Oral History of Brent Townshend

Interviewed by:
Dag Spicer

Recorded May 25, 2022
Mountain View, CA

CHM Reference number: 2022.0080

Spicer: Hello, it's May 25th, 2022. We're here today with Dr. Brent Townshend who is a remarkable individual who's done a lot of very interesting things, touching upon areas related to computing and information technology as well as molecular biology and photography and music and all sorts of amazing things. So, Dr. Townshend, thanks so much for being with us today.

Townshend: Well, thank you for inviting me.

Spicer: I'd like to start with you as a youngster and start the story early on in your life and just sort of step through how things were for you as a youngster. What your parents did, what your early interests or hobbies were and how did you enjoy school? Those kind of things.

Townshend: Sure, sure, yeah. Go back a long way there. Yeah, so I was brought up in Toronto, born in Toronto, in Canada. And my-- I lived in the suburbs of Northwest Toronto. And my parents-- well, my father was a bricklayer, a chimney builder specifically. So, he had a little small company, himself and a helper basically, and they would go around and repair people's chimneys, because, you know, in Canada there's a lot of need for those chimneys and they fall apart pretty quickly. So, and actually even before that he was doing like a lot of different odd jobs. He was doing like bricklaying and doing oil delivery, fuel oil delivery. Driving a fuel oil truck and I think I remember some nights he would be on the night shift and some nights I would go with him. And go along to the drives and they had these big trucks that had these big cabs, so there would be like a bed in the back. So, then I'd end up falling asleep aft-- you know, by midnight or something and then wake up in the morning and get home at 6:00 a.m. or something.

Spicer: Oh, my goodness. Where did your dad and your mom come from? What is their origin originally?

Townshend: So, they both were born in Toronto. My mother's father immigrated from England in like 1910 or something like that. So, he was born in 1904, I think. And so, he came over with his family. On my father's side, it was maybe another generation. Yeah, my great-grandfather immigrated. Maybe in the late 19th Century-- also from England. So, they're both-- you know, a little bit of family tree to look up. I went back to the town that my-- on my father's side that they were originally from and everything and there were still some other Townshends that were in that small town and everything.

Spicer: What town was that?

Townshend: It’s called Woodbastwick in Norfolk.

Spicer: Oh, interesting. Wow.

Townshend: And because my Aunt had started doing these family tree things so it got me sort of interested. So Iwent up to investigate that a little bit. So, that was fun.

Spicer: So, tell us about your staying up all night in your dad's fuel oil truck and what kind of things did you learn from that besides just perseverance? <laughs>

Townshend: Yeah, perseverance. It was something different from the day-- you know, it was not that frequent. Maybe did it maybe a dozen times total or something.

Spicer: Now would this be in the winter, mainly?

Townshend: Yes. Yeah. It would be obviously for fuel oil delivery -- that's a big thing. And you know they had these big refinery plants. You'd be in the truck and drive to the refinery thing, refuel everything up like there. Which is really cool for a little kid to see all the lights and the--

Spicer: See pipes.

Townshend: -- and the pipes and the connections and everything. And so, that was the most fun part. And then to get out and start delivering fuel oil and then fall asleep <laughs> and wake up later.

Spicer: How was school for you? Did you enjoy school?

Townshend: Yeah, that was interesting. I did enjoy school, but I didn't go very much.

Spicer: <laughs> Maybe that's why you enjoyed it! .

Townshend: Well, actually I think it is. I think in many ways that's actually accurate. So, you know, for a long time I was an only child. My sister was born when I was ten. And my mother, you know, she wasn't working-- well, she was working when I was very young, but then she stopped working and was just at home. And so, she was-- she liked having me around. So, often in the morning, I'd wake up and she'd say, "Oh, you sure you want to go to school today?" <laughs> "We could go to the mall or something, or we could go out and do something." "Oh, okay." So, I would end up not going to school maybe two or three days a week. I would just go like sporadically-- well, maybe more than that-- three or four days a week I would go to school, and the other days I would just do other things. And that was carried on through elementary school and part of junior high school. But then I think a lot of…why I said it being accurate about liking school, by the time it was going to be high school, a lot of the kids were sort of fatigued of school. They weren't really that interested. They weren't-- almost like burnout even.

Spicer: Yeah.

Townshend: Whereas, I hadn't been going that much so it was all sort of like interesting. I was, "Oh, yeah, I like this stuff." And so, I stopped-- so on my own motivation, I really wanted to go to school much more and everything and do stuff.

Spicer: For high school.

Townshend: For high school. By the time I got to high school, I was really engaged and really interested and everything.

Spicer: Right, when did your interest in science and things technical begin?

Townshend: During high school, I think primarily. There was a really nice program at the high school that I went to that was a collaboration between the Ontario Science Center and different high schools. And so once a week some of the kids would go to the Science Center and they would take these classes from the different staff at the Science Center. So, it was a really nice outreach program from the Science Center that's like the Science and Technology Museum of Toronto or of Ontario.

Spicer: Yes.

Townshend: And then it was a great motivator for having fun and doing things. You know, because I remember they had this old Teletype machine. There was one session showing us how, "Oh, here's how you program this. Here's the ticker tape, you know, paper tape that you can punch out and make things and do things like that. There was also a lot of some bio things. There was all different domains of science. So, it was quite interesting to do that and to have that ability.

Spicer: You know, the Ontario Science Center, which I hung out a lot in, too, actually established a world model for science centers. It was considered almost the best of its kind.

Townshend: Right, it was quite good. It was quite beautiful.

Spicer: You were very lucky to be there in Toronto. <laughter> And have advantage, to be able to take advantage of that, yeah.

Townshend: Yeah, yeah, and that was-- I realized after all of that was not like what most people got to do. It was really an opportunity that came up randomly and--

Spicer: And it's so interesting to hear you say that one of the big sparks for your interests, being a museum person…

Townshend: Exactly.

Spicer: That really gets people going and jazzed up, so that's great. Well, anyway, tell us about high school. Did you-- were you in any clubs or [did you have] any special hobbies or projects?

Townshend: I did a lot of reading, so I was really into science fiction and read-- so I was reading a lot of-- spending a lot of time sort of-- I think I'm primarily an introvert, so now that I can categorize people, or categorize myself at least, you know, based on what gives you energy and what doesn't. I feel that when I'm on my own and just studying things, that's when I gain energy and everything. But the-- you know, other than that, you know, it was like-- I don't really remember what clubs there were. I wasn't really into sports. I was not doing much athletics. And the school was a pretty academic school. So, it wasn't--

Spicer: What school was that?

Townshend: William Lyon Mackenzie.

Spicer: Oh, yeah.

Townshend: Yeah, high school, so.

Spicer: Okay, yeah. Favorite subjects? I'm guessing physics, chemistry? And that sort of thing. <laughs>

Townshend: Yeah, chemistry, I had a really interesting chemistry professor. What was his name now, I can't remember. Oh, Peddle [ph?], Dr. Peddle. So, he was actually a PhD. Which is unusual, I think, to have a chemistry teacher in high school with a PhD, who had worked in industry and just was sort of like, "I don't want to be in this rat race," and teach high school. But he was very opinionated and sarcastic but very good, and a very good teacher.

Spicer: Yes.

Townshend: And the same on the math side, you know, like the calculus teacher was a very, brilliant teacher and everything. You know? So, I think those were the ones that stood out to me. French classes. I took all the time and never learned any French until much later when I met my wife. So <laughs>, that didn't stick very well at least in the first round.

Spicer: Yeah.

Townshend: Yeah.

Spicer: You mentioned science fiction, so can you name a couple of authors that you particularly--

Townshend: Well, Asimov at the time was just like an amazing thing and still is, and Bradbury. These are the classics when we think of all the science fiction literature was really the thing I was going for and everything.

Spicer: Asimov had this wonderful-- you know, so many of his 600 books <laughs>, were about teaching people science, or the history of science … apart from his sci-fi stories, like the robotics and all that, he contributed to the public understanding of science in a huge way. And that, I think, is very underrated.

Townshend: Sure, yeah. It makes it much more accessible and much more, you know, gives you the science without having to feel like you're reading a textbook, but it makes it really interesting. His writing is amazing.

Spicer: So, through high school, did you have dreams of university or what was your horizon like?

Townshend: Oh, not really. You know, my family-- so all of my ancestors, nobody had gone to college. And including actually even at my generation, so I had-- my father had 12 siblings, so it was a large family. I had 27, I think, 27 first cousins. So, but none-- I was the only one I believe that went to college of all that, that entire group. So, it was not sort of a standard thing to do. And I think part of it came from that high school. Because the high school-- a neighbor of mine who was like a year older, had gone there. And he told me-- and we hung out a lot, and he told me, "Oh, you should transfer and go to this high school," because it wasn't in our neighborhood. It was in an adjacent area. And it was-- I think it was his push to me that, "Okay, well, I'll go there." I mean, we had to take the bus every day to go across-- you know, it wasn't that far, like five miles away or something. But it's not like going to the other end of the city. But that high school was 90 percent college driven going into-- it was very focused in making. You know, and obviously the quality of the teachers and the--

Spicer: So, when did things click for you? I guess at the time Ontario had a Grade 13. It had five years of high school.

Townshend: Yes.

Spicer: And at what point did you sort of think, "Hm, maybe university would be a lot of fun"?

Townshend: Yeah, I think it was-- well, I mean, so you're right, it has Grade thir-- or did-- I don't think it still does anymore.

Spicer: No.

Townshend: But and it was pretty much if you weren't going to go to college, you're going to finish at Grade 12. And people that were going to go to college would do Grade 13. So, it was sort of by Grade 11, Grade 12, you sort of had to make a decision if you're going to follow the track or whatever. And if I recall correctly. You know, I mean, I've talked to so many other students and other people. Now sometimes it's hard to remember what actually happened to me versus what happened to other people. But the-- definitely by the time I was in Grade 11/Grade 12, I was pretty interested in engineering. Engineering, specifically; science in general; science, math, that was clearly what was motivating me. And so, I was pretty set on going to college. I was-- it was kind of much different I think than the college application process that goes on in the US or especially that goes on now. It's not a matter of doing all these college apps and doing everything. It was just a matter of saying, "Oh, okay, I guess I'll go to college." So, you filled out the one-page form and sent it away, and obviously, you're going to the University of Toronto, because that's the closest university. So, it's like it's almost default. And both from the point of view of admissions, it's just like, "Oh, did you have these grades in these classes? Okay, then you're in." No essays, nothing like that. So, a much simpler process and also much cheaper, like $600 a year, I think it was. Or $650 a year for--

Spicer: Yeah, you could work during the summer and pay your tuition.

Townshend: Easily. Yeah.

Spicer: So, tell us, when you mentioned you had an interest in engineering, was it electrical at that point, or some other kind of engineering?

Townshend: Well, I wasn't really sure. I mean, I really liked pure science, physics and math and chemistry. But I also saw that engineering seemed like the practical application of it. I was very interested in the theory and everything, but not without actual application. So, I wanted to make sure that I was doing something that I can turn it around and make something with it. So, engineering was clearly the draw there for doing that. But I wasn't really sure what kind of engineering. You know, the nice thing was that university of Toronto had a program called Engineering Physics-- Engineering Science, actually they called at the time. But it's really a broad engineering program that you're covering everything. You do two years of the Engineering Science general curriculum that everybody's in, and then the last two years you specialize in one particular domain. So, not only that, a little bit broader than doing a specific electrical or chemical or whatever engineering, but also it delays the decision point, too. So, basically I signed up for Engineering Science, got into Engineering Science and was doing that and then you could defer any further decision. The decision I made later was to do nuclear power. And so, actually I started off in the third year and working in the nuclear power sub-domain of the Engineering Science program and working on-- they have little mini-- small reactor in the basement there. Start to work on--

Spicer: Oh! What building was that at UT?

Townshend: Oh, yeah, that's hard to know.

Spicer: Or maybe that's not a fair question. <laughs> That's asking quite a lot. But were you in-- were you thinking of a career in that?

Townshend: That's what I was thinking, yeah.

Spicer: Like Chalk River or something like that?

Townshend: Yeah, because at the time, you know, the Canadian programs for nuclear power were really going very well. The CANDU reactor, which originated in Canada obviously, was getting worldwide acquai--

Spicer: Yeah, Canada sold one to India, I remember.

Townshend: Yeah, so there was a lot of interest there, and it seemed like a great career and it was combining, you know, physics and some math and science. In many ways, it seemed like, "Oh, this would be perfect." Though once I was in that area, probably-- I don't remember exactly when, but sometime during the third year and before the beginning of fourth year, I got more interested in the computational side and the electrical engineering side. So, then by the time I was in the fourth year, I'd switched over to the electrical engineering tract.

Spicer: Oh.

Townshend: And stayed in that sort of domain for a while.

Spicer: Yeah. Oh, I remember Engineering Science was-- you know, engineering was considered a very-- I have a couple of friends who've done both an EE and an MD, and tell me they’re basically equivalent in difficulty, but the Engineering Science people are like a whole other level beyond. So, kudos for surviving that and flourishing, I'm sure. <laughs>

Townshend: It was exactly a survival thing because the admissions was actually not that hard. So, they would admit--

Spicer: But it was a very challenging program.

Townshend: Yeah, they would admit a hundred and-- at that time they were admitting a hundred and eighty students per year. And they would fail out 120 of them by the second year.

Spicer: Oh, my.

Townshend: So, it was-- and fortunately there was a track, you know, you'd just go into one of the other engineering things directly, but it was really-- the idea was let everybody in and then see who survives.

Spicer: Yeah. And their emphasis is on theory. Would that be fair enough to say?

Townshend: Yes, there are a lot of classes in like quantum mechanics and physics and chemistry and then math, obviously, a lot of math.

Spicer: A lot of times in engineering there's a senior project. Did you have one at the time?

Townshend: Yeah, actually that's interesting. Actually, I'd forgotten all about that and just like this week when I was just looking through as you suggested… looking at some old papers to see which jogged my memory. I found my bachelor's thesis. And I'd forgotten all about this, but it was actually on doing what I was calling at the time and what was called videotext, which was basically building … I built a graphics terminal that would allow you to use it at home to receive data and get like video text, basically. Navigable information. You know, like the news, and then click on the weather and do that kind of thing.

Spicer: Right.

Townshend: So, it was really, effectively, an HTML browser before HTML existed. But not just-- it was both the software side and also the hardware side. So, I actually built all the circuit boards and built the video drivers.

Spicer: Now was this an encoder? Is that fair to say? Or--

Townshend: It was, I guess, more like a decoder. So, it was the client end. And so, the end that would go in somebody's home. So, there was already a commercial videotext service that was being piloted by Bell Canada to do this.

Spicer: Was that Telidon?

Townshend: Telidon, exactly. Telidon.

Spicer: And it used it an NAPLPS protocol.

Townshend: Yes, exactly, NAPLPS. Oh, yeah, yeah, that's right. I hadn't thought of that word in a long time. So, the Bell Canada had this Telidon project which was using this semi-standardized protocol for that. And so, what I did is I built a home terminal that would interface with that same network and everything.

Spicer: Yeah. Yeah, Telidon and their various-- the British [Prestel] and Germans [Bildschirmtext] and the French with the Minitel. **Was that really a teletext system…**

Townshend: At the time they were calling it a videotex, but it wasn't really-- it was no video involved, so it was more like still imagery and everything that was--

Spicer: But you're right. There's a great quote by William Gibson, fellow Canadian, that I like to use, "The future is already here, it's just not evenly distributed."

Townshend: Right, right.

Spicer: You know, where you see these glimpses of the future like the Telidon and you know, and it's, ah, just not quite there yet.

Townshend: Didn't quite catch on, yeah.

Spicer: You're going to have to wait, or maybe it'll just peter out and--

Townshend: Right, because even like those things like in the late '90s, there was like widespread use of these Ricochet modems and everything and so you basically go anywhere and have internet connectivity-- well, not really internet connection, but data connections to the internet, but and then it all went away. And it was another ten years before there was actually the widespread 4-- 3G or--

Spicer: I remember Stanford had a little Ricochet units all over campus in the mid-1990s. So, you've got your Bachelor of Applied Science. And what's your next step? Did you do more schooling or did you--

Townshend: Yes.

Spicer: Yeah.

Townshend: Went straight there. You know, all through, while I was at the University of Toronto, I was working summers and part-time. I was working for my dad actually. So, you know, I'd mentioned before that he was doing this chimney building. So, after the oil delivery and working for other people, he started his own small business and was doing-- repairing chimneys and everything. And it turned out-- he was from a long line of chimney builders. His father was doing that, his grandfather was doing that, and his great-grandfather was doing that in England. So, they were all in that line. And a lot of his brothers had gone into the same business as well. Since they all-- that's what they all knew. So, for a long time I was sort of in the tract of just carrying on the family business and everything. And then by the time I was starting to go college, it was getting more dubious that I was actually going to follow that route.

Spicer: Now what does that mean? You were actually in the summers building chimneys?

Townshend: Building chimneys, carrying bricks, mixing mortar, doing bricklaying and everything. So, it was a more manual experience than anything. Which was fun, too. Actually, I really enjoyed going that.

