My goal, which seemed controversial then, might seem quaint now, was to demonstrate that AI could be useful in real world, physical, and even dangerous settings. I made lots of prototypes and research platforms around the ideas of context, always testing for performance and usability. One of the first things I did when I got to MIT —and as you know, I kind of love bicycles— was to make an augmented-reality bike helmet that would be based completely on audio input and output, turn signals, and running lights. As with the wallet I described, this would be an enhanced version of something that people already use. So you put on the helmet but you get something more. This accelerometer turns on the running lights in the back and the front when it's on your head, just by feeling the motion. When you turn your head to the left or to the right, the blinkers go on for turning. When there's loud noise outside, a microphone senses it and turns off the MP3 you are listening to. Here's the MP3 input on the helmet I brought in. I am always listening to books on tape and when there's screeching wheels of a car or something it will amplify the external noise as it turns off what you are listening to. When you speak softly, the Bluetooth microphone sends this to your telephone and lets you dial by voice. The reason for this BMX helmet is partially to make a quiet sound stage near your mouth so you can talk. Yeah, also if you scream at a car this 130 decibel horn presents your honk, covering up your obscenity. Finally, when you shake your head, like you went over a pothole, it opens up the microphone and geo-locates whatever you say about what happened. When you go near a place where someone else shook their head with one of these helmets and added a statement, it is stated again: “dangerous parking lot exit”, or “gravel in hole”, or “great café.” This helmet is supposed to mediate communication from a person to the world and to improve your bike ride and your bike experience. In fact, I ran many of my meetings with my students while wearing this helmet and/ or prototype parts of it on my commute to MIT.

Steinbach: During the meeting.

Selker: Yep, they could get me to talk without other distractions when they were wherever they were and I was on a bicycle wearing it.

Steinbach: Oh, okay.

Selker: So I'd run some meetings from my bike on my 25 to 35 minute bike commute. So where did the idea for a communication-mediating AR bike helmet come from? Two places, first it came from one day I'm riding my bicycle along and a car comes out from a parking lot that had a small exit between two parallel parked cars. It was more or less hidden and I fell to avoid being hit. Somebody sitting there said, "Oh, that's the third time I've seen a bike almost get hit here this week." I thought, gosh, why can't we record existing or new safety problems and solve them for the next car or bicyclist. Today, we might wait for a few people to actually get hurt. Next it gets reported to the traffic department. Then it might be scheduled to be discussed by a committee or the city council. Then they assign people to work on it. Then they come out there, and they have people make a sign and attach it to an existing post or jackhammer a hole to put a new signpost up. It can take years to fix signage. The other thing I wanted was to move beyond how much of AR and VR work excluded the world. I wanted to use AR to help me with my hands on the wheel and my eyes upon the road.

So that was kind of that. So, I had students work on that, on and off for several years actually.

Steinbach: So you consciously restricted yourself to audio.

Selker: I wanted to explore what a rider could do without disrupting their visual senses. But I also allowed the accelerometers to control running lights and turn signals.

Steinbach: And use audio in many different ways--

Selker: Yeah. audio and motion were the only inputs to the system.

Steinbach: Okay, yes. Yeah.

Selker: Yeah. So that was so much fun and a productive alternative to visual centered AR/VR that we and everyone else had been focusing on.

Steinbach: Okay, and a lot of articles about you that I saw were about the Kitchen of the Future.

Selker: <laughs> Oh, yeah. So, here's the Talking Trivet; a place to set down a hot dish and an oven mitt to move hot dishes around with.

Steinbach: So tell me about that.

Selker: So one question is *do we make a kitchen,* or a *world*, where everything is part of one sensor net, such as the Internet of Things, or should items and appliances be autonomous and have intelligence on their own? One of my first real lessons in this was watching a friend of mine, in the mid '90s, make a Smart House. Every faucet, every outlet, every gas valve, had a sensor on it, every window had an actuator and a sensor too. So what would happen is, first of all, it cost him a half a million dollars, and so many cables. When a sensor went out it would turn off the electricity or the gas or the lights <laughs>. This happened all the time because when you have a thousand sensors, hand-wired things can go wrong. Reliability and programming were such a problem; somebody would push a button somewhere in the house and something would happen somewhere else, because there were interactions in the modes a button could be used for with the fancy system-wide computer system, like “emergency exit from here” and “going to bathroom.”

Steinbach: Yeah, that reminds me of <laughs> when I was at my son's last weekend--

Selker: <laughs>

Steinbach: We were messing with the Ethernet. And so at one point, his wife comes, "Stephan, when the Ethernet went out-- when the Internet went away, the Nest Thermostat started to heat the house and I can't turn it off" <laughs>.

Selker: Wow, what a classic example. This is what can happen. If it rained, my friend’s house would close the windows and turn off the sprinklers, all good stuff. But the window sensors and motors sometimes failed. and when his motherboard went out once, he bought a sprinkler system for $49, that was more reliable than his $.5 million dollar system. Many people were playing with Internet of Things and it’s so powerful, and yes, sensors and system integration has come a long way since my friend’s house. But your runaway Nest home-heating story is exactly the same story. The Internet Home Alliance, for example, made a demo where you could turn on the stove with a PDA. Hopefully the cat is not on the stove when you do it. Sorry, the above is a slightly long-winded way of saying sometimes autonomous are easier to work with and even cheaper than integrated solutions. So I made this autonomous Talking Trivet with a thermistor sensor on each side, a microcontroller with a small reasoning system, and a voice-output chip. Okay, you see the Talking Trivet is kind of burned. If I put my hand into an oven, it can tell that the oven is very hot and that my hand was on a pan. And if it was 475 degrees it would say “I’ll remind you to take that out in 20 minutes.” Why, because a pizza is thin and it gets hot, and a high temperature will convect enough to cook it quickly. Now if I put something heavy in, like a roast, and it says ”I’ll remind you to take that out in 20 minutes,” it would be wrong, but that’s because the temperature is too high and it will burn the outside after a short time, right? So you think about it and you reflect and you turn down the temperature to 275, a reasonable temperature for cooking a roast so the center will get hot before the outside burns. If you put your hand on a pie or bread or something that was between 212 and 400 degrees, well, that's browning. Anything that we cook on the outside that's going to get brown is going to be like that, so it will say “Ready to take out?” And if you put a pot on top of it and it was cold, it would say “Needs rewarming?”, because you don't really use a trivet unless something is warm, right? And when you put it on a hot burner it exclaims, "Fire!" That's why this got all burned because I put it there for it to say "Fire" a bunch of times. Everyone loved that. So the point is that a little rule-based system can incorporate a simple model of cooking to make these decisions that could help improve safety and cooking in the kitchen.