Spicer: Yeah, kind of motivates you to stay in school <laughs> maybe.

Townshend: Well, yeah, that too.

Spicer: You know, like, "Wow this is hard work."

Townshend: It's actually okay. My dad would always tell me, you know, he said, "You know, practically you want to be able to make as much money in life as a tradesman makes. But not get dirty."

Spicer: Right. <laughter>

Townshend: So, if you can do that, then you're successful. If you can-- yeah, so.

Spicer: Oh, nice. So, I think the next step was Stanford? Is that correct?

Townshend: Yes, so then I applied to Stanford. I applied to a few places. I think I applied to MIT, Caltech, and Stanford. Didn't get into MIT. I got into Caltech and Stanford. But I'd never seen any of these places because you have to also understand at that time, when you're doing a college search for things or something, first of all there's no internet, so you're not getting much information. You get these books and help you think about things. So, it's a very limited amount of information. And you know, I wasn't flying around anywhere. I'd never-- I'd done one flight.

Spicer: You were 22 years old?

Townshend: Yeah, I'd gone on one trip before outside of Ontario, so I was not--

Spicer: Oh, wow.

Townshend: I was not--

Spicer: Where was that to?

Townshend: That was my uncle was from Ireland. So, when I was like ten, he took me to Ireland for-- and we spent a month there. But that was the only trip I had taken outside. So, in doing the college application process, it's not a matter of, you know, doing the visits or anything else. It was like, "Okay, here's two pages about this one and this one and this one. These seem like the good science schools, so I'll apply there." So, I got into Stanford. And then before starting drove out there. And when I drove out that was the first time I saw it.

Spicer: And what were your first impressions?

Townshend: The first impression was, "This is not at all what I expected." I expected high tech, you know? I expected like modern, sort of, you know, the kind of futuristic sort of environment. And I get there and it's all, you know, low Spanish architecture and everything with tiled roofs and you know, and stone. So, it's like, "This does not look at all like my anticipation of what this is."

Spicer: Your first drive down Palm Drive, what was that like?

Townshend: Yeah, that was like, "This is great."

Spicer: It's pretty incredible.

Townshend: It was beautiful but it's like also not at all like, "Where is all the high tech? Is it hiding it somewhere?"

Townshend: Yeah. Because you know, both California from the point of view of buildings being lower versus Toronto where you sort of associate tall buildings with technology and even the campus-- the university campus is all tall buildings. And so, it's--

Spicer: And there's no basements here either. <laughs>

Townshend: And there's no basements, yeah, exactly, so.

Spicer: So, garages is where everything has to be invented, right? <laughs>

Townshend: Right.

Spicer: Anyway, yeah.

Townshend: So, it was a very different impression right from the beginning. But the classes were great. Actually, I applied for a masters. At that time the way Stanford worked is you didn't-- at least in Electrical Engineering, you didn't apply for a PhD directly. You applied for a masters. And also, I don't recall, but I think I was probably only planning on doing a masters at the time. So, but then during the masters year, you can do qualifying exams and whoever passed the qualifying exam gets admitted to the PhD program as well. And it's only one year. It's a one-year masters. I didn't have any financial aid, so it took a lot of savings. It took all the summer from before I—you know, summers, before saving up. When I came to Stanford, I-- you know, you sort of cashier there <laughs> to pay for the first tuition. So, I had enough money for one quarter. So, I paid for the first quarter and the plan was, you know, I'd read about things, you can get research assistantships from profs and everything, from the labs. So, then it was a scramble from that first of September until December to find a lab to do-- to get funded for the rest of the program and everything.

Spicer: And that is so difficult when you're busy just trying to keep your grades up to be worried about funding.

Townshend: Yeah.

Spicer: Oh, my gosh, that's--

Townshend: But I actually now-- now that I think about it, back up. I only had to pay partial because I had a Canadian Government National-- it's NSERC.

Spicer: A little subsidy?

Townshend: National Science and Engineering Research Council. So, that partially funded. But it was sort of-- the funding for that was based on the Canadian model which is, you know, "Oh, we're going to give you enough money to pay for your graduate school," which was like one-fifth of the cost of Stanford Graduate School. So, yeah, so it was a big gap between the two. But there was funding there from that..

Spicer: What was your masters project and paper?

Townshend: So, there was no actually-- Stanford did-- I don't know if it still is, and it was coursework only. There was no thesis for the masters.

Spicer: Now did the coursework lay the ground for the audio processing? The speech, the hearing work that you did later? Or is that really the PhD that--

Townshend: Well, I actually changed because I was doing-- now, at this point, I'd built the thing, the videotex thing, and I was really interested in sort of building circuits and building things. So, I ended up very focused on VLSI and chip design when I started Stanford. And that's actually where I got the research assistantship with John Hennessy with his MIPS project at the time.

Spicer: Oh, okay.

Townshend: So--

Spicer: Tell us a bit about that.

Townshend: Yeah, so, I mean, that was just the beginning of when they were doing reduced instruction set computing. So, John had built quite a formidable group at Stanford to do the-- and he was still just-- he was "just a prof." <laughs>

Spicer: Right, not President yet.

Townshend: Not President and hadn't started MIPS and hadn't done-- so it was all, as faculty he was developing the reduced instruction set computing. And so, I went with his group and everything and started working on logic arrays and doing optimization of logic arrays with him. So, that got me through until I started the PhD. And I started my PhD with working in his lab. But it was also interesting because I think maybe it was probably my mistake is I ended up picking a project with him with this logic array optimization, which was very focused. It was sort of a one-person project of a subset of a much bigger sort of thing. But I was really working on that small thing. So, it was I really felt that I was working isolated from everyone-- it was not a collaborative-- it didn't feel like a collaborative project, because I wasn't touching all the other pieces of things. I was just focused on this. And so, it was not-- so I could work at home, it was great. I could do a lot of stuff there, but I wasn't really feeling part of a bigger team.

Spicer: Yeah, so you had like a-- you felt a need to connect with people a bit more.

Townshend: Yeah, especially on-- you know, when you're building-- you know, a lot of times you're building something you really-- it's great to bounce ideas off other people to get their feedback on them and also to get-- and also to feel like you're delivering something to them that they appreciate, too. And so, and I think that the project, although it was an interesting project, because it was-- and it was also very apropos because it was needed for doing one element of the whole chip design part of thing, it wasn't really something that I was really happy with.

Spicer: Right, it was part of the tool chain, right?

Townshend: Part of the tool chain. Yeah.

Spicer: For a, like you say, this VLSI overall. You know, this high-level design process.

Townshend: Exactly, right, yeah. Is how do you make these particular subsets smaller and how do you optimize the layout of those things and how do you optimize the structure?

Spicer: Was John Mashey involved? Do you know him?

Townshend: The name sounds really familiar, but I don't--

Spicer: Oh, okay, he was at MIPS, too. Yeah.

Townshend: Okay.

Spicer: Yeah, yeah, and SGI.

Townshend: Yeah, yeah, yeah. So, I switched anyways. I switched research projects part way through to another one that was being run by Robert White. And so, that was the cochlear implant project. So, this was my first taste of something on the biomedical side. I was really involved in the signal processing. So, the project-- let's back up-- the project was really to create cochlear implants for profoundly deaf patients. And Stanford had pioneered that technology in the late '60s or early '70s. They had done the first cochlear implant. Just a single electrode in a patient that was profoundly deaf to give them back some sense of sound. At that time it was really focused on just environmental sounds, so if you're stepping out off the curb and a car honks, you know something's happening, or something like that. So.

Spicer: Help safety.

Townshend: Help safety and also helps -- even if you're a good lip reader, if somebody's here and talking, you don't know that they're there talking, so you have to look. So, there's a lot of environmental cues that are missing if you're profoundly deaf that you, even though it's very crude implant can help with. So, the project that I joined then was expanding that further to create cochlear implants that would help actually with speech comprehension and would also give the environmental aspect for those but also trying either improve lip reading ability, or actually allow people to speak without any lip-reading or hear without lip-reading.

So, the nice thing about that project and what really drew me to it, was it was a team. Right? So, it built a team of people that was like a psycho-physics person from the psychology department that was the people that were working on the electrodes, you know, actually building platinum electrodes -- or whatever they were. I'm not sure what material it was now, but some biocompatible things. There was the medical team that was actually doing surgical implants and everything that was putting these in. And then there was the computational side, which is really what I was focused on: "Okay, now that you have electrodes, what patterns of stimulation do you apply to the electrodes to give sound? And how does that map to what people perceive?"

Spicer: Can you explain-- I noticed in your CV, the word "percept." Because I think it's relevant to this discussion.

Townshend: Percept, yeah. Yeah, and so a lot of it, I mean, at once-- well, you could say, "This is just a computation of how do we get from here to there?" the problem is the only way we have of measuring what comes out the other end is what somebody reports.

Spicer: Yeah.

Townshend: Okay? So, the percept or the perception of the sound. So, how do you take these, you know, very qualitative comments and everything and convert them into some numerical model which you can say, "Okay, now we have to apply this particular pattern to give this particular sound." There's a big gap there. And that's why psychophysics and psychoacoustics is really important. It's to say, "What is the percept that we're providing there?"

So, we did a lot of work in designing experiments that would sort of quantify those things. For example, figuring out just noticeable differences. I give you two different sounds and the person is supposed to decide, you know, by pushing a button if they're the same sounds or different. And then you can sometimes give them exactly the same thing. You can sometimes give them different things. You can change them slightly. And change them in different ways. You could change the amplitude. You could change the frequency of this. You can change the pattern that you're doing in time. So, and then by getting, collecting a lot of that data, sitting with the things and running these scrims over and over again, you start to build a model of what are the factors that are changing? How sensitive is the hearing to that? The percept to that? And so, on like that.

Spicer: So, the man in the loop so to speak is critical to the whole process.

Towmnshend: So we had three regular patients… three people that had the same implant in them. And one day a week, you know, each-- you know, Tuesday, Wednesday, Thursday, we'd have-- one of them would be in for like four or five hours, into our lab. And then we would sit down and they'd be designing experiments on a-- running all these things on a DEC PDP-11 in the basement with gigantic disk drives. You know, I appreciate that from the Computer History Museum, all the-- the hardware at the time was not as compact as it is now.

Spicer: Yeah.

Townshend: I think we had a washing machine-sized disk drive. It was 20 megabytes of storage or something. But anyway, the setup was to have these computer things that are generating patterns and then having the person push buttons or report things about them that was then all stored away and then we could analyze that and figure out the things.

Spicer: Were these-- I don't know, I don't want to get too far afield, but where these people deaf from birth? Or--

Townshend: It depends-- I think of that group there was one that was deaf from birth, and the other two were not. The problem-- I mean, the problem with people who are deaf from birth is that they don't have any reference frame to explain what they're hearing. With somebody [who] was recently deaf, you give them this, they can say, "Oh, well, that's a very high-pitched sound. That's a very low-pitched sound. That's a rough sound," or something. Whereas somebody who's deaf from birth has no way of categorizing those things.

Spicer: You know, I have this image of-- I don't think this is quite the way it worked, because you guys were-- but I think of like sliders that you had able to adjust. And the ultimate would be to have the actual deaf person adjust the sliders themselves until they heard something--

Townshend: Something. Yeah, yeah.

Spicer: -- that made sense.

Townshend: That would, yeah.

Spicer: But maybe the technology didn't support it at the time.

Townshend: Well, it's no so much the techno-- I mean, you're talking about something-- the individual patterns and everything are only giving one tiny element of a piece of sound. It's not like you're getting something that's speech or user--

Spicer: I'm oversimplifying, yeah.

Townshend: So, all you're doing is getting-- okay, if I set it like this, I hear something that goes "eee-eee-eee," or something. Or I hear something that does that. But it's really-- you have to do a lot of those experiments to figure out how to build up that vocabulary of tiny elements of sound before you can then start putting them together. And I think that's beyond the capability of somebody to actually mix together with the slide controls.

Spicer: Yeah. How complex were the waveforms you were presenting them with?

Townshend: Oh, they were pretty complex.

Spicer: Were they actual words, or just frequencies, tones.

Townshend: No, through just tones—patterns, I would say.

Spicer: Yeah.

Townshend: That would give different sounds. I mean, we would still map, I mean, after we would do this we would postulate a program – a mapping -- that would take audio and convert it into something similar to what they're hearing. And we were doing that independently of the psychoacoustic side. So, you'd take the psychoacoustic data and you'd say, "Okay, given all that, we should map these frequencies to these particular things." And then we would code that and give it to them and they would then use that like that. And they would try it out and they would report back, "Okay, well, that just sounded really noisy, or sounded really terrible," or sometimes it was like, "Oh, that was-- like I could read lips better there with that or I could do something."

I remember there were three patients that we had and one was the star patient, Linda, who was an amazing lip reader. She was like-- she worked at-- I think she might have worked at Intel as a like administrative position and everything. And there were people that didn't know that she was deaf. Because she could just read lips perfectly. And all the experiments she was getting really good information from it. It was like this was like this was how we wanted the thing to work because she could-- you know, we could give patterns and she could distinguish them super well. She could do everything. And in testing it would benefit her the most. She could… it would… even though she was already really good, you know, you could create noisy situations… you could create like obscuring the person that's been lip-read or they could be turning or they could have a big beard. And this would improve her ability significantly to have this on. Anecdotally, she reports she never used it. She said it was much too noisy at work, and things like that. It was just like, "I just like--," she'd say, "I like it silent. I don't like all that stuff."

Spicer: Oh, yeah. Almost like the hearing aid problem in which wearers complain, "I'm hearing too much."

Townshend: Whereas on the other end-- yeah, exactly. It's too much. On the other end we had this other patient, Ray, and he got-- you know, you can do all the experiments. He got zero benefit from it. It was not able to-- it was not giving him anything. He loved it! He would be reporting anecdotally, "This has changed his life. He's so much happier with this. It's so much-- and we could see from the experiments that it was doing--

Spicer: The data wasn't doing--

Townshend: It wasn't-- it's not really helping you at all. But percept--

Spicer: Placebo effect, yeah. Well, that's fascinating. Tell us more about your role on that project. Like you were on the DSP side you mentioned.

Townshend: Yeah, I was working in signal processing. I was designing psychoacoustic experiments in conjunction with the psychoacousticians, spending lot of time with the patients, as well in running the experiments or testing out the hypothesis and trying to do them. But then also on the signal processing side, to take acoustic waveforms from microphones and then convert them into patterns of electrodes. My PhD thesis was based on the following problem: the problem with the electrode that you're sticking them in the inner ear, the cochlea, which is this fluid filled spiral chamber and there's effectively around 30,000 neurons that are there. And they're spatially organized by pitch. So, one end responds to very high-pitched sounds and one end responds to very low-pitched ones. Ideally, you'd want to be able to turn on each neuron independently. But we're coming in with a very coarse set of electrodes, eight electrodes. But even worse is that it's all fluid-filled, so it's all conductive. So, you stimulate the first electrode and you're creating a pattern of current down the entire length.

Spicer: Like a wavefront.

Townshend: A wavefront of that.

Spicer: Yeah.

Townshend: So, what I worked on is saying, "Okay, if we want to stimulate one area in the middle, yes, we turn on that electrode, but we also put negative current on the pattern around it. So, basically beamform inside the cochlea to create a focus. But we had to do beamforming in a way without having any actual quantitative measurements inside. So, it's all based on reports of what people are hearing. So, you could just basically push and pull on two things and get it to the point where the person couldn't tell the difference of whether you turned it on or not. And then the trick was then to take that reports of this plus/minus exactly here adds up to zero and say, "Okay, that's how much these things are interacting with each other." So, my PhD thesis was really on how to do that measurement of all these different spreading and then deconvolve that so that you could get really sharp narrow peaks of the stimulation.

Spicer: a lot of Stanford PhDs go and start a company based on their dissertation research. Was that your path? What was your next step there?

Townshend: Yeah, no, I don't know what was completely in my mind at the time but I didn't really consider, I don't think at the time starting a company. I was pretty set on the research path. I was looking at the possibility of faculty things, but primarily I was looking at industrial research, so my post PhD sort of job hunt really was SRI; Bell Labs in New Jersey; and IBM in Upstate New York; and Bolt, Beranek and Newman doing speech recognition research in Boston.

Spicer: Great! Those are all leading centers of that sort of industrial research.

Townshend: Industrial research.

Spicer: Yeah.

Townshend: So, I interviewed at those places and talked to different people and everything and I ended up choosing Bell Labs at that time.

Spicer: They are, yes, I mean <laughs>, of that list, I would say they're almost the best place for psychoacoustics … they've got a century long tradition--

Townshend: Exactly!

Spicer: -- of dealing with audio processing and understanding speech and intelligibility and all that stuff.

Townshend: Yeah, no, there was a really strong research team there. As you said there was a lot of history in doing-- understanding hearing. There was some of the textbooks that we used in understanding perception of sound and everything were written by Bell Labs people.

Spicer: Was Licklider one of those guys…?

Townshend: I believe… uh, I'm not sure now.

Spicer: No, okay, yeah.

Townshend: My name memory is not the greatest.

Spicer: No, that's fine. I just thought you might know him. Yeah, yeah. Okay, yeah, so Bell Labs, that's a fantastic assignment! Tell us about that.

Townshend: Yeah, so I mean, it was really exciting. I mean, first it was a move to the New York area. New Jersey/New York, which was-- I'd never lived there. I never really--

Spicer: But being Canadian you were used to the winters.

Townshend: Yes, the winters were not an issue. It was leaving California was more of an issue. But at the time, it was like, you know, next step. Try something else. Go somewhere else.

Spicer: Yes, yes. And it's a real world-center of that, so.

Townshend: Yeah.

Spicer: Yeah.

Townshend: And meanwhile I also had met who is currently my wife. So, we met there at Stanford during our PhDs. She was doing her PhD.

Spicer: Oh! Tell us about that a little bit!

Townshend: Yeah, so she was doing—she was also Canadian, from Montreal. So when she left Quebec her father told her, "Don't come back with an American," primarily because, you know, people—

Spicer: That's a good Quebec attitude. I like it.

Townshend: Yeah.

<laughter>

Townshend: People lose their child to the—

Spicer: Oh, okay.

Townshend: --to <inaudible 00:44:14>.

Spicer: That's right. Yeah. Yeah.

Townshend: Of course, he never said, "Don't come back with an English Canadian," because that, everyone understood, was absolutely forbidden, you know. That was much worse than an American.

Spicer: It's already understood. Yeah.

Townshend: Yeah.

Spicer: Oh, my gosh, that's funny.

Townshend: You know, the whole tension between English and French Canada's right there at that border, but anyways, we met there at Stanford. She was doing her PhD in structural engineering for earthquake resistance, so she was basically working on developing methods and tools for designing earthquake resistant or earthquake handling buildings and everything.

Spicer: Very good. The right part of the country to be studying that.

Townshend: Yes. Yeah.

Spicer: Right. I'm sorry. I just, I remember at a gig you had at Lavalin in Montreal. Would she have been working there too?

Townshend: Yes. So she had been working at Lavalin.

Spicer: We can come to that later but I just thought structural engineering, yeah, maybe there's a link there.

Townshend: Yeah. Yes, mm-hm. Yes, there is a link there. So yes. So she was there at Stanford. She'd started a year after me at Stanford. We met like second year there or something and then we were dating then, so when I left to go to New Jersey she was finishing up her final year of PhD and then she eventually moved to New York as well too.

Spicer: Where did you guys live? Did you say New York?

Townshend: Yeah. So the first year lived in New Jersey near Bell Labs, in Murray Hill, New Jersey. Then after that we moved to Manhattan and lived in the West Village.

Spicer: Oh, my goodness.

Townshend: Yeah.

Spicer: That must've been fun.

Townshend: Yeah. No, it was definitely a fun place and everything and it was--

Spicer: Yeah, and so what kind of work did you do at Bell Labs, and--

Townshend: So it was--

Spicer: --was it applied or more theoretical kind of?

Townshend: Yeah, it was kind of both. I was working on psychoacoustics again. So I was working on how people hear things, and primarily the-- there's a phenomena in hearing that is-- says that when you hear one loud sound there's masking, which prevents you from hearing things that are at a higher frequency than that. So it's a, you know, in some sense it's a sort of, ah, anecdotal psychology… somebody notices. It turned out at the era it became very important because there was a transition of the telephone network to be a digital network, and especially for wireless communication. If you can compress speech and transmit it digitally at a lower and lower bitrate, you can pack more speech onto digital transmission lines. So, for example, you know, a transatlantic cable, which is carrying digital calls that has a certain bitrate, if you want to stick more calls in there you can compress the speech to a higher degree and pack it in more tightly and also then for wireless communications. So...

Spicer: By the way, sorry to interrupt.

Townshend: Yes.

Spicer: But they did this with analog in the analog era as well, right, by limiting the channel bandwidth and I think it was zero to basically a three kilohertz.

Townshend: Exactly. So, you know, the telephone channel has got limitations. It's got a certain amount of background noise, which, you know, it's picking up hum and picking up buzz and it's got a bandwidth, as you mentioned, it's got a bandwidth limit which is limiting how much-- really how much information is coming through there, so... But what they wanted to do is, with the transition to digital, was to maintain the perceived quality that it already had, but they'll pack in the bits more tightly. And so it's a fight against, you know, as you compress things you get more noise. So this is where the psychoacoustics comes in. It says, you know, if you make the observation that low frequencies mask higher frequencies, well now you don't have to encode the frequencies above a low frequency tone as much because people can't hear it, and it brought in the area of perceptual coding. As opposed to just seeing a metric, I want to compress this and re-expand it so it was as close to the original as possible. That's not the criteria anymore. The criteria is can a person tell the difference between the two? And so now it becomes all based on your hearing ability and everything and what a human can hear, not hear, which is also why the frequency range is limited too. I mean, you can't hear very high frequency sounds, well, much higher than three kilohertz. But above 20 [kHz] nobody can hear and most adults it's like 8 or 10 [kHz] that they can't hear above.

Spicer: Is it like in the old RIAA, the pre-emphasis that they used to put on vinyl LP records?

Townshend: Yes, so--

Spicer: And deemphasis at the other end? Yeah.

Townshend: Right. There are a lot of perceptual things that you can do to improve the quality of a recording or whatever to try and--

Spicer: Right. So you're essentially changing the relative weights of the frequencies in real-time or...?

Townshend: Right. Well, the perceptual coding is even different than that. Say that you cut it up into a low band and a high band and then you encode the low band with, you know, five bits of information or something, so you convert it digitally, and then you look at the high band and ask, "How many bits do I need here?" Well, if this was a very loud sound I probably don't need anything. I just throw this away and it'll sound the same, but if it was lower then I can put-- I need to put more bits over here, because now people would be able to hear that. If it was completely silent in the low end they would be able to hear whether that high-pitch sound is present or not. So you're basically doing an allocation of bits to the different parts and allocating your noise margin to the different pieces of the signal.

Spicer: Right. And then this would've resulted in an actual circuit at some point, right?

Townshend: Well, this would result in actually much more than a circuit. It results-- or it did result in the standardization of how you encode speech over the networks and everything. So at the time, you know, there was PCM, which was storing things at 64 kilobits. Then there was adaptive PCM, which is lowering the bit in an objective way. It was basically encoding the same thing but sort of compressing the data. But then you got into these lower-bit recorders which were CELP [Code-Excited Linear Predictive] was one of them, and different acronyms of things now. I've forgotten most of them, but they were pushing the bitrate down until you could over a digital line, you know, high-- get the same quality as-- you were previously sitting at 64 [kilobits per second]. Get it down to 16 or 15 or 14 kilobits per second, and then you go even further you get it down to 8 or 4 and it sounds not quite as good but it was great for cell phones and things like that in digital. Be there you haven't even-- you can't afford very many bits. So that resulted in, you know, since it was AT&T, Bell Labs is-- it was directly applied work. It was going into the telephone system.

Townshend: Yeah, and they were packing in-- well, they're already-- they already were transitioned. Just now they're saying, "Can we pack more calls onto the same amount of digital bandwidth that we have?

Spicer: And this is like quite apart from multiplexing or anything else, right?

Townshend: Right, right. It would-- allows you to do more multiplexing.

Spicer: More modulation if it's like--

Townshend: Yeah, yeah. More modulation message. But it is effectively multiplexing. Take that same thing, instead of having one call now you multiplex 16 calls onto that same line.

Spicer: Wow. Do you remember the standard, just-- or maybe <laughs> that's too complicated.

Townshend: No, no. I know CELP was one, but, I mean, a lot of it was just like numbers and like ITU, dada-dada-dada… And I wouldn't say-- I don't want to overstate it. I mean, I worked on a tiny piece of that: collecting the psychoacoustic data and everything that was going into the metrics of how; if you can collect enough data, you can then write a program that will predict how good this sounds, what call a 'mean opinion score.'

Spicer: I see the link to your dissertation there.

Townshend: Yeah, yeah.

Spicer: I mean, it's very related, and you mentioned earlier that when you felt a bit isolated on your master's and the doctoral dissertation gave you the chance to collaborate with a real nice team… did you find that team approach at Bell Labs too?

Townshend: Oh, yes. Absolutely.

Spicer: Bell was a collaborative environment?

Townshend: Absolutely. It was a very collaborative environment with really good people to work with and working on things, and--

Spicer: How were you resourced? Pretty well, if you needed anything?

Townshend: Yeah, that was the other thing I was going to say, the resources were amazing in there. I mean, like, you got everything you wanted. At the time, Sun was just taking off -- we all had Sun workstations that were on the desk and that was the cream. And the world's largest anechoic chamber, it kept being put in the new York times as "The quietest place on earth." So, you know, this gigantic chamber you could go into.

Spicer: How many Life Magazine articles on that chamber have there been?

Townshend: <laughs> Yeah.

Spicer: What was—what were they testing in there? Because it was very large, right?

Townshend: Well, the—yeah. I mean, there were many different things but we ran experiments in there too. Mean, like just in terms of, you know, opinion score, figuring out, you know, does this person hear these subtle differences or not, right? So you really need a quiet environment to be able to do that.

Spicer: Oh, so you run the experiment in the chamber with the people? .

Townshend: With people, yeah. I mean, that was rare because it's expensive and there's a lot of other uses for that, but there were times that we did that. Mostly we did it in smaller sound chambers, like basically room-size anechoic chambers, and with headphones, you know, noise canceling, very high-end headphones inside anechoic chambers, inside anechoic rooms, because, you know, if you've trying to see if you can tell the difference between that little bit of noise in the background or not, you really need to get rid of fan noise or—

Spicer: Little clicking.

Townshend: Yeah, whatever it is.

Spicer: Yeah. Now, this is the same problem we had earlier in understanding how people describe how they perceive sounds, but how did you perceive the anechoic chamber, if you can describe that in words?

Townshend: Oh. It feels like something's missing, really. It just—you go in there, you just, it's—you don't really notice consciously that it's super quiet, but you just feel like there's like, ah, there's something missing, <laughs> right. Just like we don't notice the little backgrounds of fans and things, hums in general world. You don't notice that they're missing but you do have this feeling that, "This is weird somehow…"

Spicer: <laughs> When you speak what does it sound like?

Townshend: When you speak it's just very flat, dead, right. You can still hear yourself on this thing but you don't-- there's no reverberation. There's no echo.

Spicer: Okay. But two people could hear each other if they were six feet apart?

Townshend: That's fine, yeah. Oh, yeah. Yeah. It's very clear and everything, but it's just very flat and very...

Spicer: And now, your wife. Oh, let's give her a name.

Townshend: Oh, Michèle.

Spicer: Michèle. <laughs>

Townshend: Yeah.

Spicer: Was she working with you at Bell Labs or...?

Townshend: No, no, she-- but well, when I started at Bell Labs she was still finishing up her PhD and then she started working for Ammann & Whitney, which was , or still is, a bridge building company.

Spicer: Oh, okay.

Townshend: And they're the ones that built the Brooklyn Bridge [1]originally.

Spicer: Oh, fascinating.

Townshend: So she was working on structural engineering for them for designing resistant structures.

Spicer: Wow.

Townshend: Yeah. And that was in Manhattan, so-- which was also why we ended up moving to West Village, so then--

Spicer: That's nice. How far a drive is it from-- or did you take the train? How'd that go?

Townshend: I drove mostly. Sometimes took the train, but it's like a half-hour drive.

Spicer: Oh, it's very close.

Townshend: Oh, yeah.

Spicer: Wow. Didn't-- I've never been to New York, believe it or not. <laughs>

Townshend: Oh. Okay.

Spicer: So I have no conception of how close things are, but...

Townshend: Yeah, from Lower Manhattan there's the Holland Tunnel that goes to New Jersey, so it's-- the Holland Tunnel was, you know, like a five-minute drive from where we were living, so you just drive down, go through the tunnel. Then you're in New Jersey and then it's-- you're on the interstate highway for, you know, 20 minutes, so... if there's no traffic.

Spicer: Right. What was going on, if you can remember, were there other interesting projects at Bell that you know of at the time that piqued your interest...?

Townshend: Yeah. I actually got involved in a few. One of them was the development of C++. So Bjarne Stroustrup was just up the hall from me, and so C++ was really just taking off at that timne-- well, not even taking off. It was sort of being seeded and everything. So he'd just written that language and designed it

[1] [Interviewee's note] Was actually the Williamsburg Bridge, George Washington Bridge, and others in NY.

and everything, and so I was using some of the early C++ versions for what I was doing. In fact, I worked on the first vector library for C++, so I wrote the vector library for him that was using effectively GPUs, but other processors to accelerate the computations and everything.

Spicer: Can you explain for our audience what a vector library does?

Townshend: So, you know, so basic programming languages, they have primitives for adding numbers or subtracting, dividing, but often when you're doing a lot of large mathematical problems, like you'll have a vector, like for example, an audio signal is a string of numbers. It might be thousands or ten-- hundreds of thousands numbers long. Now, if you want to take two of those signals and, say, add them together, you could just go through and add each of the individual things, but as the length gets bigger and the amount of computation you have [to do], it all gets very slow. So what you want to do is create a library that says, "Okay. I'm going to give this function in the library two of these long vectors and its function is to just add them." You can build a basic version of that library that internally just runs through them and counts them, but then you could also say, "Okay. Now I know that this computer that I'm running on has this other coprocessor - digital signal processor on it, so I could move those two vectors to the digital signal processor, let it compute it, give it back to me and then I pass it back to the person that called it." So transparently to the programmer now, this function now runs a hundred times faster than it used to. So that's the idea of a vector library. So C++ in the beginning didn't have a vector library, so I worked with that group and built the vector library.

Spicer: So vectors, from what I know about Cray research and so on, are all over science and engineering. Right?

Townshend: Yes.

Spicer: So this would've been--

Townshend: And you see--

Spicer: --very useful for--

Townshend: Absolutely, and you see now--

Spicer: Universally.

Townshend: --with all the machine learning research and work and everything because it, I mean, really the whole renaissance of machine learning has really come from having the ability to compute these things quickly and everything, and so the increase in computing speed and the ability to use GPUs to do the processing makes the current AI techniques possible.

Spicer: Let's just jump back a bit to Bell Labs.

Townshend: Yep.

Spicer: How long were you there?

Townshend: Three years I was there, yeah. Three and a half years, I think, yeah. Yeah. So I was working on the project with the speech coding. I was also-- related to that, you know, for sending speech over the telephone lines, the other big application of psychoacoustics to coding is for music. So another group there was working on music encoding. So how do you-- how many bits do you need to store music and to play it and everything?

Now this was just after, I think, CDs had come out in maybe ’83 or ’82, or ’83 was the first commercial use of compact disc and everything, so that was the first exposure that people had to digital music and everything, and the quality of digital music, which was amazing. I mean, I remember when it first came out and saying, “Did you listen to this?” This is crazy how good the quality is of CDs. But CDs are at a very high data rate, so as soon as you want to be able to store lots of music, or, more importantly, to be able to stream it over a digital connection, like a telephone line, you need to compress it and--

Spicer: And in this era-- sorry for interrupting, the data rates, people are essentially using modems, right, dial-up?

Townshend: Mm-hm.

Spicer: This is the dial-up era.

Townshend: This is the dial-up era, so the typical modems at the time that I was at Bell Labs were around 9600 bits per second, you know, 10 kilobit or something, and that was really the high end. The probably more common [rate] was 1200, 2400 bits per second, so if you can imagine, that’s bits, first of all, and per second, so 2400 is, you know, is 300 bytes per second, and there’s some overhead there, so downloading a megabyte is a major endeavor.

Spicer: <laughs>

Townshend: You know, and hours, hours of download. So getting music compressed to a lower bitrate is valuable both for storage and also for being able to transmit it over digital lines.

Spicer: And psychoacoustics plays a big role here too, right?

Townshend: Exactly.

Spicer: And are you driving towards mp3…?

Townshend: Exactly. That was the… actually, that was what came out of all that work, is mp3. Well, and the earlier mpeg encoders. So some of the people that were on that group were from the Fraunhofer Institute in Germany, which--

Spicer: Ah, yes.

Townshend: So they started that work there or they collaborated with Bell Labs and everything. They went back and then that's where a lot of follow-on mp3 work was. So at that time it was more like the early mpeg encoders, and then it was evolving into mp3.

Spicer: I think [the leader] was Karlheinz Brandenburg?

Townshend: Yeah, so he was there at Bell Labs then. He was like two offices from me.

Spicer: Oh, I didn't know that.

Townshend: Yeah, yeah.

Spicer: See, I thought the story kind of was a Fraunhofer story, but you're saying--

Townshend: No, he--

Spicer: --there's a Bell link too as well?

Townshend: Yeah, yeah.

Spicer: Ah. Well--

Townshend: Yeah, yeah, yeah. They were all right there.

Spicer: How interesting.

Townshend: Yeah.