Steinbach: You demoed it <laughs>.

Selker: Yeah, it’s a simple thing but people loved it, so I got to demo it for Martha Stewart and I demoed it for the Cooking Channel. We made lots of kitchen things with localized intelligence. We made a leftover dish with a display for how long it had been in the fridge. We made a system that would take a picture of what's in the fridge every time you open the door, so you always know what's in it without having to open it. We did very interesting experiments. For example, we did one where there's a picture on the fridge of what's in it. What is in a fridge is always a bit of a mess and people barely paid attention to the picture. But when the picture only fades in and is presented on the door as you're walking towards it, that one stopped people from opening the refrigerator. It presented them with information for where they might look; they would then consider what they wanted before opening the fridge. When we projected snowflakes and made the noise of wind when people opened the freezer, they would close it much quicker. The wind was so surprising it actually raised goosebumps for me the first time I experienced it. We made a faucet that could tell if you had your hands underneath; it'd make purple water that was warm. If you had vegetables it would make you blue water that was cold. If it saw a pot, it'd make hot water for washing it or getting water to boil.

Steinbach: Also with a camera to do image processing?

Selker: Exactly. You've seen that there are faucets now that color the water; that came from Leonardo Bonanni and Ernesto Arroyo’s work in my Counter Intelligence lab. I don't probably have it here but we made a Smart Spoon to sense salt, pH, temperature, and stiffness to guide you through cooking. The craziest thing we made may have been the dish maker. Why have a dishwasher when you can have a dish maker? So students Sam Sarcia, Robert Gens, Leonardo Bonanni helped me make a machine that would turn a piece of plastic into a bowl, a mug, a cup, or a dish. So you can just program it and so that way you don't have to always have cupboards full of teacups that you're going to use once in your lifetime. You just make them when you need them. You could put the cups back into it and they'd turn themselves back into a piece of plastic for the next plate, cup, or bowl you needed.

Steinbach: So as a matter of principle, do you prefer that everything has its own intelligence versus a networked world where the intelligence is in the Cloud?

Selker: Well, the Cloud is an extreme.

Steinbach: Or in a server, yeah.

Selker: Yeah, the Cloud is getting so convenient it lets me have the same experience on any computer or phone. It maintains my data integrity and backs it up without my effort. The cloud is so fancy for collaboration, as nothing has to be transferred. The Cloud is so powerful, I can get access to infinite storage and processors so cheaply for a short time, to do machine learning for example. Still, it also has its own security and reliability issues. The Cloud is not always secure. If the network goes down, then my access to my Cloud information goes too.

Steinbach: Yeah.

Selker: So there's a funny story about Magic Leap, which is they had a storm in Florida so we couldn't do any work in Seattle. <laughs> That's how Clouds can be, sometimes.

Steinbach: Okay.

Selker: Yeah. So reliability is a very important question. Why make things more complex than they need to be? Sometimes complexity is dealing with lots of data off the Cloud, sometimes complexity is getting data to it. Privacy is another concern and standards are another concern. So, for example, a decade ago many companies made incompatible Internet of Things (IOT) systems for the home: LG , Samsung, Phillips, and Sony, all made their own home-network strategies and none of them interoperated. So I was told, maybe this is in Korea, when if you were going to buy an apartment you made sure it has the right kind of network for the stuff that you have <laughs>. Such problems with integrated Cloud-based IOT systems are diminishing. As IOT develops, the interoperability is developing better too.

Steinbach: Okay.

Selker: Yeah. So there are these tradeoffs. In cars we have wonderful automatic things, for example, with power steering, which is that when the engine turns off there's still mechanical steering. And the question is, how do we make things that are reliable like that.

Steinbach: Failsafe.

Selker: Yes and **fail-soft** too**,** degrading gracefully when one part doesn’t work right. Even where it is worth it to have everything connected, if you need it to be reliable when the network or some other part of the system is down. That's kind of the question because at Nest, as you experienced, they didn't get it quite right. Connecting to the internet today is almost a service like water and electricity. But its only almost a reliable thing.

Networking can bring us many exciting things. I worked on the Kitchen of the Future with Merloni, who made smart appliances. In 2005 the refrigerator would turn off the heating element in the stove for a few seconds, when it started up. So it would be balancing all these power spikes. They would let you call your dryer to turn it on when the power was cheap. They did all these things, but the extra computer in each appliance to do it was expensive. So others were underselling Merloni. The power balancing was important but not so visible or obvious to customers to want to pay to save that money for power in the future. People weren't ready to pay for these coordinating power features. Still, power-load balancing is a high priority for increasing the robustness of our power grid.

Steinbach: Or your plug-in hybrid.

Selker: Yes, a plug-in hybrid can help balance the power load by charging when power usage is low. If you think about, for example, hot water. These tanks are full of hot water and don't need to put in energy at any specific moment. You start taking off the hot water and filling with cold water. The way it knows to turn on the heater is it gets too cold. Maybe it should start turning on its heater before it gets too cold, or not put in cold water till you are finished using the hot, after you have gone to work and the power grid is not so burdened, or some other strategy for helping time shift the power-request spikes.

Steinbach: However, currently my dumb gas hot water heater does not need any electricity, at least mine is not hooked up to the electric grid.

Selker: Cool, but CA is special with less than 10% of water heaters on the electric grid, but nationwide like 40% of water heaters are electric, so they can be used to time shift electric power. Electric dryers, electric refrigerators, and to a small extent, electric air conditioners can time shift too.

Selker: So you're saying your thermostat is completely mechanical.

Steinbach: In the water heater, the thermostat.

Selker: Yeah. It would have to have electronics in that thermostat to include it in a use-based power savings scheme.

Steinbach: If you wanted more smarts you would need electronics to support it.

Selker: If you take a look at your thermostat, yeah, it's probably just a bimetal strip. Maybe it doesn't even have a thermal couple and is very unlikely to fail.

Steinbach: Yes, so it's-- it's fail-soft, as you said.

Selker: Your heater depends on a fairly robust single mechanical control, but has no way of knowing when it breaks or communicating anything about itself to other things. It is fail-soft because if it fails it probably doesn't keep heating and doesn't boil itself dry.