Spicer: Now, why would Bell be interested in transmitting music?

Townshend: Well, it's another use of transmitting--

Spicer: A service to customers?

Townshend: A service to customers. Bell was very interested in everything related to multimedia and things. They were very interested in teleconferencing. They were doing a lot of work on teleconferencing at that time. There was a whole group up the hall from me that was doing virtual presence and everything.

Basically creating conference rooms with dummies that had actually all the audio, the speakers and microphones and everything, cameras and everything, and trying to do remote video conferencing.

Spicer: Now, what year is this? This is very early.

Townshend: It is like the late ‘80s, like ’88, ’89, think. So there was a lot going. I mean, like you said, the technology’s already there. It was just in different pockets and everything, so they were doing, you know, video teleconferencing with presence and everything…

Spicer: Okay. So that explains why they care about sending signals of any kind.

Townshend: Yeah, and so they cared about music, they cared about audio, they cared about video, cared about all this, you know.

Spicer: Now, the video would’ve been quite a challenge, I imagine.

Townshend: Yeah, but not at all infeasible, because you, you know, although we’re talking about dial-up modems and things like that, the bulk of what they’re interested didn’t really care about modems because there is digital subscriber lines [DSL]. You can get a T1 line or higher things.

Spicer: Leased lines sort of thing?

Townshend: Leased lines, yeah. So they were at, you know, the kind of speeds that we still-- we already had. They were megabits or even tens of megabits per second. So similar to the kind of speeds we’re--

Spicer: They’re very lucrative for the phone company,

Townshend: Very lucrative for the phone company. It was completely feasible for a company to have an office in New York and an office in San Francisco and have a digital connection between them at megabit speeds that you could run video, live video and everything over.

Spicer: Interesting. Yeah. You know, in the early days it was called, teleprocessing.

Townshend: Yeah.

Spicer: IBM had-- was, you know, made a big splash when you were able to connect System/360s [mainframes] and terminals in different cities together …

Townshend: Yeah.

Spicer: --IBM had its own thing going on with networking too really early on, so...

Townshend: Correct, yeah.

Spicer: But anyway, so Bell Labs. Is there anything, before we move on, anything else you want to say about Bell? Your time there or...?

Townshend: Yeah. I'm glad you mentioned Karlheinz, because I, you know, that actually tied into something, to some of the later stuff too, because I'd communicated with him following his time Bell Labs too, for both the mp3 issues and everything too, so think...

Spicer: Yeah. So let's see. What's next…you're just leaving Bell Labs.

Townshend: Leaving Bell Labs. So Michèle and I decided to get married. You know, I proposed to her in Central Park.

Spicer: Nice.

Townshend: She wanted to move back to Montreal, so we decided that we'd move to Montreal. So I left Bell Labs in early 1990, and we moved back there. While I was at Bell Labs, one of the interesting things that I noticed was, in doing all the audio work was that is was really hard to get audio interfaces, audio hardware that would actually do the kind of quality audio that we needed, though there wasn't really-- we were sort of building our own stuff and--

Spicer: Like A to D's and that stuff?

Townshend: A to D's and D to A's and things like that.

Spicer: Yeah.

Townshend: So there was definite need there. So what I decided to do was to start a company when we moved to Montreal.

Spicer: I knew it was going to happen sooner or later.

Townshend: Yeah, yeah.

<laughter>

Spicer: That's great.

Townshend: And this was sort of-- it was a completely bootstraped company. Was no external funding at all of it, but effectively Bell Labs funded it and because they needed these interfaces and they needed several of them. So, when I was leaving and, you know, I was on great terms and everything… they were trying to get me to stay but, you know, I was decided, but I suggested, "Well, our group needs these digital interfaces. Other groups need them. How about I'll design and build digital interfaces and sell them to you?" and they said, "Great." You know, "We-- this a big need that we have for a lot of different things," and I also said, "Well, how about you pay for them now?"

<laughter>

Townshend: And--

Spicer: It's not Net 30. It's the opposite of Net 30.

Townshend: Yeah.

<laughter>

Townshend: So-- and they agreed and then so they bought, you know, like on the order of 20 or 30 of these devices at about $5,000 each.

Spicer: Oh, wow. Can you tell us a bit about the circuit, what was on it and...?

Townshend: Yeah. So it's basically a rack-mounted device that has a digital signal processor inside, it has a CPU inside. It can run programs. It actually does not have an analog-digital or digital-analog converter, which is interesting, because it is a effectively a sound interface. What it has is an interface to digital audio tape [DAT] machines. So at that time, both with CDs and digital audiotape they had a standard digital output. So it was like a either fiberoptic or a coaxial output that carried the digital data signal.

Spicer: Right. Is that the weird little S/PDIF connector on--

Townshend: Yeah, S/PDIF was the eventual standardization of that… So they were accessible to get really high-quality digital-to-analog converters built into a digital audiotape machine.

Spicer: Oh, how fascinating.

Townshend: Okay.

Spicer: So they bought DAT machines and--

Townshend: So they would bought-- so they-- and we-- and Bell Labs had a lot of DAT machines. They were using it for a lot of that, for that work and everything, for the audio work, and they also had, you know, studio type audio equipment that was going into things, but what they didn't have is any way to get that stuff from that to a computer to do analysis or back again.

Spicer: Right.

Townshend: Okay? So what I built was a thing I called a DAT-Link, which was basically taking a computer interface, a SCSI interface at the time, on one side, and then a digital audio S/PDIF or fiberoptic output. I actually had multiple… there were like three different standards. So it had all three standards, or three semi-standards. And then inside it had digital signal processor, because the other issue was sometimes the formats that were stored on digital audiotape were not the formats that people would work with on the computer, and it would take a lot of compute time to do conversions and a lot of the conversion software wasn't very good. So inside the box it was taking the digital audio in. It was doing sample rate conversion. It was doing filtering. It was doing-- all in the digital domain, and then it was outputting the converted output [so] it would run to your computer and you could store it on your computer and you could even run everything real-time. That was really the big limitation of the sample rate conversion, was that if you have an audio file that sampled at 16 kHz on your computer and you want to be able to play that in real-time through all this pipeline, it has to get up-converted… all these things… with low latency. So that was the function of this box. It was taking that digital stream in with, you know, milliseconds of latency and outputting to the correct output type.

Spicer: What was your favorite-- well, not your favorite, but what was the DSP at the brains of this thing?

Townshend: That was TI, the--

Spicer: The 56001 or the TMS320?

Townshend: DM-- oh, no, actually, wasn't. It was Western Digi-- it was the AT&T one, the DSP32C, which was eventually. Yeah.

Spicer: That makes sense you'd use an AT&T chip. <laughs>

Townshend: Yeah. Yeah, yeah. Yeah.

Spicer: Yeah. <laughs> That's great.

Townshend: Later on, I used some of the TI ones for other things, but yeah, that was DSP32C.

Spicer: Oh, good. And did you just build these on your kitchen table?

Townshend: Pretty much, yeah.

Spicer: Yeah.

Townshend: Built the-- we had a condo in Montreal and--

Spicer: Oh, nice.

Townshend: --I worked from home while Michèle went to work. She was working at Lavalin in Montreal, and then I would work on designing and the circuits and everything, and then I developed a network of subcontractors in Montreal that would do, you know, print a circuit board design, do stuffing, do, you know, enclosures, then do packaging and all that stuff. So we ended up with a whole pipeline to do it with a sort of a one-person operation at the beginning and then expanded that to two people. The most we ever were was three in that company.

< There was several interachanges here not in transcript >

Spicer: Can you explain just quickly before we leave this topic how your device was part of the larger flow of which it was a part?

Townshend: Yeah, so, I mean, it ended up with a lot of different customers, which was interesting. So the first customer was Bell Labs, just for doing acoustics research. They have a very high-quality signal that they want to get out to headphones for somebody to hear or I want to do a recording at very high quality that they can analyze. So that was the first application …

Spicer: …and then ultimately have that audio waveform available in digital form.

Townshend: Exactly.

Spicer: Right.

Townshend: To acquire it in digital form.

Spicer: For whatever processing.

Townshend: Yeah, for doing analysis or for doing storage or for doing, you know, whatever you want to do with it. Soon after though, there was interest from the music recording industry that was like, "Well, here's a good way to get data into-- from a recording studio into computer to do analysis and do things," so a high-quality version of, and at that time there was, you know, Digidesign did a lot of things, was just starting and maybe even hadn't started then. Yeah. I actually did a part-time job when I was in Stanford doing my PhD. There was a company called Opcode Systems in Palo Alto that was doing digital interfaces…

Spicer: I remember them.

Townshend: Yeah, they'd just started and wanted a music interface for, you know, just for a keyboard.

Spicer: Like a MIDI interface?

Townshend: A MIDI interface.

Spicer: Yeah. Right.

Townshend: And so I saw they had them and I just drove over to where they were doing it. It was just a little low-rise building and the only person there was the guy that started the company, Dave Oppenheim, I think, and, you know, I saw him and I said, “Oh, I wanted to buy one of those MIDI interfaces.” He said, “Ah, sure, sure. We can do that,” and then, you know, start talking and he’s, “Oh,” you know, I told him I’m Stanford, you know, and he was asking what I’m doing. Said, “Oh, well, you know, maybe you could help. You know, we need this thing for this thing called this timecode synchronization and it would be really useful to be able to synchronize audio with SMPTE,” which is the motion picture standard for doing it. So there was a MIDI timecode that had MIDI time and SMPTE was for the motion picture industry. But, you know, nobody has any way of converting between the two, and says, “Think that’s something you could build? Design?” and I said, “Yeah, sounds like I could.” You know, “I mean how much would it be?” you know. <laughs> Like I want make some money, I’m thinking, you know. I could charge him a thousand bucks or something to do something like-- I mean I’d done some little interfaces for other people before, and, “Yeah, I could do an interface like that.” You know, and he said, “Well, we don’t have much money but I could give-- we could give you like, you know, if we sell some we’d give you like five percent of the sales or something like that.” I don’t know. I mean, I don’t know if those can be anything, <laughs> you know. Maybe you’ll sell 10 of them. But I agreed and then it took way more work than I thought. Took like a lot of evenings getting it to work right and then I’d come back to him and show him how it worked and he said, “Ah, not quite good enough, you know. It needs to handle these noisy condition, need to do this,” and “Ah, okay.” And so I was completely like, “Ah,” so frustrated with this whole this and saying, “This was-- I’m going to get nothing out of it.” So I finished it finally and then like a year later I got my first royalty check, which was like a hundred dollars or something. I said, “Well, I got something,” and the next quarter I got like a thousand dollars, and it just kept going up.

Spicer: Oh.

Townshend: And then it ended up integrated in many products that they had, and so it was like, you know, tens of thousands of dollars coming from this thing.

Spicer: Wow.

Townshend: So I had this idea that, you know, at that point that was sort of why I wanted to come back to that. It sort of inspired this idea of doing interfaces of things. It’s like could be a profitable business and everything, and so doing the digital audio interface, which is just really converting from one format to another similar to what I did for Opcode, it’s something attractive and it turned out it was, and it was used in actually-- and that’s why I come back to also in some of the same products, you know, like those-- what Digidesign or other people had at the time and you end up with MIDI-SMPTE timecode converter or you end up with a digital audio interface.

Spicer: You could see how your product would be bought by every studio in the world probably.

Townshend: Yeah.

Spicer: Like doing film work, for example.

Townshend: Right. For doing that conversion. So it ended up being inside other products. It was kind of hidden but that circuit or that design was--

Spicer: Did it get-- did they do a shrink or...?

Townshend: Well, it was basically on a like a little Motorola processor, so it was all self-contained as there was little--

Spicer: It was just a small board?

Townshend: It was just a little subcircuit that ended up on many products.

Spicer: Okay.

Townshend: Yeah.

Spicer: So it's mainly software then?

Townshend: And software that's running on a little processor to do it all digitally and everything.

Spicer: Oh, fascinating.

Townshend: Yeah. Yeah. So then, started that, we had like-- it was like Michelle and I would celebrate every time we would sell one, you know. We were-- you know, $5,000 sale or like a thousand dollar.

Spicer: What was your cost of--

Townshend: Yeah, about a thousand for one. Yeah, for the cost of everything, so it was a high-margin business. No, you know, I mean, really one or two other employees just to help support things and so... But--

Spicer: And what a great personal satisfaction too, like selling something you made and it's your thinking imminent in everything in that circuit… must've been very rewarding.

Townshend: Yeah, it was.

Spicer: --ship product, as they call it. <laughs> But, you know, that's part of your soul is in that machine,

Townshend: Exactly. It was...It was fun, and the uses of it were really varied… we had one that was a research group that was investigating whale sounds, bunch of them. they would put them actually on the ships that they were going out and use them for, you know, converting from the hydrophone data in real-time to the...

Spicer: Ah, that's fun.

Townshend: So yeah.

Spicer: Yeah. Okay. So let's move on to the next chapter. You're still in Montreal and what's going on next?

Townshend: So while I'm in Montreal I also started teaching, so I took a consulting professorship at McGill, and I started teaching digital signal processing to some of the students there, so like an adjunct professor. So that was good. I was getting to meet the students and everything. I actually hired one of those students, Eryk Warren, who was in one of my classes and ended up coming to the company on DAT-Link and future companies as well. But one of the things that happened there is that I was talking with another professor there quite a bit. You know, he was the one that was the regular faculty that was teaching signal processing and everything, and we're talking a lot about-- that was Peter Kabal. We were talking a lot about the digital telephone network and about modems and the idea of things, and he was sort of chatting about the whole thing and was talking about the fact that really the whole network is digital, so, I mean, we're doing these modems but the network itself is already carrying stuff digitally all the way from the central office -- between the central offices and everything.

Spicer: Backhaul.

Townshend: The backhaul and everything, so if I phone you I have a little piece of wire that goes to my central office that's analog and then after that everything's digital until it gets a mile away from your end and then it's back to analog.

Spicer: Good old copper.

Townshend: Yeah, and so people were addressing this at the time already in terms of ISDN, integrated services data network and digital subscriber lines, DSL, was all happening, those ideas and everything.

You're not actually changing the copper but you're putting something, a new adapter, on the ends of the copper, so you're putting a new device at the central office line, so instead of creating an analog signal there you have to have-- encode it digitally onto that copper line with a different modulation scheme, and then you put a device at the subscriber end. So that copper wire was already proven to carry high data rates, megabits of data, over that local copper wire. So basically you got a network that's all digital. You've got a copper wire that can carry megabits of data, and then we're stuck though sticking an audio-like signal onto it because of the hardware, that little piece of hardware that's sitting at the central office. You know, in the long-term you'd say, "Well, we'll just change all the central offices," but that was just like infrastructure, a major infrastructure issue.

Spicer: Yeah.

Townshend: And it's what's happened now. I mean, you can get digital subscriber lines pretty easily, but at the time it was a daunting task to do that and you can't do it on a per-person basis. You can't say, "I want a digital line." You'd have to have somebody go into the central office and change it. So we had a lot of discussions about this, and at one point I had the idea, said, "Well, wait a second. Sometimes the other end that I'm talking to does have a digital subscriber line." Like if I'm talking to another person we both have these copper wires, but if I'm talking to a somebody that's for example serving music, serving up a music service, a digital music service, well, since they're doing that they could afford to buy a digital line to the telephone network, right, because they're a company that's in the business of providing digital services.

Spicer: What is the difference between a digital line and an analog line?

Townshend: Well, they actually get a T1 or something, some actual thing that's carrying digital.

Spicer: Oh. Oh.

Townshend: From their premises all the way into the telephone company.

Spicer: Would that not necessarily be fiber but it could be?

Townshend: It could be fiber.

Spicer: Could be.

Townshend: Could be fiber. It could be copper. But it's high data rate copper. It doesn't require-- it's never going into analog waveform that looks like speech.

Spicer: Right.

Townshend: Okay?

Spicer: But it requires like a special technician to come out and run the cable, run the wire?

Townshend: Yeah. Well, we're talking about a business on that end.

Spicer: Yeah.

Townshend: We're talking a company, so it's--

Spicer: Oh, okay.

Townshend: --in an office building or a server room somewhere that they're running it. Okay?

Spicer: Yeah, yeah.

Townshend: And that was common. People-- the companies already had digital connections into the telephone network. Or AOL, for example, right. AOL would have digital. It would have a bank of modems, right, to have all the dial-in, but they'd also have digital lines to go to their providers of other content and everything. Okay. So they would have a mix of the two. So in the discussion, I was observing, "Well, actually, half the problem's already solved because if I want to talk to AOL or a digital provider of music, then most of the network is already digital. It's only my last mile is the only problem." And also, they don't really care about what I have to say. I mean, I may give them commands, mouse clicks or keyboard, but that's all super-low data rate, so the only issue now is getting data from the far side of this little subscriber line to my side of it, downward, one way on one end. So it's very asymmetric. It was sort of everybody looking at sort of a four-piece problem.

You have to get up on this side, down on this side, up on this side, down on this side, so it was all these four links that were a problem and each of those links creates noise and creates problems. So when you look at that whole problem as saying, "Well, no, it's only this one step. We have digital on this end and we have a voice signal on the other end," then the solution sort of becomes obvious that there's-- all you have to do is try and work backwards, because whatever signal-- just forget about that it's an analog line. Just send your bits, raw bits, as whatever the bits you wanted to send, and the phone line will do weird things. It'll make weird noises and everything, but at the other end it's just got to work backwards. It's got to figure out, "Oh, given this result, what were the bits on the other end?" Which was a completely different approach than everybody'd been taking about modems. Modems were all about encoding the data as a sound that you could then listen for that sound and decode it back to data. This was a nonmodem, effectively. This was just saying, "I'm not even going to try to map it to a sound. All I'm going to do is feed my digital-to-analog converter eight bits."

Spicer: Bitstream.

Townshend: Bitstream, and it's a completely random bitstream effectively. It's going to do random stuff.

Spicer: But is it still voltage levels, right, being sent?

Townshend: Still voltage levels. It's still going to create an analog signal.

Spicer: But not tones?

Townshend: But not tones, not-- no patterns particular. It's just going to create whatever random-- if I keep giving it the same bit pattern it'll just give a flat line for a while, right, so with-- so absolutely, just getting rid of all the encoding, and it turns out that that's feasible. You can actually get the signal at the other end and figure out, "The only way I could've seen this particular signal is if the bits up there were this particular pattern." So it works backwards.

So it it basically means that now you've got the same bits that central office had. So you've eliminated the the effect of the copper wire going to analog. So that was the idea that came out of those discussions at McGill or, you know, or the idea that I brought home from the discussions, and so-- and so then I said, "Well, that's really a cool idea, especially now that people are starting to use the internet on a--" because this was getting-- this was like '93.

Townshend: Yeah, yeah. One thing I forgot to mention before and is important, I think, is the motivation for being interested in this, all these telephone lines. So, you know, I, as mentioned earlier, at Bell Labs and worked with-- on the psychoacoustics and was interested in low bitrate speech coding, specifically I was really interested in the music side, and I had the idea then that wouldn't be great if you could just listen to any piece of music you wanted at home? You know, you didn't have to go and buy something, you could just like choose it? Now, you know, contextualize it. Obviously, we do that all the time now, but that didn't exist then and it wasn't really--

Spicer: This is 1990?

Townshend: Yeah, 1992, I think it was. Right. So, I mean, first of all, you know, well, it just didn't exist, right. Even though there was some online stuff, you know, like AOL and things like that, and the internet existed for long time in terms of being able to send data around, send email, send things like that. I had a first email account in 1979 or something, but--

Spicer: But there was no Web.

Townshend: There was no Web. Exactly. The web was just happening then. At NCSA there was just the beginnings of HTML around then and the use of the web and the Mosaic browser and stuff like that. And there was definitely no music on demand. So, I was thinking about this and, you know, the stuff I'd seen at Bell Labs with the predecessor of mp3 that was going on was getting lower and lower bit rates. And modem speeds were increasing and by that time it was up to like 28.8 or maybe 33.6 kilobytes per second on the modem. So, so I was, you know, really actively trying to bridge that gap. I was saying if we can get the data rate up as high as the music compression rate, we wouldn't have a gap at that point. There was music compression running at 140 kilobytes or something and data was 28, I said, so we had a 5X gap or something between the two, it is to get those to converge, then you can do music on demand and then you can have a dial up thing that gives you music. So it was the idea of my-- it was called-- I called the project Music Fax, you know, music fax. <laughs> Like facsimile, the fax machine.

Spicer: Oh, interesting. Music Fax. Okay.

Townshend: Yeah. Kind of a silly name. <laughs> So, I started communicating more with Karlheinz Brandenburg and with the current statuses and going back and forth saying, "Well, how much bit rate can we get this down to? Could we actually get it down to a region that is, you know, with the latest work and everything, maybe not CD quality but really good quality over a lower bit rate?" And we went back and forth by email for a long time. And really, the conclusion was well, we could get down to 60 or so kilobits per second, but below that it's really degrading the music quality.

Spicer: And that's where the ear begins to notice.

Townshend: You begin to notice. And the current techniques weren't able to get below about 60 kilobytes without perceptually degrading the quality. They're already, if you looked at the actual waveform, they're completely different, but the ear heard them the same. So, the gap was narrowing but it was still off. So I'm saying, well if we get the modem data rate up higher, then we could bridge this gap. And the thought process went on saying, well if you do have music on demand, you've got this big server somewhere in the server farm. They have digital line connections to the phone system. So there's no problem there, they can pump digital data all the way to your central office, but they just can't get that last mile over the copper without changing infrastructure. So it said that when you focus it like that, you think, okay, it's an asymmetric situation. We don't care about upstream data, we really care about downstream data. We don't care about the far end being a copper wire. All we care about is this very, very specific case. And the discussions came and then thinking, oh well actually that's easy. We just ignore the problem. We just send the data as if it's just data and then it turned out that worked, that actually did something. And so all of a sudden the gap was met between the music on demand and--

Spicer: I'm sorry, I just missed what was the breakthrough there that allowed you to--?

Townshend: It was, it's kind of strange. The breakthrough was really the observation that we only cared about one of the links and we only cared about it one way. We're not trying to solve the general problem of how you send data from point A to point B when both people are dialing it -- ends have a modem. One end doesn't have a modem, they just have a direct connection, and the other end only has a, needs a one-way modem, they don't need a two-way modem.

So you simplify the problem and then you realize that we actually don't even need any modem because we can do this reverse-channel characterization. So work backwards from whatever audio signal we receive at home and reverse calculate what the bits were going into the codec at that end. And so I thought of that and said, wow, that could possibly work. And so then I ran a simulation just using MATLAB. So, and I still do a lot of stuff in MATLAB. MATLAB's a really useful tool for this kind of thing. But so I built a simulation that, you know, I said, okay, I know what the noise characteristics, I know what all the things are. It was actually really easy.

It's like if you add the noise and put the thing into the simulation, you create a synthetic signal and then write a little program to decode it to work backwards. And it turned out it worked. I mean it was able to decode this thing that went in. And so I said, wow, that's great. That's a solution. And as soon as I came up with a solution of how to do the music, I realized, well wait a second. We're having blossoming of the internet. Everybody wants to download information, download image, download pages from the internet. That's all one way also. It's exactly the same problem. The internet provider has a direct connection.

All of a sudden I realized, oh, this is way bigger. I don't actually have to build the music demand service; just the modem itself is going to be the thing of value -- the ability to download at higher data rates. So that was the beginning of that. So I wrote a patent application for that in '93-- '93 or '92, I forget now which it was-- and started prosecuting that patent in Montreal. Soon after that, Michèle and I realized that that, you know, a lot of this sort of the patenting, the legal infrastructure for the whole idea of licensing a technology thing wasn't-- was definitely blossoming more in Silicon Valley than there, that there was a lot of knowledge about that kind of doing that kind of transaction, doing that kind of thing. And also we missed a lot of our friends who were here and everything.

So we decided to move back to California to Silicon Valley. We came back, came down here. I was still doing the DAT-link, the dat link device. So it's sort of moved the company that was doing the DAT-link down to California and was continuing on that. And the student that I had up there in McGill, he also moved down, Eryk. So we sort of set up shop in Silicon Valley, started expanding that and trying some other little products. And in parallel I was working on this patent for the modem. And then maybe it was another six months or a year later before I realized, you know, there's all these other, the DAT-link, the other projects, they're all really interesting, but this modem thing is, like, a real game changer with application work. So I decided to start trying to license it to a modem maker to see if, what the interest is. So that started the whole-- triggered a process of, you know, going out and trying to shop around this idea to modem makers.

Spicer: Did you have a working, well, I guess--?

Townshend: I had a working thing.

Spicer: Yeah.

Townshend: It was a MATLAB program.

Spicer: Oh, okay, yeah, that makes sense.

Townshend: So I never actually built one. I mean, I knew how to build it. I could have built it. I had actual real data from the phone line so I could, you know, like collect some samples, some digital signals from the phone line that would be exactly the same what you'd get from this device. And I can take that signal and put it on the computer and run the algorithm to decode it. So I knew I could do it, it's just a matter of I didn't actually take that algorithm and put it onto a DSP chip and put it into a box that would do it.

Spicer: So the patent actually has no specific embodiment?

Townshend: Well, the embodiment is a description of how to do it.

Spicer: Is the description.

Townshend: Yeah. So the embodiment is--

Spicer: But it's not reduced to practice is-- is what I should say.

Townshend: Well--

Spicer: Or is it?

Townshend: It is.

Spicer: Oh. Okay.

Townshend: I learned a lot about patent law. Reduction to practice doesn't, you don't actually have to build something physical to reduce to practice.

Spicer: Oh, I didn't know that.

Townshend: You just have to explain how to build it. Okay. So the actual reduction to practice in this requires you to enable somebody else to build it.

Spicer: Right. So you got a great lawyer who--

Townshend: Yeah.

Spicer: Describes it technically and--

Townshend: Yeah. And there was not really, I mean, there was no issue there. I mean, it would have been easy to actually physically build one if we needed to, but there was, like, the enablement was already there from…

Spicer: What-- Describe the process of shopping this around. Did you have like an agent or somebody working for you?

Townshend: No. No. You know, I'd had some experience, you know, before with the DAT-Link company. You know, there's a lot of times that I felt that I didn't have the business background or the things to negotiate things. And so some friend of a friend said, you know, that did an MBA would, you know, be a consultant or something and do it. And it was always eh--

Spicer: It was not that useful?

Townshend: It was never that useful because it came down to a lot of the stuff - once you're past the first meeting, you're sort of, it's between other scientists or engineers that are making the decisions and everything. And it doesn't help to have the business guys in the room to do that. Once you get the meeting, it's just a matter of talking shop really.

Spicer: Right. It's kind of like the way diplomacy works, right. The ambassadors talk.

Townshend: Yeah.

Spicer: And then their staff people work on the actual practical aspects.

Townshend: Right.

Spicer: People beneath make it work, make it happen. So tell us the companies that you approached.

Townshend: Yeah, so, so it started off not so great. <laughs> So the first one I talked to and you know, it's, you know, I sort of researched the companies. The biggest player in the modem market was Rockwell. So, so they were building a lot of the existing modems at that time. So I contacted them and said you know I have an idea for this and they responded. Actually, I think they get a lot of people coming in with things, with ideas, but what makes the difference is, you know, oh, yeah, I was at Bell Labs and I was a Stanford PhD and I've done this stuff and working here and I think I have a way of increasing data rates for modems. And, you know, would you like to discuss.

So that was sort of the lead-in to the whole thing. So they responded. I think-- I'm not even sure if I sent it to anybody else. I think they were the first ones I contacted. And they responded and they scheduled a meeting and I went down to L.A. where they were headquartered, somewhere in L.A., and met with their modem director, the head of the modem division, and some of the scientists there and explained what I was doing – everything confidentially. You know, like a confidential presentation. And they had questions and they understood the idea and everything and they thought that was great. You know, they said, this is interesting and we'll get back to you.

And then I contacted other companies. US Robotics was the other big player in the field at the time and I contacted them and scheduled a meeting to meet with them. Actually, well, I'll come back to U.S. Robotics, actually. It's actually, it was funnier or more interesting the way that worked. Meanwhile, Rockwell came back with an offer and said okay, we'd like to, you know, purchase your intellectual property, purchase your patent and everything. And we would offer, you know-- we think it was like a half a million dollars or something. And I said, wow, okay that's pretty interesting. But you know, I already realized that it was going to be worth more than that in the longer term so I was continuing to talk to others.

I contacted U.S. Robotics. I talked to the director there, Michael Seedman, and got him on the phone, you know. It was, I think that was actually a cold call; I don't even think I emailed him first. I just cold called and said, "You know, I have a modem thing and they directed me to him." And he says, "Yeah, yeah." And I said, you know, "I'm Stanford, da-da-da." "Oh. Okay, okay." And I said, you know, "I have a way for modems to go faster." And Michael recounted the story after. He said, they'd been trying to get modems to go faster, okay. And they realized and there's this whole thing called the Shannon Entropy-- Shannon information Theory which says theoretically given all the parameters of that copper line and what's going on, that the maximum speed would be 35 kilobits per second. You can't go faster than that that the maximum speed would be 35 kilobytes per second. You can't go faster than that. It was theory, right?

You know, so we were-- they were-- You know, 95 percent of the way to the theoretical limit. And Michael had this engineer that worked with him, Andy Norell, which is like a genius engineer. He's really amazing.

Understands modems and everything perfectly. And Michael recounted, you know, every six months or so he'd talk to Andy and say, "You know, you're sure there's no way that we can go faster?" And Andy would say, "No. You can't go faster than that. This is the limit and there is not any way that goes--" And so, okay, and so Michael’s on the phone with me and I say I have a way of going faster and then, you know, "Well, you know, a lot of people think so, but we think it's max speed." And I said, "Well I've got these credentials. I've worked at Bell Labs, I know that--" He said.

"Wait a second, I've got to get somebody else in the room too. I'll get Andy. And you know, Andy comes in on the conference call and asks and Michael asking, you know, "Is there any way to go faster than 33?" He says, "No, 35 is the limit. And, you know, and theoretically--" And I said, "Well, you can do it like this." You know, I say it in, like, three sentences, you could do this and this and this. And Andy says, ""Oh yeah, that would work." <laughs>

Spicer: So much for the limit.

Townshend: Yeah. It was just like--

<laughter>

Spicer: Hard and fast limit.

Townshend: Right. Because the question wasn't that the limit was wrong. The limit's correct. It was what the parameters you put into the calculation of what the limit is.

Spicer: I thought so, yeah. There's something not right there.

Townshend: Because one of the things that goes into that is how much noise there is that it's picking up. And there is a certain amount of noise. And if you calculate it, the noise, it's going to limit how much speed you can get. This issue is that the noise is not like noise from a fan or noise from a random source, it's noise from the conversion of the digital data into analog data. So there's a little difference there.

Spicer: It's quantization noise.

Townshend: Quantization noise.

Spicer: Right.

Townshend: And the thing is when you work backwards like this, you're actually, the noise is no longer noise, it's a predictable quantity.

Spicer: Right.

Townshend: So you can actually subtract it out again. So now the noise is effectively the leftover, the electrical noise, which is--

Spicer: And the limit no longer applies.

Townshend: The limit now is suddenly tenfold or a hundredfold higher.

Spicer: Yeah. How interesting.

Townshend: So what was interesting, though, to me was that it only takes one or two sentences to convey the entire invention to somebody that's in the field. It's just like once you say do this and this and this, that's all you need. And then you realize, oh yeah, you can do it. So at the fundamental level it's super simple; it's super, you know, simple to explain--

Spicer: Do you remember those three sentences?

Townshend: Well I don't actually remember exactly, but.

Spicer: Okay.

Townshend: I could restate the sort of thing, it's just like--

Spicer: So why don't you, yeah.

Townshend: Yeah. It's just like that, you know, the-- Well, maybe can I do that? Yeah. You don't actually need to modulate anything, you just apply the bits at one end, you get a signal out that's going to depend on what those bytes were and then you work backwards and figure out what the bits must have been to give you that signal. And for somebody in the modem industry, it's sort of completely the wrong way of doing things when you first look at it, because you're not doing any of these fancy modulation schemes or anything. On the other hand, when you think about it that way, you realize, yeah, you could calculate the bits back there. That would not be that hard.

Spicer: Can you explain what you mean by work backwards for laymen?

Townshend: Sure. Yeah. It's sometimes difficult to gauge what… So the idea is, you know, if you send some digital waveform, it's stepping up in little things like that, okay. When you convert it into analog, you get a smooth thing that looks like this. Now, if you just look at that smooth one and you know that the only things that the other end could have done is put a level here or a level here or a level there and you know what the timing was, that it was only for this time window that it could set it for here, now, this time when it could set it for here and there, then you could say there's only a finite number of possibilities: either that level was here or was here or was here and this one was here or here or here.

When you see that continuous waveform, you say, okay, if it was the levels were here and here and here, we'd get something different, we'd get a different waveform if it was here and here. And if you work backwards, when I'm saying work backwards is you find that pattern that must have been present there that would give the thing that you observed. So now you know what the levels were at each of those time frames and that's exactly the byte rate that the telephone network is using internally.

Spicer: Right.

Townshend: That's the--

Spicer: Right. And what is the-- Is that a form of error correction or--?

Townshend: Not really, I mean, and that's again, that's the way that people would approach that-- usually they would apply the algorithm and then they would add extra bytes to correct any errors. This is just--

Spicer: Because when you, just theoretically, or, you know, I'm just guessing, but if you increase the speed, the byte, the error rate would increase maybe?

Townshend: Right. But in this case we don't have any control of the speed or the thing. This is all governed by the telephone network.

Spicer: Okay.

Townshend: The telephone network is running at 8,000 samples per second. It's running at a very fixed rate. Every 1/8000th of a second it sends a new 8-bit number.

Spicer: Okay.