Anyway, it has been fun thinking of lots of ways of making appliances smarter. I think refrigerators are a very exciting area. I made something called Living Food, a way that we probably use a third as much power for the refrigerator. I worked on using projectors throughout the kitchen to add imagery to the floor, counters, cabinets, and even on the appliances. So you go to look for your contact lens on the floor and the projector makes a grid on the floor to help you know where you have looked. The kid kneels down on the floor, a camera recognizes there's a kid down there and puts a tic-tac-toe game on the floor that responds to footsteps. Your friends come over and you put the granite tile look on the floor. If it's just you, maybe you make the floor look like it's a grass lawn <laughs>..

Steinbach: But getting back to the context-aware computing. In general that also would need a connected sensor grid, right?

Selker: Yes, it depends on what you're doing. Our context-aware floor certainly was a connected-sensor grid that integrated with other sensors, computer systems and effectors, but the Talking Trivet stands on its own.

Steinbach: Fused sensors.

Selker: Certainly that Talking Trivet was made to show that a simple thing by itself could recognize and respect goals. It was not part of a sensor-fused IOT system.

Steinbach: I guess. Yeah.

Selker: Yeah, the first demo I made for context was a coffee cup and put thermal-- I painted photochromic polymer on it. So when you put coffee in it, it would turn brown, "Hot" would be displayed in orange letters. When you put ice water in it, it would turn blue and "Cold" would be displayed on its side. It's a tumbler and it's a mug, right? The mug had no computing but it certainly has this idea of context change. The question is how to make things that are reliable and useful.

I tried to show this in multiple domains: I made the Bed of the Future, the Kitchen of the Future, the Car of the Future. I made my whole laboratory, with more than a dozen running demos at a time, context-aware with a smart floor. This was a sensor grid connected to all the computers in the lab. So, anyplace you walked in this laboratory it would run the demo if the demo was up, or play the video if it wasn't. If you were alone, it would talk to you. If you weren't, it would notice where the pattern of people are and try to group them. It used projections on the floor to show you where to go, label demos, and make social commentary. For example, if you were standing apart from a group, it would project a podium beneath you and direct a spotlight at you to allow you to speak to the group.<laughs> If there were two separate people or groups, it would draw footsteps to introduce you to each other.

Steinbach: And among other things you worked on I saw a mail truck.

Selker: Yes. We built a concept vehicle to demonstrate like 8 different new business models for the US Postal Service.

Steinbach: So that kind of ties in with the Car of the Future?

Selker: That's right. And USPS was one of the biggest sponsors that MIT Media Lab had at the time. I got a couple great theses with the fabulous Boris Paskalev and Jordan Bryanov, and there's a nice video about this 2.5 ton concept vehicle on YouTube. It included a surround mirror instead of a rearview mirror, created from putting cameras all the way around and integrating them, making a very ergonomic way of seeing all the way around the truck. Since these trucks are parked in some of the most expensive property in the world, if they were parked on the street at night, they could actually be a billboard, so I made billboards out of an array of displays on the sides, before those were so readily available. And then one of my favorite things was that you have a printer in this truck and when somebody wants a print job as you're driving along, you're printing their job to deliver with the day's mail. We had this idea that a lot of people are going to buy "Harry Potter" the day that it comes out so why not have a bunch of those things that might be purchased today on board and let the network tell the truck where to drop them off. That's a good use for a network, right? A person can add to the postal delivery the obvious new thing, a few minutes before the mail arrives. Those trucks are running about 20 percent full mostly and so you can have a lot of things; like you know you're in downtown San Francisco, you keep a couple of the fashionable office chairs of choice in your truck because somebody's going to want to buy a new office chair, right? <laughs> It kind of becomes a warehouse and a bunch of other things. It turns out that postal drivers are often the first person to find out somebody's died; things are not getting taken out of their mailbox, so why not make that part of their job? We put a laser pointer to show the driver where the next box to find is. We made a way of turning on the emergency brake when the driver got out of his seat; we played with lots of ideas. In another concept prototype for them, Manas Mital helped me make a clip-on radar for a postal vehicle to alert the driver of oncoming dangers. Rural mail carriers get in head-on collisions because they're screaming in and out of the shoulder to put mail in the mailboxes at the side of the road. I am told they're really good at the four-wheel skid to go sliding up next to this post box. Anyway, so I made a clip-on postal-car-identifying "light" that also had a warning horn to alert the driver of an oncoming car. I did a lot of things for the postal service. They were wonderful. I mean they have complicated, sophisticated technology and they serve every address in our country. But at that time President Bush was trying to privatize the postal service and they were losing a lot of their best people and they didn't get go too much further with many of these innovations.

Steinbach: Yes, and I think the government is pulling money out of the postal service -

Selker: Oh well; why provide infrastructure when you can reduce costs?

Steinbach: I also found a mention of you taking your students from MIT to the Burning Man. Was that a research project?

Selker: Yes I made one project for Burning Man as a Media Lab exploration. So Win Burleson came with me the second year I was at MIT. We had this grand idea to map out where all the hot spots were in the playa at Burning Man. We had a weather balloon with a wireless infrared video camera and wanted to project the images of the camp on a 15-foot dome to see the activity. The dome had all these projectors with imagery of the fires and everything. It became quite a magnet for activity and people did shadow dancing inside. We brought a tank of helium and a generator and everything. That was a lot of fun but the wind kept the images from being real-time like we wanted.

Steinbach: Too much wind.

Selker: Yep, it was surprising to me that even at night there was typically too much wind for our balloon that year. We did have some imagery but it was not as easy to get as I was hoping. It was great, I'd love to do another big display that would help people know where they are, but be easy to set up and operate, but that's just a possible future story.

Steinbach: We are here to have you talk.

Selker: And I'm happy to be here too.

Steinbach: Another topic that has accompanied you over the years is dealing with voting, which at the moment is of course of current interest, right, about hacking of the election and hacking of some counties' voting systems. I think that Russians managed--

Selker: So– this is a complicated thing. So in 2000, Nicholas Negroponte sent around an e-mail, "I'm about to have a press conference about voting. What should we say today?" I responded, "Whenever you do something that's complicated , if you don't do it often and especially if the stakes are high it's easy to make mistakes." He responded, "You're it." So The Caltech/MIT project we built from that wrote a big paper about the problems of voting in 2000 that still gets citations and helped justify the Help America Vote Act. I made prototypes and tested them for improving every aspect of voting technology, and I've never had so many arrows in my back, by the way, as in voting technology.

Steinbach: Really.

Selker: Yeah, I even got a death threat.

Steinbach: Oh.