Townshend: Okay. So that's 64 kilobytes per second. So every 1/8000th of a second it's got one number and then it converts that number into a level. So that's that step. So if you know in this time window it was step number 122, then you know those 8 bits that were there at that time because it was the 8 bits that encoded 122.

Spicer: I see.

Townshend: And now you move over another 1/8000ths of a second. You figure out what number that was. And now again you've got 1 out of 256 levels, so you say that was level number 210. You put those together now and you've effectively got 8 bits of information from that first timeframe, 8 bits in the next one, till you've got all 64 kilobits.

Spicer: That are known to be correct.

Townshend: That are known to be there. Right. They're the bytes that are there. You can't get more than that. Well now I'm saying the theoretical limit-- But this one, it was already digitally sent through the network at 64 kilobits per second. And now it's just we're working backwards and figuring out what those 64 kilobits per second with the--

Spicer: Is there a technical term for that procedure that looks back? Or the essence of your patent--

Townshend: I mean, yeah. I would just channel-- I mean, part of it, what people call channel characterization, so it's like figuring out what the channel is doing, how it takes your signal, your digital step signal and converts it into an analog signal and goes through it. So it's characterizing your channel that's coming from the central office to your home.

Spicer: And I'm guessing that for those of us of a certain age who have heard the sound of those modems, one of those weird sounds is the equalization sound maybe?

Townshend: Yeah. So there's, so this, it's very different. Up to 33.6 all the sounds are of a different character from the 56K modem.

Spicer: Yes.

Townshend: So in those ones, they're designing a pattern of sounds in sort of in a, you can imagine a space of frequencies and of offset in time, phase, and they're mapping out a pattern or a ‘constellation,’ they call it, of all these different positions. And each positions in that space carries a certain number of bits, you know. So if you have a constellation of 16 different positions you could be in frequency and phase, you get 4 bits of information from that. And so a lot of the ping-pong you hear at the beginning is mapping out that constellation space to figure out how far apart different points are in there. Like these are, they're sort of fuzzy points because of noise being added and you don't want them to overlap, otherwise you can make a mistake and you have to error-correct it as you mentioned.

So the ping pong is figuring out this map of constellations and figuring out how close you can make all these, which then ultimately gives you the bit rate. For a 33.6 kbps modem if everything's clean, those constellations are separate, you get, I don't remember, probably 128 points in the constellation or something like that. And but if the line's noisy or if it'll downgrade it'll maybe only give you 28 or it gives you 14 kilobits per second or whatever depending how those constellations map.

Spicer: So it steps down as--

Townshend: It steps down gracefully so that you can get something to work. It's different in the 56K modem because all it needs to do is just apply random bits for a while, a known pattern of random bits. So it implies, you know, okay, both ends know I'm going to send a 42 then a 78 then a 126 and then a da-da-da-da. Just this sequence of bits. And the other end is just saying, okay, I know what the sequence of bits coming in. I know what I see. What was the mapping function that changed this to this. And then take the inverse of that mapping function to go the other way. So it's a completely different approach.

Computationally, it's way easier. The 56K modem takes much less processing power, much less. You know, where people had gotten with all these constellations and everything is very complex signal processing, very complex as you said channel equalization first of all. And applying all of these different techniques that people had learned over the years to really try and squeeze out that information.

Spicer: Does the channel equalization characterize the expected maximum bit rate?

Townshend: Yeah. I mean, it's two things. There's a spectrum of frequencies, right? So you want to know where you've got lots of things getting through. You can boost up the things that are low and keep those things that are high. Okay. That's one thing. But then there's also noise added to that. So and then the constellation pattern is separating points in that space from each other by more than the noises fuzzing them out.

Spicer: Right.

Townshend: Yeah. That's sort of a quick tutorial on both existing what I'm saying or prior modem technology and then 56K technology.

Spicer: I don't remember. Did anything happen after 56K? Did we go faster?

Townshend: No.

Spicer: No.

Townshend: Because it's-- The theory limit is hard in the sense that the rest of the phone network is only sending 64 kilobits up to the central office. So if you want to go higher than that, then you have to change something internally because the bits aren't there?

Spicer: Right.

Townshend: Yeah. Like a T1 line is subdivided into, I forget now, 16 or maybe 16 subchannels. So and each of those has 64 kilobits per second. So that's it. I mean, when you make that long distance-- that call to the, phone call to anyone, in the middle you've got 64 kilobits. So it doesn't matter if you were able to compensate more for the copper line, you're still limited. The middle channel is already digital.

Spicer: I remembered in engineering playing, we did a little phone lab. We had SLICs [subscriber loop interface circuits] and TSACs, the time slot assignment circuit.

Townshend: Oh, yeah.

Spicer: It was really fun, actually, knowing how the phone system works.

Townshend: Yeah. It's quite sophisticated.

Spicer: Tell us about the, you know, the modem and what happened. I mean, it was obviously a home run for you…

Townshend: Yeah. So Michael Seedman made a huge difference, I mean at US Robotics. So he basically, you know, I just had to phone him. He's asked Andy. Andy hears it. Andy says, "Oh yeah, that will work." And then they say, "Okay, can you come out here and talk to us?"

Spicer: That's great. I love it.

Townshend: And he was such a respectable businessman. He's a guy that, you know, here's something of value. I'm going to pay you the value for that, right? Because you know, we're both going to do really well because we've been trying to increase the modem speed and this is going to increase the music speed.

Spicer: U.S. Robotics owned this 56K--

Townshend: Yeah.

Spicer: Modem space I think.

Townshend: Yeah. So they came out and we talked for, we negotiated a license for a few months and executed that at significantly more than what Rockwell wanted to pay. And meanwhile, though, Rockwell realized that here they are, they're head-to-head competitors with US Robotics, right. They're the two dominant forces with, you know, a billion dollar market or something. So what's their choice now? They realize, oh, now if US Robotics goes up here, and they're stuck here, they're going to lose all their market. So they figure they're going to--As I said, it's easy to convey, right; that [one] meeting with them was enough.. So they start doing it anyway; they basically built their version of that. U.S. Robotics called it X2 and Rockwell called it K56. And you know, as I mentioned, you could go to 64 kbps but Michael, rightly so, and with Andy and others decided well, let's just promise 56 kbps.

Spicer: Ride the wave.

Townshend: And then we might be able to get, it may actually run higher than 56 kbps. It can run up to 64 kbps depending on the condition. But it was a really good call because it meant that, you know, most of the time you would actually get 56 kbps; sometimes you get a little bit more. But if we marketed it or positioned it as a 64 kbps then it would always be falling, it would never exceed, and but it would sometimes fall short.

Spicer: Yeah. Also just like from my naïve perspective, the difference is so marginal, are people really going to spend another $300 dollars to get the--

Townshend: 56 to 64?

Spicer: Say 12 kilobytes per second more or whatever it is.

Townshend: Yeah.

Spicer: So, anyway, so, yeah. Well, that's great.

Townshend: So they both did it and they both ended up and launched--

Spicer: Did you file it an interference with-- against Rockwell or anything?

Townshend: Well they didn't have any patents. I mean filing an interference is really if two people file a patent.

Spicer: Well, from your patent, though.

Townshend: Right. Well, they infringed it.

Spicer: They did infringe it, yeah.

Townshend: They did infringe it and then there was a long protracted lawsuit.

Spicer: Oh, okay. Sorry.

Townshend: There was a ton of litigation. So Wilson Sonsini here in Palo Alto, you know, represented me. And so first of all, Rockwell basically stole it and did it, right? So it was not only infringement but misappropriation of trade secrets because it was a confidential disclosure to them. It was all sorts of things. So they offered money and then I said no and they wouldn't do it based on, is my take on it, here's an independent inventor. It's not a company, it's just some guy. We can do this and we can spend $10 million dollars on legal and he's never going to be able to fight us and everything. So he'll just have to eventually take whatever we give him. And that's what would have happened except that Michael, Michael Seedman came along and said, "Oh, this is a really good thing. We're going to make a lot of money. Both of us. Here's a ton of money." And then when they launched it and said, you know, "You might want to go after our competitor too with some of that money too, because--" <laughs>

Spicer: Did they help you in any other way?

Townshend: Oh, they were very helpful in everything.

Spicer: Yeah, in various ways.

Townshend: In various ways. I mean, they built the implementations and everything, the physical implementation, they built everything, they got it working, they marketed, they did everything.

Spicer: Because it's in their interest, obviously, to have that strong patent for themselves.

Townshend: And the strong patents and everything. And they helped in, you know, providing information there's maybe over 100 patents related to this and everything, so, so we litigated. And we did a lot of patents. So Rockwell ended up with a long litigation which ended up… and they were the, you know, I litigated with multiple parties. But I've learned a lot about patents. There's all different kinds of patent litigations and lawsuits and licensing and things. There's, you know, some of it gets a bad name from, you know, patent trolls that are really saying you happen to have done this thing, which I have a patent on. You didn't, maybe you didn't know-- You probably didn't, they probably didn't know and they probably could have made other choices that didn't do it, but now they're going to get hit up for this, you know, and hold you ransom for it.

On this patent, there's no way to do, as far as I know and still don't know, any way to get up to the higher speed without actually doing this method. So it’s not just a patent on the thing you happen to do, it's a patent on the enabling technology, the technology that enables this. In Rockwell's case in particular, not only was an infringement of the patent, but they got the idea from me. I mean, I'm the one that told them how to do it, right? So it was, it's very direct, like, they stole this from me. So we litigated that and eventually came to a settlement, a very significant settlement with them. They ended up paying much more than they expected to pay.

Spicer: Did they admit anything?

Townshend: Not really. No. The, I mean, it went quite far in the lawsuit and went through, you know, like they have these things called the Markman Hearing, which is really interpreting all the claims of the patents and everything. And we got through that.

Spicer: What a nightmare.

Townshend: Yeah.

Spicer: I'm so sorry to hear that because, you know, great creative people like you come up with these ideas and then…

Townshend: And then spend a lot of time in litigation. Yeah.

Spicer: Yeah. That's the thanks you get.

Townshend: Yeah.

Spicer: God. Really bad.

Townshend: It was interesting. You know, they sort of shot themselves in the foot. First of all, they, didn't… You know, what they should have done, obviously, is negotiate fairly and everything. They would have got [the rights] a lot cheaper than they ended up paying. They ended up-- and I see this very often because I'm involved in a lot of small companies and a lot of other ventures and everything, generally a large company that ignores a patent does better in the end. They end up not paying as much for forgiveness as they would have to get permission. So, so it becomes a business practice to walk over IP and assume that you can you can fix it later.

Spicer: Yeah. Kind of ‘come and get us’ attitude.

Townshend: Yeah. Come and get us. And ultimately it ends up, you know, that they don't pay as much as they would have in the first place.

Spicer: Yeah.

Townshend: So--

Spicer: And it really is such a David and Goliath story with the inventor and the--

Townshend: Right.

Spicer: Yeah.

Townshend: In this case, but even in the case where it's other companies they still do the same thing. In this case they ended up paying more than they would have, which was-- made me happy.

<laughter>

Spicer: It did. Vindication, yeah.

Townshend: Firstly, because they were over optimistic about things they were going to do in the future. So they ended up settling based on a spinoff company that was going to do something and giving me shares. But then they didn't actually do that and the penalties for not having done it were much higher than anything that they would have wanted to pay. And then we litigated against, we basically went around the industry and licensed everybody else that was doing it, which was a lot of players. You know, maybe--

Spicer: Was this reduced to a chip?

Townshend: Yes. Yeah. So there were chips. There were people making the chips, there were people making the products, there were people making the upstream end, the, you know, basically the for the servers ends and there was improvements and everybody was involved in it. So the biggies, you know, like Texas Instruments, Intel… We had litigation with all of them, with everybody. Well, we had licensing negotiations. Some of the companies we licensed straight off; others ended up in litigation.

Spicer: I'm mentally walking the aisles at Fry's 25 years ago and thinking, well US Robotics was always very prominent, number one.

Townshend: Yeah.

Spicer: Then I think was Rockwell's called KFLEX?

Townshend: Yeah. K56Flex.

Spicer: Were they legal copies?

Townshend: No. Well, they were--

Spicer: Like a lot of the Asian and Chinese and Taiwanese--

Townshend: Yeah, I never went after anybody at the level of the box modem except for the ones that were vertically integrated. It was always about the chips that were implementing it. Because otherwise you're going after 1,000 different people to get licenses and everything, but there was only, you know, a half a dozen--

Spicer: Like 10 makers or something.

Townshend: Yeah, 10 maybe that were doing the low-level stuff that was actually everybody else was using. So as long as you licensed the chips that everybody was using, then the license would carry through to the box modem at the end.

Spicer: I see. That makes sense.

Townshend: Yeah.

Spicer: Well, what's the next step, what happened next? We still got a ways to go.

Townshend: Yeah, so that was-- Wow. Yeah.

Spicer: We're up to 1993.

Townshend: Yeah. They were like '90-- Well, by the time the modems launched it was '96 and everything.

Spicer: Okay.

Townshend: So, yeah. In parallel then at the time the modems were, you know, all these lawsuits were happening and the modems were going, I started another company. So I sort of co-located with another guy that was doing speech recognition stuff in an office building in Menlo Park. And we were talking about how it would be cool if you could use speech recognition to determine how people spoke different languages, how well they speak a language. So there was a big push, especially for, you know, educational environments, like for especially for students, foreign students that come to the U.S., they need to take an exam called the TOEFL, Test Of English as a Foreign Language. And there's also a spoken language component to that, the Test of Spoken English. And the written test is fine, it's easy to automate and to put it on a computer and things like that, but a spoken language test required interviewers to sit down with somebody and listen to them or have a discussion with them and then give an objective rating of this. So, so you know, at that time, speech recognition was okay. It was pretty good at figuring out what was said if you didn't make a lot of mistakes, but it was okay. But it was really good at but at, it's kind of funny to say, it was really good at recognizing things if it knew what you were saying already. So if I tell you to repeat a sentence I already know what you're going to say. So speech recognition is really good at recognizing that, okay. It seems like a dumb task, right?

Spicer: Is that related to you limiting yourself to its specific vocabulary?

Townshend: Yeah. All I'm going to do with it, make speech that recognizes that Jack went up the hill. And the only thing it's going to work on is Jack went up the hill, okay? If you say anything else, it's going to get confused, okay, but it's really good at Jack went up the hill. What that allows you to do is first of all, just to determine whether or not you really said Jack went up the hill and then if you did, it allows you to pull out all of the details of how you said it exactly. How did you pronounce it? What was the timing? What were all these other variables?

So all of those you can combine to assess how well do you speak English, okay, the most important one being the first. If I give you a sentence in a language you know well, well, actually, let me back up. Say I give you a sentence in a language you don't know at all. If I say something in Chinese to you now and ask you to repeat it, you're just going to-- you're going to fail. Even if it's, if it's maybe one sound, you know; if, you know, if I say, "Bonjour" and ask you to repeat that, even if you didn't speak French you could, "Okay, 'Bonjour.'" I can remember the sounds.

Spicer: Well, even a parrot can do that, right?

Townshend: Exactly. You can remember the sounds. And that's related to short-term memory, right? You can, whatever, you know, short-term memories, you can remember about seven things.

Spicer: Yes.

Townshend: And they were seven chunks and they don't have to-- they can be at any level, conceptual level. So if you don't understand the language, you're basically memorizing it based on remembering seven sounds to put together. Okay? If it gets longer than seven sounds then you can't really, you can't repeat it. Okay?

Spicer: And that's because they have no meaning for you, right? They're just sounds.

Townshend: They have no meaning. They're just unrelated sounds.

Spicer: They're not words.

Townshend: Exactly.

Spicer: Yeah.

Townshend: Now, if you understand the language at a slightly higher level you can understand the words. So now I could give you a seven-word sentence that you could repeat without having any understanding of it. Now what happens if I give you a 14-word sentence? The way a human can reproduce that is they can remember the meaning of the sentence and they can regenerate it using their knowledge of vocabulary and grammar and a little bit of memory of exactly how you phrased it. So you can repeat word for word a 14 word sentence even with your 7 word short-term memory.

Spicer: Even with the same intonation probably.

Townshend: And with the same intonation and the same, you know, is it a question, is it a statement, is it different things. So it turns out that's a very powerful way of determining if somebody speaks this language and how well they speak it. You just give them long sentences and ask them to repeat them. And the speech recognition now can do that perfectly because it knows what the sentence is, so it can tell if you've actually repeated it. And as a bonus you can pull out intonation and timing and other things, so you can get other metrics. So you can basically, what I'm saying is you can build a very good automated measurement of spoken language ability. So we launched this company called Ordinate to do that.

Spicer: Ordinate as in the graph?

Townshend: As in the graph; you know, the abscissa and the ordinate, so it's the measurement, a measurement access. And it was very popular. I mean, we did language testing for many governments, like, for immigration testing, you know,,,

Spicer: So this actually works.

Townshend: This actually works.

Spicer: How'd you validate it?

Townshend: So, so we put it into a 10-minute test format that you take over the phone. So you get an ID number, you get a piece of paper and you phone the thing. You follow instructions that you were given over the phone and on paper and, and then automatically, a minute later, it's reporting the results of that test, of your spoken language ability.

Spicer: Something, I got lost there. giving you, you got a piece of paper with instructions.

Townshend: Yeah.

Spicer: And it's telling you to just read?

Townshend: Well, some of the-- There's different components. So the most valuable component is the repeat section. Say, in this section you'll just repeat whatever sentence you hear. And it says, "Bonjour" or "Hello."

Spicer: Okay. So they read this thing and then they have the test with the headphones.

Townshend: They have, well, there's other sections that are reading sections, so read aloud. So it says, "Okay, in this section you have these 10 statements. Can you read those aloud?" So now you're just reading aloud. And other sections that are asking, you know, "Do you hear, what is this?" Right.

Spicer: Wow. So they need to read as well.

Townshend: Yeah.

Spicer: Like, obviously--

Townshend: So but independent metrics, too.

Spicer: Yeah, yeah.

Townshend: You can tell, "Oh, this person speaks English very well. The reading ability is not that good. Their intonation is off." Yeah and so and it works very well. And the way you validate it, and the way we did validate it, is you have people take the test and also get human raters to measure them. So to have them interviewed, right? So we had many, many people that were interviewed and what we found is that we could predict… so we take three human interviewers, independent, and then you can average their scoring basically of the person. The computer agreed with the average better than any of the individuals agreed with the average. So the individual raters had more variance away from the average than the computer did. The computer was predicting what the average humans would, how they would rate them better than the humans could.

Spicer: And the raters were professional, right?

Townshend: Professional raters, interviewers. You know, there's a whole, the US military has a whole group called the Defense Language Institute which does a lot of--

Spicer: I know it well. I used to have all their records. You remember those? Living French, Living Japanese?

Townshend: <laughs> So, yeah, exactly. So they have expert reviewers for many language. So we started off, we did English. We did Spanish and we did Arabic. We did, you know, many different languages and built these tests and then they were used by, you know, for university sort of like TOEFL type things. They were used by immigration, countries to do immigration because a lot of countries require for giving landed immigrant status to be able to speak their native language at a certain proficiency level. High school--

Spicer: Speak their native language?

Townshend: I mean, speak the country--

Spicer: Or English?

Townshend: The national language.

Spicer: English, yeah.

Townshend: Yeah. The Netherlands was one of the first ones that did it, so then they had a Dutch, we did a Dutch test for them so that would validate how well they speak Dutch before they became a Dutch citizen.

Spicer: Is this business still in business?

Townshend: So this business was acquired by Pearson Education.

Spicer: Oh, my goodness. Wow.

Townshend: And then, and so it's still in operation under that whole--

Spicer: That's another great success.

Townshend: It ended up with Pearson. It was required by Harcourt I think originally and then by Pearson.

Spicer: Any special software tricks from your PhD or previous work [in this product] ?

Townshend: Well, speech recognition is all signal processing, it's all audio processing, it's all very related to the whole thing. At Bell Labs at the time there was a speech recognition group as well that was doing a lot of the early speech recognition thing. So, it's, and Jared Bernstein, my partner in that, he had been at SRI in the Speech Recognition Group before too and as well as being a linguist interested in language. So, we built that company. We built the test, it was an automated test, and also we sold a lot in Asia too for, like, high school testing and things like that. So that was very good. And then it got acquired in 2004, I think, from that. I mean it's still a small company. When it grew, I think-- by the time it was acquired when we were thirty-five people, or something like that.

Spicer: What an important niche, though. Like--

Townshend: Yeah, and still--

Spicer: -really--

Townshend: -operating.

Spicer: -amazing, yeah. Did you have to involve people from the government to get their seal of approval at any time? Like the TOEFL people, or the--

Townshend: Well, TOEFL definitely. Yeah. We worked a lot with ETS, and with other testing organizations, and everything. Then there was a lot of government funding, and we worked with early reading, too. We also could use the same kind of metrics to assess children, of how well they can read, because you can still have them read aloud, listen to that, and then assess the reading ability. So we had some government funding from SBIRs, and other funding agencies for doing that kind of thing. It was really interesting. Yeah, so I was CEO of that company, and Jared was the president, and we did a lot of work on that.

Spicer: Wow, that's terrific.

Townshend: Yeah, and it worked out really well. The previous thing, as I said it was bootstrapped, and this one we had some investors. But it was all pretty small from the scale of venture capital investment, right now. But it was a great return for everybody.

Spicer: Right, and this would all run on a PC, right? No special hardware?

Townshend: Yeah, well, in fact, you didn't even need a computer, because we had servers running, and then you could dial in--

Spicer: Oh, it's web-based.

Townshend: -from a cell phone, or web. You could take it over the web, or you could also take it straight by phone. Because a lot of places, especially in developing countries, where they were interested--

Spicer: It's true.

Townshend: -they didn't necessarily have-- they had cell phones, but not--

Spicer: They don't have internet, necessarily--

Townshend: -necessarily the web.

Spicer: -<laughs> yeah, okay.

Townshend: For doing voices, actually, it works better to actually do it in a phone call, because you get enough quality, and you don't have all the issues with latency, or the internet connection not working well. It's much more reliable.

Spicer: True.

Townshend: So even now, it's better to do it over a phone call.

Spicer: Yeah. What's next, what happened next?

Townshend: So Ordinate, so then we sold that, and that's when I moved to Paris, Michèle and I moved to Paris. By then, we had two kids, and so we wanted them to get more of the French environment. They'd been studying, going to school here in California at the French-American School, which is now called the International School of the Peninsula. So they got their French background, but we thought it would be good for them to really be immersed in French for a while, so we moved to Paris. I got an apartment in the middle of Paris, and then they went to the local schools, and I started doing photography there. The company sold, done with that, done with the modem stuff.

Spicer: Oh, nice.

Townshend: And so I signed up for a professional photography program in Paris, and then started doing sort of a whole range of photography, from photojournalism to fashion photography, to fine art photography, and things like that.

Spicer: Wow, this is really amazing. You know, where did you come up with this side--

Townshend: Well, I--

Spicer: -<laughs> of your personality?

Townshend: I'd always liked photography, and I also liked sort of the idea of art and science, in some ways. Michèle's also been a great influence on that, of really having an artistic side and a science side. So it was really a way to explore that. I tried playing piano, and I'm terrible at it, right? Don't hold a tune very well, and this… tried the guitar, and tried different types of media, and everything. But photography, it has both a technical aspect - technically how do you do it, and how do you make something work? And then an artistic side, of how do you do composition, and what…the material, and everything. So it's--

Spicer: Were you using film or digital at this point?

Townshend: I was using some film. I mean, in the program I was doing some large format. Actually, while I was a Stanford PhD, I did a lot of photography, too. I'd done a lot of darkroom photography. So that was sort of my side thing.

Spicer: Ah, okay, like a hobby?

<Some not transcribed here>

Townshend: A hobby thing, yeah. So I'd done a lot of view camera work, with eight-by-ten negatives, black and white, and then processing in the darkroom.

Spicer: You had a camera that was eight-by-ten?

Townshend: Yeah, the view cameras … you have a hood, and you have like a bellows, and everything like that.

Spicer: -from the 1900s?

Townshend: Yeah.

Spicer: With the big bar of flash powder! <laughs>

Townshend: Well, you don't need the big flash, but the same idea.

Spicer: Really?

Townshend: I mean, and for doing studio photography, view cameras are very nice devices.

Spicer: So that's what they're called, view cameras?

Townshend: View cameras. So you basically-- it's just a track, like a tripod track, and you mount two things. You mount on there a lens, at some point, and the lens you can slide up and down, you can tilt it, and you can position it, right? Then back here, you mount also on the rack a film holder, okay? So here you have your film, and here you have your lens, and now what you do is in the film holder you put a piece of ground glass instead of film.

So now the image that's coming there gets projected onto the ground glass, and you can -- and this is why you have a hood, so you can block off the other light -- look very closely at that ground glass image. So you can see exactly-- it's like the photograph is sitting there. It's just like you would see on the back of a digital camera, except even more authentic, I would say.

Spicer: Wow.

Townshend: It's super high resolution, much higher than any digital. So you can put a magnifying loop on that ground glass and be looking at little details, and everything.

Spicer: Oh my gosh.

Townshend: So you can set this up, and you have complete control. So for example, say you want to take a picture of a building. If you tilt the camera up like this, okay, to look up at the building, where there's a normal camera, the lens and the back are fixed together, the normal camera, or with an iPhone, or anything. So you tilt it up like this, so now you get all of the lines of the building are converging together, so you get perspective distortion.

On the other hand, with this setup, you keep your film playing parallel to the building, and move your lens up. So now all the images gets projected down, and there's no distortion of lines, and anything. So you can do all these neat thing. If you tilt the lens, on the other hand, you change the focal point. So now normally with the camera, what you focus on is a flat line there. I could take this lens here towards you, tilt it this way, and have the bottom of your shoes in focus, and your eyes in focus at the same time.

Spicer: Wow.

Townshend: Because I can line that thing up.

Spicer: That's remarkable.

Townshend: So you have super flexibility. So that's why people still use-- that's just the ultimate in flexibility, you can put that there. Instead of the piece of film, you can put a digital back on there.

Spicer: Oh, okay. So--

Townshend: Yeah, what side, hold them to the side there.

Spicer: Can you still get paper, like from Ilford, or from--

Townshend: You can but it's harder. It's not worth it because the digital is now at the [same] resolution.

Spicer: So in Paris, tell me about-- it was this course, how long was it?

Townshend: It was for the year.

Spicer: Oh wow.

Townshend: So it was doing a lot of studio work, learning--

Spicer: What a perfect city--

Townshend: -studio lighting.

Spicer: -to do photography.

Townshend: Yeah.

Spicer: Oh my gosh. <laughs>

Townshend: Then doing assignments. For example, we got assigned to do a fencing tournament, so it was a three-day fencing tournament. So going there and shooting the fencing tournament, shooting the participants, and shooting the whole scene to create a photojournalism view of that thing.

Then we worked with fashion designers to do fashion shoots, worked with a stylist, makeup, all the different other fields to try and set up things. Worked a lot with studio lighting…

Spicer: What was the name of this program?

Townshend: They're called Speos, S, P, E, O, S, which is related to some Greek mythology, of Spéos is basically a camera obscura, from Greek mythology.

Spicer: This is really neat, so-- and I guess you're getting into photography a bit because now you've done reasonably well with your inventions, and you can sort of take some time off…

Townshend: So that worked out pretty well. At that point, I came up with a series of photos which were semi-scientific, versus art. What I realized is when I was doing the view camera with the film negatives and everything, it was like I was trying to divide up; have sort of an art side, and be in art mode, with no technology involved here. Versus doing tech stuff, which is all on the computer, and computation, and then signal processing, something like that.

Partway through that I was realizing, "Well, what's different about my—what could be different about how I'm attending photography [school] is to use the technical side, and to not try and separate the two, just do it all together". That worked really well. I mean, it changed how I was doing photography, and it allowed me to create stuff that was actually interesting, and different from what other people were doing. The main thing was this series called Looking Up, which was a whole set of photography that was focused on the sky, so centered in the sky, but was super wide angle, like 200 degree wide angle. So that you end up with photos that were sky in the middle, but the perimeter is what's normally going around in the world. It's actually multiple photographs, it's stitching everything together, and it's all doing it at super high resolution, like gigapixel sort of resolution.

Spicer: What tools? Do you use Photoshop, or--

Townshend: No, it's all custom software, and everything. So that's what I was saying, it was combining all these things. There weren't any tools, at least then, there are better tools now. But to do this kind of stitching and reprojecting--

Spicer: … this is '94?

Townshend: No, this is 2004.

Spicer: Oh, 2004. Okay, yeah.

Townshend: So it's a little bit more recent. But still, I mean, there weren't really good digital cameras, they were just…

Spicer: Manipulating images of that size is not in the cards? <laughs>

Townshend: Right.

Spicer: At that point.

Townshend: So I was making these big-- these were like six-foot wide prints, and everything.

Spicer: Did you have a show?

Townshend: Yes, I had several shows. Actually, I still have a gallery that represents me here in San Francisco, that shows my work and everything…

Spicer: I'm going to have to look up your photos!

Townshend: Yeah, …Minnesota Street Project, there's a gallery called Themes and Projects, that I worked with for a long time, and there's super good guys, and everything, in there.

Spicer: Right now, what kind of photo projects are in interesting you?

Townshend: Well, now I've been doing more installation projects, more larger scale installation art, primarily Burning Man. We had an installation that we did as part of a project funded by Burning Man for one of the main square plazas, called Pulsefield. Again, this is really going heavy on the technology side, technology art. So it was basically a center of the circle, which was maybe thirty-five, forty feet in diameter, and put LIDAR units around the perimeter that would track everybody that's in this center space. So, basically, we could-- from the computer, we could know up to maybe 50 people, of where everybody is.

Spicer: What's a 'tracker' in this case??

Townshend: So it's using laser, it's using time of flight laser to find where everybody is.

Spicer: Nice.

Townshend: The same LiDAR types of units that are used in self-driving cars. So we did that at about knee level, so we know where everybody's knees are, both knees individually. So tracking everybody, and then video projectors all around that are projecting onto the ground. So I'm projecting imagery on the ground that's based on where everybody is. That gives a whole bunch of possibilities, and there are a lot of fun things built with this. For example, one thing is we just made a little soccer game, so there's just a ball sitting there, and you can walk up to it, and you can kick it, the virtual ball, and you can kick it into the goals, and you can do things.

Another one that's really nice, and I really enjoy, is we did a-- and I say "We" because we work with family members, and other friends, and everything, developing the applications, and the whole thing, and everything. We did a liquid simulation, so basically simulate water using the equations called Navier-Stokes equations, which calculate the differential equations of motion, and everything. Then each person is basically… you can think of it as that their shoes are spurting out colored oil, and as you walk around you're leaving a stream of oil.

Spicer: <laughs> Ah, that's funny.

Townshend: You're also stirring the liquid, so you can stir it with your feet. So everybody else is influencing everyone else. So you get in there, and you get these streaks of oil that are coming, different colors from different people, and you can get everybody to run around a circle, and create a little vortex in the middle of all this stuff, where you can do--

Spicer: You should do that here.

Townshend: Yeah. So--

Spicer: <laughs> I'm going to keep you in mind for our <laughs> next exhibit, yeah.

Townshend: I did two shows of this at the Exploratorium in San Francisco.

Spicer: Wow, that must've gone over very well?

Townshend: Yeah, it went really well. So it was a little difficult, the floor surfaces. It's nice to have white, buy depending on the situation and it's a lot of work to set up, but-- because you've got LiDARs, and you've got the cameras, and you've got… and there's also sound, it's also got music. So the music is also algorithmically-generated based on the positions of people…

It makes all the sound effects, but also then things like the Navier-Stokes depending on where people are, you get ambient noises, changing drones. I work with a friend Marco Saenz, who's an amazing musician, that helped put together different soundscapes, and everything, and then based it on how people move.

Spicer: Yeah, that's quite the 'happening,' as they used to say, yeah. Just skipping ahead a little bit to the next adventure in your life…

[2:26:50]

Townshend: So then after Paris, we continued our French immersion and moved back to Montreal for a couple of years. While there, I started to get more interested in the bio side. As I mentioned, early on I was doing cochlear implants, it was bio from sort of a bio engineering perspective. But I'd been in internet things, the modem stuff, and a few other projects that I've mentioned, and then the speech recognition.

But I was sort of feeling that it was getting less interesting, sort of the internet-computer EE side of things, that basically everything has been invented, and we're just doing improvements and things like that. And then a lot of internet startups that are just really good marketing machines. So what I was thinking is bio, on the other hand… 1% of the things are discovered, and also there was a human genome project that just happened, which was creating sort of a more rational, I would say infrastructure for doing biology. When I was a grad student originally, biology was a lot of unrelated facts that you're sort of memorizing, and sort of remembering that this goes here, and this--

Spicer: The Krebs Cycle.

Townshend: The Krebs Cycle, exactly. The chemistry, the…

Spicer: Well, molecular biology changed all that, right?

Townshend: Molecular biology changed it completely. So all of a sudden now, you had this very quantitative formal framework onto which you built the knowledge. So now these unconnected pieces of knowledge became tied to the genes, that became tied to the pathways and everything, within those genes, and--

Spicer: And that happened in our lifetime, even in the last 30 years.

Townshend: Exactly. That happened in that period from mostly in the '90s, and early 2000s. So I was looking at that, and saying "Well, this is really cool. Maybe I could apply some of the signal processing, and ideas here, into the bio side." So my wife's brother, Philippe, he had a friend, Michel Tremblay, that was a director of McGill's Cancer Research Institute. So he put me in contact, and so I went and talked to Michel Tremblay, and he was psyched, enthusiastic. He said "Ah, that's great." You don't know anything about molecular biology. He says, "Why don't you come into my lab, and I'll have somebody teach you how to do the lab stuff, and you can take some classes at McGill."