Selker: <laughs> But I got to testify in subcommittees in the Senate and the House and the National Academy of Science, and more, it was great fun. The security agencies weighed in by saying that there are so many easy ways to hack an election that don't have to do with the electronic records. On the other hand, people got very excited about this security issue and what we saw in our analysis of what really happened in 2000 and 2004 and 2006 and even 2008 was that registration errors were the number-one place that voting-- that votes were lost, over 2 million or so in 2000—

Steinbach: That was in--

Selker: —If a "volunteer" goes to an event hoping to register Republicans and you register as a Democrat, maybe that registration gets lost or changed. There was a whole trunkful of registrations found in March of 2001 from the 2000 election. You don't know if you've really been registered when you fill out a form that somebody's given you, lots of problems. Purging is another registration problem that happens.—

Steinbach: But how would you deal with that?

Selker: The Help America Vote Act mandated provisional voting, the requirement that polling places that didn't find you on their roster be required to allow you to mark a ballot for federal offices to be counted if you were found registered later. But as a voter this is the last solution. First of all, if you don't register with the actual registrar, you don't know if you've been registered. If you don't get a card back saying you're registered, you don't know if you're registered. Make sure you're registered. People think they're registered because-- well, what if you moved, oops, you're not registered anymore, and there's a lot of things like this. So first of all there's a lot of purging that's been done, which is if people don't live here anymore we get rid of their names but— that's why it's valuable to check that you are registered to vote where you live.

A couple months before the 2004, 2008, and 2012 federal elections I sent out a list to Secretaries of State of simple things to do to make the elections more successful, for things that could be done right at the last minute to improve the voting that time.

Steinbach: But how do you know if you are registered?

Selker: That's a good question. If the name is John Smith, it's really hard, and there were tens of thousands incorrectly purged in 2000 in Florida, so I made a system to evaluate purging. So registration's a very interesting topic. Now the really great thing is that almost all states have registration places you can go online and register and you've registered and you get the feedback from them that you've registered so that's very different from in the past, very much. The simplest way to register is directly with the government and get confirmation.

One million votes were also lost in the 2000 election due to polling-place operations. Polling-place problems, such as people go to the wrong polling place, the lines get long, they give you the wrong ballot, the ballot equipment has problems, can cost votes. There's a whole lot of very simple things to solve these problems that we worked on, including accessibility for people with disabilities. I've got lectures that show pictures of a lot of things done ad hoc at the last minute that confuse voters at the polling places. Frantic poll workers respond to inadequate election official planning by making ad hoc signs on paper with Sharpies; when confused or faced with frustrating situations, poll workers try to make up their own rules that are running the voting places. A lot of people were turned away for not having ID in 2000 where there was no ID law. I've even seen places where there were two pieces of paper on the polling place itself; one of them says you don't need an ID, one says you do. Sometimes things are posted where you can't read them.

Then there's the third problem that lost a million votes in 2000, ballot design. I designed a ballot called SAVE, which when you make a mark you see a confirmation: you see how many ballot races you haven't yet made selections on. It reduced errors by a third for normal voters and 3 times for people with reading disabilities. 14-1/2 percent of voters have dyslexia. Without treatment, reading disabilities cause people to make multiple times the errors of people that don't have the problem.

Steinbach: Is it electronic or--

Selker: That was electronic so when-- by the way-- and we can get into the electronic stuff. That's a very long, complicated topic-- I spent lots of experiments determining what happened with various allegations of fraud. The problems that lost votes on machines were universally caused by a confusing user interface. But when it became politically hard to discuss improvements to electronic solutions, I made some other solutions. So this paper-ballot magnifier solves many of the same problems on paper that SAVE solves with an electronic interactive ballot, but not confirmation feedback. This standing voting magnifying glass can help voters with paper ballots in several ways. Its LED light, it turns out, is very important for people with bad sight. You can really improve your acuity with light. The magnifying glass being stable and sitting on something is helpful for people with tremor; it's also helpful for people with dyslexia because the most important thing you can do for people with dyslexia is structure the visual search. So when you move this down the ballot that gets rid of almost all the problems that dyslexics have—

Steinbach: Because they see one line at a time.

Selker: Exactly, it keeps their eyes on the race they are considering. For the people that forgot their glasses, by tying this to the ballot booth and including this card with graphical non-textual instructions everyone can find and figure out how to use it-- it's always in the polling booth. I've watched hundreds of polling places and what happens is if you go into a polling booth and you shut the curtain and you don't have your glasses, you might find yourself just too embarrassed to come out and ask for a magnifying glass, and you just don't vote. So by having the magnifying glass there you solve that problem. So it's funny that here I am again, like I've said in-- several times in this, I've made electronic solutions and then I've made physical solutions to the same problem. I made a few thousand of an earlier design of the magnifying glass that are in use. I made these illuminated magnifying glasses for the Election Assistance Commission. But quite frankly there's a lot of other problems with the paper ballots as well and the security of paper ballots; printing, handling, and counting have all had difficulties and take attention.

Steinbach: Security in what sense?

Selker: Security in that a ballot gets taken or voted by someone else or the boxes get lost or the poll worker adds a mark as they are counting it, or the recount ballot numbers are slightly adjusted or extra ballots appear in recount.

Steinbach: Really.

Selker: Yes, and security, as in I watched an election official taking a whole bunch of ballots with a pencil, going into the back room to look them over and bringing them back, I expect they did nothing wrong but there is no way to tell that. Security, as in when in the state of Washington the state governor won by nine votes; each time they recounted they found a few more ballots to count. Security, as in I had an election official that watched the counting in the state of Washington during that situation. There was a guy and two women counting ballots and each time they'd count a pile of ballots he'd have a couple more votes for one person than the two women. He wore a suit and after a while they'd accept a couple of the votes he counted that they didn't. Even though there's three people counting, there's intimidation possible. So security, as in the state of Oregon when I watched, I saw that after they closed the door and the truck was inside the polling counting place; there were many places different peoples' fingers had to touch these ballots. Now maybe that's changed by now and no one puts lead underneath their fingernail and marks a ballot afterwards. So everything has potential for problems. I've done lots of studies and written papers showing these things about voting. In my view it comes down to one thing: no single agent, be it mechanical mechanism, computer, or person should be in a position to change a vote. If you have one person logging on to the back-end voting database, you've got a security problem. If you have one person looking at the ballot in private, you've got a problem, and so that's my biggest thing. The biggest thing I have worked to communicate with the voting technology community is the need for Single Agent Independence in the voting process. I worked on the federal Voluntary Voting Systems Guidelines and I worked on getting the Election Assistance Commission started, but it's always been a difficult endeavor to get right. My political scientist friends that worked with me at MIT and Caltech and Harvard all said that this is more political than anything they'd ever done in their lives <laughs> so--

Steinbach: And the stakes are high.

Selker: Exactly**,** the stakes are high is the whole point of elections. So I finally started making voting technology improvements that would help people that everyone agreed to help: those with disabilities. My most recent project in this was for a federally-funded project to make and test five different kinds of technologies for people with disabilities to vote. Audio voting is an interesting approach for sightless voting, and polling-place operations are really extremely much more difficult for people with disabilities than other people. There are a lot of good ways of improving these things. I also made a simple tool for testing election registration and voting support web pages for accessibility. Instead of telling the designer all the things that are wrong, it shows graphically what the implications of your mistakes are, so the designer can see them clearly and change them easily. I'm still busy trying to get the Election Assistance Commission to consider deploying things like my magnifying glass. I am trying to get them to pilot a graphical polling place evaluation and support system. I am trying to get them to pilot audio support for voting. I am trying to get them to pilot my system to better support ballot design for disabilities. Finally, I am helping create more usable, more secure voting approaches with a Nicolas Blanchard.

Maybe my biggest success in voting was that I worked very closely with the Chinese elections official, Feng Binghong, to help him evaluate and design their voting equipment. I didn't realize I was doing this.

This Chinese kid kept sending me this paper he was working on. He compiled the perspectives of the voting technology experiments and research from all over the world. He kept saying, “Well, what do you think of this?” and I’d mark it up a little bit, then finally one day he says, “Well, I made the decision.” I met this guy; I don’t think he was even 30. He was in charge of all the voting systems in China and carefully made a very thoughtful choice for China; special paper scanners that only scan what the voter sees. When I met him, he asked, “Should I go to MIT?” I told him that I couldn’t imagine doing anything as important as he was doing right now.

Steinbach: Machines--

Steinbach: But you fill in by hand.

Selker: Yes, the machines he was making were for polling place scanning of paper ballots you fill in by hand. Then hopefully nobody else grabs it and then starts looking at it for problems. I had a voting official do this once in Arlington, MA. Anyway, what theirs does is it reads the words that you read instead of it having a cartridge with the ballot on it in the scanner. Unlike typical paper-ballot scanners, there is no way that a wrinkle or a mistake in scanning will change your vote with their system. It does OCR to read your ballot and that- that’s a big damn deal. It’s the future of paper ballots because it ends many problems I have seen in ballot scanners that can lose or change votes with paper ballots.

Steinbach: How can there be a wrong ballot in a polling place?

Selker: If you put a standard paper ballot in the wrong scanner, the ballot module in the scanner can misinterpret the marks based on its mapping of marks to races. If you put a wrinkled ballot in a scanner it can miss counting fiducial marks and misattribute votes. If you use an instruction-less ballot ,such as Inkavote, in the polling booth, the selections will be incorrectly marked. There’s something called a split precinct in Chicago and other places where you have the dogcatcher in this part of the precinct and those guys have the water bill in that part and then they have two ballot booths, one for each ballot type. You’re an A ballot or you’re in B and if you get them mixed up and put them in the wrong scanner; it will count them wrong. I actually saw this happen in Chicago. Voting officials had not labeled which booth was supposed to be used for which ballot, so the voter was randomly using the correct or the incorrect instructions with their ballot. This meant the people that entered their paper ballot in the wrong booth did not vote as they meant to for the senate race.

Steinbach: Bizarre.

Selker: Sadly, that mistake impacted a few hundred votes. It’s easy for there to be lots of unforeseen problems. I’ve seen people putting their hands into ballot boxes to pull through a ballot that has jammed the polling place scanner. I wondered - did it get scanned? I have seen high-speed scanners that jammed; when I saw this in a demonstration in Broward County, Florida, I asked: “Which ballot got scanned and which one did you not yet scan?" The person showing me wasn't completely sure. So, some places put numbers on ballots so you can know, and some places it's illegal to put labels on the ballots because it could identify them. Actually, voting officials are super vigilant and work hard to ameliorate these problems. I am only presenting them to help people see what happens when we aren't careful and one person or machine is in a position to lose a vote.

Steinbach: Yeah. I guess as you said in the beginning it's something that's done rarely, right, and for very few people it's their direct job that they do all the time. Right?

Selker: Exactly, what's interesting is people always worry about the older people that are running polling places. That is not what I have seen. I find the older poll workers are often the best poll workers and even most resourceful. They are practiced, earnest, and committed, having done it for years and are used to handling all the issues that come up. Again, the real thing I take home is whatever you do, practice it and check it.

I have been honored by so many exciting moments with Don Norman, the man who formed the first Cognitive Science department at a university. Together, we have consulted on the future of the cell phone, we have consulted on haptic feedback, and I have been lucky enough to have him in several workshops I ran. Anyway, he told me a story, he was in a hotel and he filled out his paper ballot and his wife filled out her paper ballot and then they checked each other's against the templates that they both had made to vote. Even being careful, they each found an error in each other's ballot! Confirmation of selection is so important. Check it. One thing I did when the voting community was talking about paper audit trails was to test it against an audio verification. If you select "Smith" and it speaks "Schwarzenegger" you know you made a mistake without having to find a separate audit paper next to the ballot to read it. I did an experiment comparing paper confirmation and audio confirmations. We found 80 percent of people with audio could distinguish the difference and 15 percent of people with paper. This was a huge difference. And getting them to report an error was even worse. None of the 52 voters when using paper reported either of their two flipped votes, while several reported the flipped votes when auditing the selections with audio.

5% to 15% of paper audit trails on the electronic voting machines didn't print when they tried them in Ohio. Some of the ideas that people promote very heavily with even big funding weren't the big solutions people were hoping they would be. Most of the improvements to voting since 2000 came from more carefully administering registration, more carefully checking ballot design and its process, more carefully training and monitoring poll workers, and creating ways of carefully storing and auditing voting data.

Steinbach: The electronic voting machines?

Selker: The electronic voting machines actually were more of a solution than you would know. They helped by giving voters feedback as to what they had voted. And in many cases, they got the creating and administering of ballots to have much better oversight.

Steinbach: They could have everything. They could have the feedback and--

Selker: That's right, and in fact we have some good data about them and I hope this isn't a side story, but I'm going to say it anyway: In 2004, we got the data that said that in the states that did best with paper marking, close to one percent of people didn't succeed at voting for the top race. The places that used electronic used four different types of equipment; Sequoia in Nevada, Diebold in Maryland and Georgia, and a mixture of those and ES&S in Florida. None of them had more than 0.4% of people failing to make that selection. In all four states electronic voting was used statewide; the electronic voting machines reduced lost votes by over 0.5% compared to the best statewide use of paper ballots. The most improved: Georgia, which in 2000 had 3.2 percent of people go in and not select a President. That state reduced lost votes for President by a factor of 8 with electronic voting machines.

Steinbach: Every 30th voter wasn't counted in Georgia in 2000?

Selker: Yes, when 3.2% of voters don't select a candidate for President you have many problems that have to do with administration of the election. The change of technology was coupled with taking responsibility for all aspects of the election out of the hands of the local officials. Oversight was improved with hundreds of independent experts deployed to local polls. Ballots were being checked and finalized by the Election Center at Kennesaw State University. Georgia had gotten rid of several single agent problems in their voting process.

Going down to 0.4% not making selections was astonishing in 2004. The political scientists had never measured less than 1% and had rationalized 1% not selecting a president as protest voting: when people go into the booth and don't vote. Then suddenly in 2004 we have this tremendous change in states that give feedback for each selection you make, and then a big political movement stops that and we're back to voting on paper.

Steinbach: What do you mean? That it was nixed?

Selker: 27 states made it illegal to use electronic voting machines after 2004.

Selker: It was just a big political movement by a Cryptographic community that didn't have members that actually viewed the demonstrated problems. It was started by the brilliant and deeply respected security expert Peter Neumann and nice guy. But somehow he spent a few decades of his life trying to stop computers from being used in airplanes and banks. To be fair, Peter's concerns are important, but the way it played out cost the government a lot of the $3.9 billion set aside to improve election technology in ways that made technology that was immediately obsoleted.

Steinbach: I guess you'd have to prove that it's secure. Right?

Selker: I think you have to be able to solve the biggest problems you know about and continue looking for others as they come up. Elections are contests, the history of them is an arms war of getting people to vote as you would like, problems come up.

Steinbach: Yeah.

Selker: <laughs> So we look for fraud in various ways. I think that you use multiple methods and you make sure that no one can make mistakes. For example, the mistake that happened in Volusia County, Florida in 2000, where one person got rid of 16,022 votes on their back-end computer database. CNN caught it because they saw that votes had disappeared that had been reported minutes earlier. It was the continuous reporting of electronic records that tipped CNN off. Before, nobody had an electronic database and nobody could see what happened to these partial results. But, why is there any software in the world that lets a voting official remove votes? Why is it that this person wasn't caught, as it was someone with administrative privileges and was at the counting office? Could it be that we have no audit trail on who logged on to corrupt voting data? My frustration is I have not yet been successful at getting things like administering the back-end voting database to require multiple people. The voting community has not prioritized legislating these important Single Agent Independence issues. Again, nobody should be able to set up or change any voting system by themselves, right? There has to require another person to independently check that things are done right. Where using paper, where using electronics, where using anything, we have to have people supervising each other to have non-fraudulent elections. I worked hard on this and still have passion for improving voting. As I point out, policy is not yet solving the many problems it could. I was the co-director of the Caltech-MIT Voting Technology Project for many years. I organized and helped organize many workshops including election officials and federal election people and election companies, researchers, and pundits on these topics. I wanted voting improvement to be my public service to society. I thought that voting technology would be a cheap, useful thing that America could export that would help democracy. It has been more complex to create consensus and improve our voting technology than I ever imagined.

Steinbach: I hadn't thought of it like that.

Selker: Maybe the work had some positive effect. Less important is that I got the Scientific American Award for Public Policy. And the AAPD Thomas Paine award for improving voting.

Steinbach: Okay. Anything else from your MIT time that you have stuff to show?

Selker: Well—

Steinbach: Or was that all?

Selker: Oh, I have lots of things. I taught a class called Industrial Design Intelligence, and so I've always loved physical design. So I am showing you a bent plastic clip with a pin that I put on a DVD to let it be the name badge for a person at a meeting. It's just a simple example of something that kind of repurposes something and deepens its value. It was kind of neat to put the whole results of a conference on a disk and have that be the entrance badge.

Steinbach: That's your name tag.

Selker: Yes, and they came with red pins to pin to your clothing if you didn't have a pocket to hang them on. The red accent that I am proud of in the TrackPoint--

Steinbach: That is the TrackPoint. I was wondering.

Selker: The simplicity of using a piece of bent plastic to create a label from a badge was the point. I think what's really fun about design is how it can make value from what it does, not what it's made from. And so I spent a lot of time teaching students the value of thinking about the need for whatever you design to have a functional purpose, an aesthetic component, but base your design iteration and success evaluation. The thing that's interesting about aesthetics is aesthetics can be part of the message; that is, it teaches you what to do, how to do it, and it's a memory aid. It lets you understand what its value is, and in its being noticed reminds you that it exists. And then evaluation: historically, the human factors people test things that the engineers make and they don't know how to design from an engineering point of view, so they don't get taken seriously enough. The aesthetic people are looked down on by engineers because they are just making things more expensive. So I really try to teach that the more you can integrate the industrial designer, engineer, and human factors people into your head, the better you will see ways to improve design from several perspectives. Instead of the multidisciplinary approach of bringing experts in various things together, I am hoping to reach higher and get each person in the process to see multiple ideas from multiple perspectives. If you hold many ideas in your head and you let them compete, you can avoid getting so attached to an idea that you don't seriously question it. Another example of a simple kind of transformation is the FlyingMic ball that I've used in many conferences. You put the lavalier mic inside of this large foam ball and place the microphone sensor in a tube to let a person speak into it. You just toss the ball to somebody and they catch it. The facilitator can get the microphone anywhere in the auditorium in the second it takes to pass it. When I put up my hands, it naturally indicates to toss it back. So the really great thing about this is that it takes advantage of what people are used to doing with a ball. By watching the ball go towards the next person to speak, it gives everybody a second to know who will speak next. Then that person speaks into a microphone. So now instead of lining up people in the aisles to ask questions, what we have is a conversation that ping-pongs around a conference room. So that's the kind of thing I was trying to get people to design, things that are natural to use, functional, and hopefully aesthetic. I teach courses on how to design that kind of stuff. MIT also was a lovely place for me to take what I'd learned at IBM about creating a way of bringing innovation and business together. I brought lectures and workshops on design innovation to the National Research Lab of Taiwan. I tried to bring Industrial Design Intelligence to people as diverse as Mars Candy, Campbell Soup, Merloni Appliances, the US postal service, Motorola, Ford Motor company, Lear, IBM, LG, Samsung, Ricoh, Minolta, Google, Target, Steelcase, and lots of other interesting companies. I would work with them to try to create cultures of innovation and invention.

I was also proud to be one of the top producers of funding for the Media Lab for many years. I had a lot of fun and learned so much trying to get inside the heads of these different sponsors. But one of my biggest successes also, besides the students are always the great big success, is recognizing that all of those platforms, the smart car, the smart kitchen, the smart bed, all these smart things I've been telling you about, they succeeded when the computer's social feedback was appropriate for the user. And so even when you see this ball, this ball flying to you, it is making a social statement to you and others that you are being given a chance to speak This interest in social statement in communication motivated me to start a research project at the Carnegie Mellon Silicon Valley called Considerate Systems. Considerate Systems is thinking about what we can do to make social feedback succeed. I have a bunch of demonstrations now in research projects that show that if you have social feedback it can improve lots of kinds of interactions. So there's a book called "Peripheral Interaction" that I co-edited with Doris Hausen and Saskia Bakker that talks about the idea that maybe the most important thing about interfaces is that they not take your attention away from what you want to attend to. Interfaces have always presented themselves in the foreground. But now we are always using smart phones and computers in public, with people in the foreground. Interacting with smart phones is currently so distracting that it is the number one culprit for automobile accidents. It is critical that the computers start hanging back as much as possible, so as to distract you as little as possible until you need them to. So I have a bunch of examples of how to make human-computer interfaces that try to require attention only as necessary, to help meetings, driving, etc. I am on a rampage to get people to think about how to make computers deferent.

Steinbach: So I was going to ask you how would you define social feedback. Is that because there are multiple people and everybody sees who gets the microphone or--

Selker: Yes, as an example, the FlyingMic makes everyone aware of who will get the ball without making noise or anything. But social feedback can be anything that reminds you to be respectful of the person that you're communicating with, right? "Social feedback" is a much broader term than "considerate feedback." There are simple considerate things, like the 1930s' example of a door that opens when you go up to it with a basket of groceries. So we recognize that you need something, opening a door is a social statement already, and so we end up with these things working together. Or we can have an active social utterance just by saying "Welcome" to each person that comes in, often what a maître d' does, but if you look a little pale and they say, "Welcome. Would you like to sit down for a moment?" That's a much more difficult task. That interpretation of the person's condition, and a commitment to actually respond to their need that is not what you were planning for them. That requires sensing, a dynamic model of the user and an active agent to respond adaptively. We talk about considerate things that have a model of a social interaction, and as long as I have a model and I'm not inappropriate, I do better than without it. I'm very excited about that and it's something that I actively work on, still doing research projects in that area.

Steinbach: And so you've already mentioned Carnegie Mellon. That's after MIT, right or--

Selker: Yes.

Steinbach: I guess we're in the time after MIT now?

Selker: We are. We're in the time after MIT and we're in the time after Carnegie Mellon. At Carnegie Mellon, I helped put together the PhD program and I used to mentor the new research faculty. It was great fun building it up from zero to seven million dollars a year of funding. I organized over 150 speakers to come to CMU while I was a professor there. Now I consult. Well, I was in Perth, Australia, worked with Curtin University on lecturing and working with professors just last week, so I continue to work at different universities but I also do a lot of my own stuff. I've always been an inventor. I'm always building. My hands are always dirty. I guess I want to show you just for the fun of it a couple of things that I just did on my own.

Steinbach: Okay.

Selker: So one year I took off part of a year when I was in college to pretend I was going to be an individual inventor. I made a desk that you pedaled to light your book, and I made this, a rechargeable flashlight for a car. This was to plug into the dome of a car and be a rechargeable flashlight, but that was kind of a fun little project I did. Even earlier when I was in-- when I was a child my father showed me a machine that would spray plastic. He was working on nonwoven fabrics so I put my hand underneath this thing and I made a spun nonwoven polyethylene glove. It was very warm and I wanted to make a machine to make them, but this was when I was 13. I repurposed some things in this machine I tried to make. You'll see that there's a little bit of plastic still on this heating element - this one I made at home doesn't work very well, I didn't have enough pressure and didn't have as good as the nozzle as the one I worked with at the lab. But I dreamt of making clothing that you would just spray on yourself, but that-- I just didn't have organization enough to do it. Now by the way just this year there are several forays into that, companies that are actually thinking about how to spray-- how to sell something spray-on.

The most recent thing that I made this year is this, an ultrasonic sensor that goes around your leg-- so with your leg sitting in here—it makes a tomographic ultrasonic image of your limb. It is a simple robot with this computer. This is the working part; I just didn't want to bring the carriage track and vessel to put your limb in. The machine is a bucket you put your leg or arm into. This, if we had an USB cable hooked up to my laptop computer, we'd be running it right now to scan, to build a really good coherent image from ultrasound. I have a bunch of reasons for making this. It is simple. First of all, two years ago I made a shirt-folding machine. It was a 21-axis robot; you've probably heard about, FoldiMate. Very complicated. This year I made a pill-compounding machine with Daniel Kraft, it compounds up to 17 different medicinal spansule types. I wanted to make something simple this time. This is pretty much a one-axis robot, it just goes around your limb on a hoop carriage track, and what can it do? It turns out that, actually for a lot of purposes, ultrasound is better at soft imaging than MRIs. It's orders of magnitude cheaper. Ultrasound has been difficult for people to use because it takes years to learn how to hold it and find structures in the body. This takes that out of their hands. This makes 3D models of the structures. It's been difficult to use because the imaging doesn't go deep and by making a compound image, this can image up to 6 inches deep. I've got a better sensor from Interson, my fantastic partner, an ultrasound sensing company. So, I'm excited about that project and that's an example of something I'm hoping to make to make medicine cheaper and better

Steinbach: Now that's only a cross-section of where you are--

Selker: That's right and—

Steinbach: --so you have to kind of push your leg through to get the whole leg.

Selker: If you want to get the whole limb. This has 128 sensors and it can use multiple sensors to focus the measurement beam. The design is meant to look at a specific problem in an arm or leg. I might want to look at my Achilles tendon in my leg. I might want to look at tennis elbow or golfers' elbow in my arm, or carpal tunnel adhesions in my wrist. For these I only have to image part of a limb. I had an epicondylitis that was bad for 20 years but I didn't want to spend money on an MRI. When they finally did it, I only had 20 percent of my gripping tendon left. They did a little surgery here near my elbow. That's a very simple thing for something like this to identify. A lot of things that we don't actually get imaged could make us more aware of problems early on. It is battery operated and I envisioned that it could be possible to take it to a sports field. 23% of people that are sports field players will have some problem with their Achilles while they're playing sports and it'd be great to know whether it's ruptured or just sprained. It's also much faster than an MRI to make my Ultrascanguide image; just a minute or so. So that's my excitement. Maybe I shouldn't be talking about it too much yet but anybody that's interested in helping me with that, that's something I'm having fun with.

Steinbach: And for that you have your own company.

Selker: Yeah. I'm Selker Design Research so I'm always building prototypes. I've got lots of prototypes laying around, things that I'd love to take to market and sometimes do, but then I also consult for big companies, like at this moment Magic Leap and Sentient and little startups too.

Steinbach: Okay. I know you got lots of awards and things. How about you talk about a few that you are most proud of?

Selker: Well, that's really sweet of you to ask. Every celebration helps us feel good and whenever a student would come to me and tell me later in their career that I helped them earlier, I mean, oh my gosh, it makes me so happy. So it's been the statements from people whose careers I helped that have been my favorite affirmations. It's the personal things, like helping Joe Rutledge retrain himself from being an algebraist to working on this TrackPoint with me. I mean the ways in which he and his wife appreciated that and the impact we made and you just watch it in his steps moving him towards where he and I together got so many awards. I think career development is always my favorite reward. I was very honored to be named an IBM Fellow. At the time I did it there were 150 ever, now maybe it's more, maybe there's 200 something. That was really cool. It was cool because people treated me as though I could do something, and let me do things too. It's about how people treat each other that matters more than anything else. Yeah, I got access to so many opportunities to make things better through that. The Scientific American Award, I was very proud of that, as it came as a recognition that all I was doing in voting technology mattered to others.

Steinbach: For what was that?

Selker: That was a policy award around voting. It was a Scientific American 50 so that was a pretty exciting award. I also got something called the Thomas Paine Award for disabilities; it was given to me by a senator in the Russell Senate Building and that was a pretty cool thing to get when I was having some trouble feeling valued for the voting work. Did it change anything about my life? I got several other exciting things; the 2008 Tech Fest award. Best paper awards can be a lot of fun but, I think really the biggest reward was watching when millions of products that are helped by my work get used by people. So my PhD work, which is this AI system for help, it's in every OS/2 shipped, right. They still ship probably half a million of these a year. Do I ever hear anything about it? No. So, the impact of people noticing something that you did like the TrackPoint is a lot more fun than the adaptive help system that millions used in an operating system that was not as important as Unix, Windows. Macos or MVS. I often think that one of my biggest rewards is something like an interview, like this, where I get to tell a story to lots of people, in a public forum on radio or TV and stuff. I think that actually it's the things that matter to people; how much do these videos get watched and who wants to take the time to watch me for two hours? I hope this interview touches someone. <laughs> I think getting invited to be a professor at Stanford and MIT and CMU, I think those are incredible honors. And for all you just getting started, I actually think getting an undergraduate degree was probably the hardest degree I ever got. But my PhD was a lifelong achievement dream for my father as well as for me, and that kind of felt great even though maybe it was not the simplest way of helping the world. Might I have done better by not spending 12 years of my life chasing a PhD? Yeah, I was invited to help start many successful companies; I helped a bit but deferred for academic goals. I wanted to get the academic stamp of approval. Did anything change for me when I got my PhD? Well, it felt good and within months I had my first child and had the TrackPoint going to product. It was a very exciting time.

Steinbach: What would you think? Would you always think "I should have" if you hadn't? Right?

Selker: Yeah my dad always wanted to finish his PhD and didn't. It was a validation to do it. Furthermore, now I realize that when you talk to somebody that has a PhD you can often tell. The depth and rigor that is required-there's a lot to learn from it, but then sometimes you get rigor other ways. <laughs>

Steinbach: Okay. Well, thank you very much for the interview and since you're not done inventing maybe we'll have you back in ten or twenty years--

Selker: That will be a pleasure

Steinbach: Okay.

Selker: It's great of you, the gracious host, and I appreciate all the work you've put into this too.

END OF THE INTERVIEW

Appendix: URLs of videos about Ted Selker's work:

1. TrackPoint: https://www.youtube.com/watch?v=jHcrR6Pvy-w
2. COACH: https://www.youtube.com/watch?v=_Kgm_5bcU0o&t=2s
3. wrist rest: https://www.youtube.com/watch?v=VMCiY-HoXl4
4. power supply: https://www.youtube.com/watch?v=RKLVGiKVD_g
5. EyeR: https://www.youtube.com/watch?v=V630mSiauXw
6. vending machines: https://www.youtube.com/watch?v=FeSEvdBsV9k
7. Invision: https://www.youtube.com/watch?v=O7eyjC3xvKM
8. IBM: https://www.youtube.com/watch?v=xNoWk_hL0AA
9. RWAV: https://www.youtube.com/watch?v=HUXTnK7X2yI&t=4s
10. coffee table: https://www.youtube.com/watch?v=f2w4TNKwQEY
11. speakers: https://www.youtube.com/watch?v=eSJbjmZaAI4
12. Chrysler: https://www.youtube.com/watch?v=unLkItbTDAU&list=PLmySohKj-jR7mgFsFhkq0cJYMQrj21Dlw
13. Spoon: https://www.youtube.com/watch?v=25LFnmjruII
14. dish maker: https://www.youtube.com/watch?v=83JZtne1gg8
15. Bed: https://www.youtube.com/watch?v=uea7jzAwp9g
16. Kitchen: https://www.youtube.com/watch?v=uVEtBjb6AhE
17. USPS: https://www.youtube.com/watch?v=mLUP0fz2HzU&index=3&list=PLmySohKj-jR7mgFsFhkq0cJYMQrj21Dlw
18. concept vehicle on YouTube: https://www.youtube.com/watch?v=mLUP0fz2HzU&list=PLmySohKj-jR7mgFsFhkq0cJYMQrj21Dlw&index=3
19. FlyingMic: https://www.youtube.com/watch?v=Qhl8S-KRjPw&list=PLmySohKj-jR5iUz06MdPeU178ODcbTieY
20. FoldiMate: https://www.youtube.com/watch?v=BDAnhYSr1kI
21. Ultrascanguide: https://www.youtube.com/watch?v=iFAjUG0CTlk