So that's what I did, I came back to school. I'd taken organic chemistry a long time ago, I took it again. Took molecular biology classes, took all those, and meanwhile, I was going into his lab, and the research assistant taught me how to pipette, and taught me how to run some experiments, and things. His lab was really focused on a phosphatase, PTP1B, which is a molecule that's common in--

Spicer: And it cleaves phosphate from--

Townshend: Exactly.

Townshend: …and overactivity of it is implicated in metastasis of cancer. It's also implicated in diabetes. It's implicated in many, many different things, incorrect function, or overexpression. So they were on the hunt for a molecule that would inhibit this phosphatase as a potential drug candidate. I was looking at some other sort of more rational biology. There was this thing called aptamers. These are little sequences of nucleic acid, like DNA, or RNA, that bind to things, that actually stick to things. What's cool about them is that the way you find them is by doing evolution, you actually get a big pot of a lot of random ones, and then you sort of pull out the ones that stick to what you're interested in. You amplify those again, you make more copies of the ones, and you let them mutate a little bit, and then you do the experiment again. You pull out the sticky ones, and you do this over multiple rounds, and eventually you end up with a pot of these molecules that are really sticky to the thing you want them to be.

Spicer: Right. Is that a DNA synthesizer you're talking about?

Townshend: Well, you're using DNA synthesis during the process, but the actual thing, it's called SELEX [Systematic Evolution of Ligands by EXponential Enrichment], but it's a technique that was invented in 1990, or so. But it allows you to start with random molecules, and effectively you're doing evolution in a test tube.

Spicer: Amazing.

Townshend: -the ones that stick to what I want, I'm going to call them more fit, and keep them, and kill off the other ones. The thing we want to stick to is this phosphatase.

Townshend: Basically, think of the pot you put the phosphatase in. You keep all the molecules that have stuck to it and throw away the other ones. The remove those molecules; use a technique, Polymerase Chain Reaction, PCR, to amplify those, to make more of them, and then you do the experiment again, and get the sticky ones. Meanwhile, you also can do an experiment where the things that stick to other stuff that might be there are thrown away.

So there's positive and negative, I can get into a lot of the details. But the ultimate goal is you have stuff that's really sticky to the PTP1B. So I worked on that after sort of this training period, got a grant from the Canadian government to do this research, and we found a really sticky molecule to it. Not only that, it actually inhibited the activity. So you could get something that sticks to it, but doesn't make any difference to how it operates. But better is getting something that actually inhibits it. That got carried forward, and into testing in mice and everything, and still has potential to be a cancer therapy. I would say 'potential.' The problem is nucleic acid RNA, is really hard to get into the body at the right place, which is a completely independent problem of getting the molecule to stick to it. That's really the limiting factor in using these for treatment, these RNA molecules. But that's a big resurgence now, because of COVID, and everything else. Alright.

Spicer: So really interesting that you just made a complete gestalt switch into biology. What prompted that?

Townshend: <Some missing transcript here> Yeah. I'd done the thing with the-- that language was really making a product, a physical product, and after that I was thinking "Okay, I've done-- I don't want to do physical products, conceptual products are better." Did Ordinate, which was really software product, right? I did the modem, which was really completely an invention, and there was no physical… like I said, there was… I never made a product, didn't even actually ever sell anything other than the actual licensing. I said "Oh, that's really where I want to be, is in the invention field." I don't want to have to build things, I don't have to sell things, I don't have to market things, I just want to make ideas that then can be…

Spicer: Methods and processes kind of thing.

Townshend: Methods and processes that can be used by other people to do what they want to do. So then I was thinking "Well, maybe it's harder to find those things on the EE side, because a lot of people are doing that." But on the bio side, there was a lot more potential.

<Some missing transcript here>

Spicer: But biology and medicine are so new… we're just getting started. It feels like we're in the… almost galvanic stage of medicine, right, where we're still making batteries out of zinc plates, and--

Townshend: Yeah, no, it's true, and there's a lot of analogies between-- and that's actually-- I will even say even more specifically, bioengineering is really interesting, because then you're taking the engineering aspect, and applying it to biology. That can have output that is therapeutic, like for human medicine, but that also has a lot of other potential.

So how do you harness biology to do things? That can be making chemicals, that can be doing bioremediation, that could be doing carbon capture, and that could be doing all sorts of things. Obviously, therapeutics are a big part of it, or diagnostics, but all sorts of other things too. Getting that understanding of biology is really important. I think it's a blossoming industry. You see Stanford's bioengineering departments growing, everybody's got bioengineering departments now, and they didn't have those 20 years ago, they didn't exist.

Spicer: It's true.

Townshend: On the side of medicine, I mean, sort of one specific side of it, but that's also, I mean, blossoming, and there's so much more knowledge there.

Spicer: So much of medicine, or at least public health, I should be more specific, is dependent on really simple, basic things that we knew-- we've known about for 50 or 100 years. You know, it's just getting the like polio virus…

Townshend: Yeah, viruses and--

Spicer: …yellow fever, and all those things.

Townshend: There's a lot of other things--

Spicer: There's a lot of human suffering that happens which ten cents worth of an antibiotic would alleviate. Yeah. But anyway, yeah, this is very cool, and part of the 'designer medicine' thing I think you're getting at too, right?

Townshend: Mm-hmm.

Spicer: …that would be the next logical step, which is to understand the patient's genome, and then tailor therapies to that.

Townshend: Right, to understand the genome, to tailor them, and to tailor, yeah, biological systems. I mean, you could even imagine things like from bioengineering side. Say you could engineer bacteria that can identify cancer cells, okay? Then you can just put that bacteria into your bloodstream, and it'll go around and attack cancer cells, right? So it's a biological market.

Spicer: Because right now all we're doing is shutting down cells that multiply quickly…

Townshend: Right… that uptake of toxic chemicals at a higher rate than other cells uptake the same toxic chemicals. So, not the greatest. <laughs>

Spicer: Another application could be designer antibiotics, because the antibiotics do quite a number on your gut flora for a lot of people. I mean, the dysbiosis that results is actually quite serious in some populations. They're never the same after, with just one course of antibiotics.

Townshend: Absolutely.

Spicer: So getting a tailored antibiotics that doesn't wipe out the good ones, the good microbes would also be great.

Townshend: Right, yeah, and I actually was involved with a company called EpiBiome a few years back, that was doing bacteriophages. So basically, there's a lot of viruses that attack bacteria, so you can actually design, or find, or evolve viruses that attack particular… exactly what you're saying, exactly what you're saying.

Spicer: Yeah, phages are cool. They're little… the way they look. Yeah, so I know we've got maybe another, you know, 15 or 20 minutes or so, and then so why don't we move along, and go-- at some point you started Shazam. So, I'm not sure, is that--

Townshend: That was in the middle there, that was probably--

Spicer: Oh, let--

Townshend: I maybe even jumped over part of that…

Spicer: Let's dig into that, because that's really important.

Townshend: Yeah, so I think that was 2000, 2001? Or maybe '99. I'm not a founder of Shazam, so--

Spicer: Are you an investor, perhaps?

Townshend: Investor. So what happened was there were two students, MBA students from Berkeley that had the idea of… they were basically looking for a company to start. What was the idea? They sort of came up with different ideas of what would be an interesting product, and they brainstormed and said "Well, it'd be really cool if we could do music recognition. That would be a really cool app," if you could phone a number on your phone, or put a code, and then your phone would tell you what music is playing.

So they had that idea, then they said "Well, we're not doing any engineering. How do we do this," right? So they came, and this is classic, but in this case it really worked well. So Philip Inghelbrecht and Chris Barton were the two there, and they had this idea, and then they talked to people, different universities and things. They talked to a prof here at Stanford, Julius Smith], and he pointed them to another guy, a former student, that does a PhD with him, and was a really brilliant engineer. So they came and talked to him, and he thought about it, and said "Oh yeah, I think I know how to do that." So he became the third co-founder, and meanwhile, Julius said "Oh, but you should also talk to Brent, because he's kind of interested in this kind of signal processing stuff, and maybe he can give you some advice about how to do patents and legal stuff, and everything," since you know about all the IP stuff.

So they got Avery Wang on board, and then they contacted me, and then we had lunch in Menlo Park, and they explained what they're doing. I said "Oh, that's super cool. Here's the attorneys you should talk to, and here's how you should do the patent things. That's really cool. Can I give you some money to invest in this?" They hadn't had any investment, so that next day I wrote them a check, and that was their first funding for that company.

After that, they went around, and they built up the idea more. They built their pitch deck, and they approached VCs, and they got VC-funded, and then I invested in the subsequent rounds as well of that. Then I was on the board for most of the time of the life of Shazam.

Spicer: Can you tell us what's going on technically with Shazam? How it works?

Townshend: It's pretty interesting. It's just basically finding a signature at each little timeframe. So it's reducing the sound it hears in this timeframe into a small compact signature, okay? Then it's looking up in a database of all of the signatures, of all the recorded music it's seen, and finding a match against that. I mean, obviously, it's more complicated … there's little timing differences, there's when you do the signatures, it's how you do the signatures. So Avery came up with a lot of great ideas in there, and they patented those ideas, and they protected it quite well, and they built a system.

They started in the UK, interestingly. So they were here, but they basically started the company in London, and the primary reason was that this is pre-iPhone, you have to think, this is pre-PDA. So, and, clearly, you'd want to be able to do this with your phone. What there was in the UK, and other parts of Europe, is there was idea of getting short codes that send SMS messages. So you get short codes that say "Here's a four digit-- a pound, four, one, six." I could be the provider for pound four, one, six, so it's a short call. You could make the call and hold up your phone, this is on a regular phone call, and then it would text you back by SMS, the identification.

Spicer: Wow, so you dial pound four, one, six, and that accesses--

Townshend: Then hold your phone for 10 seconds.

Spicer: And that calls their server.

Townshend: That calls their server, it listens. Then it sends back a text message with the identification.

Spicer: Cool. Wow.

Townshend: So you could do that in the US, too. Short codes weren't as popular, so you'd have to dial a full phone number, but you could have it on your speed dial. But more importantly was the UK had a facility for charging the receiver for text messages. So the business model said it costs you twenty-five cents to do this, so you can do this, and when it sent you the text message, it bills you twenty-five cents. Even better, it was the phone company that put that fee on your phone bill, and then the phone company remitted it back to Shazam.

Spicer: Oh, yeah, they're collecting money for you.

Townshend: They're collecting the money for you, you don't have to bill it, you have automatic there, and you couldn't do it in the US. US has no facility for charge back SMS. So they did it in the UK, and it was great, and it worked, it was growing, and then in 2004, the iPhone launched, and they became one of the first; they immediately said "Well, this is obviously what we need to do." They launched on the app store, they're one of the very early apps, it was like the number one app on the app store, and it worked even better. So they did a lot of the front end processing on the iPhone itself…

Spicer: You know what I like about Shazam, is that it, for me, embodies Arthur C. Clarke's saying about any sufficiently advanced technology being indistinguishable from magic. The fact you can just hold the phone up and it tells you what song is amazing… and that also appeals to a really basic human sort of human stress point, like "What is that song?" <laughs>

Spicer: Really clever, and it could be quite educational too, like learning classical music, or whatever.

Townshend: Yeah. Interestingly, it's not identifying the song, it's identifying the recording that's playing.

Spicer: Oh, the actual performance?

Townshend: [Yes]. So if it's Beethoven's "Fifth Symphony," when you get the identification, it'll tell you that was the Dallas Philharmonic's 1982 recording of that.

<missing transcript>

It is heavily used by the recording industry for rights management, for like "Is the radio playing this copyrighted version, and do we collect royalties from them? Is this TV show doing this?" There's all sorts of companies that use this technology for all of the rights management. Then, obviously, Apple eventually acquired Shazam, and now it's part of…

Spicer: Oh, I didn't know that.

Townshend: Four or five years ago. Not that long ago. So, yeah, four years ago, maybe. So they acquired it, and it's now part of the iPhone, and it's on the main page of-- like the control panel of an iPhone now. Also, Siri automatically does it too, so you can just tell Siri "What's the name of that song?"

Spicer: Oh, I see, nice. Yeah, and then what is Shazam's-- what are their plans for the future?

Townshend: Well, they're gone-- I mean, they don't exist anymore. I mean, well, they're acquired by--

Spicer: And so-- **Spicer**: Within Apple, I mean.

Townshend: They're Apple. I mean--

Townshend: Interestingly, another <laughs> this is funny. So one of the other people at Ordinate that I worked with, Ognjen Todic, after he left Ordinate, used that speech recognition engines to listen to songs to figure out the lyrics. So, basically, the problem is you have a song that's playing, you also have somewhere on the internet, or somewhere you have the lyrics, but they're not lined up to each other. So he created a company called Tunezee, which lined those two things up. Then Tunezee was acquired by Shazam, and then Apple acquired Shazam. So if you notice, there's a lot of Apple stuff now that has lyrics identifications. It seems like it's all coming from that whole history of that path…

<Missing transcript>

Yeah, so that's kind of cool. So then, let's see, let's fast-forward a little bit, where I was at McGill. We came back to California, I started working at Stanford sort of in the same kind of role…

Spicer: But in biology this time…

Townshend: In biology now.

Townshend: Previously, I was also being a consulting professor at Stanford for a while, too, in electrical engineering, and digital signal processing. But then when we came back, I was more on the bio side. So I connected up with Drew Endy and Christina Smolke, a husband and wife who both have labs in bioengineering.

Spicer: Wow.

Townshend: They invited me to come into their labs to continue sort of work on aptamers, these pieces of RNA, and everything. So I've been doing that now for a long time.

Spicer: So you're still in grad school? <laughs>

Townshend: Still in grad school, still been doing that.

Spicer: That's great. What a wonderful life--

Townshend: Yeah, and--

Spicer: -that's really fun.

Townshend: -it's been-- doing experiments there. So there I'm actually doing the actual-- a lot of the lab work--

Spicer: Yeah--

Townshend: -the physical lab work--

Spicer: -pipettes and stuff.

Townshend: Pipettes and everything, as well as doing-- a lot of it is high throughput sequencing, of using DNA sequencing to infer things, and I also have robots to do robotic things. So there's a lot of different technologies involved, but it's really-- it's exciting. And then--

Spicer: Do you set those plates, the DNA plates--

Spicer: -the company that was out in-- that made them all. I can't remember. First company to make those. They're Affymetrix.

Townshend: Oh, Affymetrix, yes. So the DNA arrays that have probes on them that you can flow something over and they stick to them. That kind of technology is prevalent now. I mean, the big push is always now high throughput. It's like how do you scale things, and sequencing, DNA sequencing is really an amazing tool for doing that because if you can take an experiment that you would normally do with lab tools to measure on a plate reader, or do things, if you can change the output so that it changes the sequence of something, then you can mix millions of experiments together, and the DNA sequencer can do it at scale-- hundreds of million-- billions of reads of data that can come back, and then tells you the results of the experiments. So all of a sudden you can multiplex something at a million scale, and put together experiments in ways that are amazing. Maybe that brings up the last stage of my whole story, which is last year my son also-- Raphael, he started a company based on his PhD work. So he came to Stanford to do his PhD.

Spicer: Oh wow.

Townshend: He worked in structural biology with machine learning, and he got a really nice publication in Science. It was in the cover of Science last year.

Spicer: Oh, I'm going to look that up. I subscribe. What's his-- same last name?

Townshend: Same, yeah. Raphael Townshend.

Spicer: Raphael, okay, good.

Townshend: I'm super proud of him and his sister. They're both incredible.

Spicer: What a crowning achievement that is, wow.

Townshend: Yeah, and so he was doing structural biology and machine learning, and she was doing mechanical engineering, and also at Stanford too.

Spicer: Wow.

Townshend: Also, art. She's an amazing artist, and has got a great art career. But Raphael, I'm bringing that up here in my story because Raphael started a company last year based on his PhD work to do machine learning on RNA, to predict… using machine learning to predict structure of RNA molecules for drug development, and everything.

Spicer: Do they use cryo-EM at all?

Townshend: They do use cryo-EM. Yeah, they use cryo-EM data right now, they're actually not doing cryo-EM in-house, but they're using an..

Spicer: That's a technology that's changing everything. Those are amazing machines…<some transcript missing> lots of preparation but easier than x-ray crystallography, apparently--

Townshend: Yeah, better to--

Spicer: -because it's hard to get proteins to crystallize.

Townshend: Yeah, definitely, the technology's evolving on it. So he's sort of using that and other techniques to figure out that. So I'm ending up doing a lot of the lab work there now. So I've been sort of transitioning to helping him out in--

Spicer: So you're helping your son?

Townshend: Yeah, so--

Spicer: Oh, that's lovely. <laughs>

Townshend: Well, I would say I'm working for him. Or I could say--

Spicer: You're working for him?

Townshend: Yeah.

Spicer: That's great.

Townshend: Or maybe I should say I'm working for somebody that works for him. <laughs>

Spicer: Yeah. Oh, that's really nice.

Townshend: So that's fun. We get to drive up in the morning to Oyster Point to do that…

Spicer: Is that-- what does he do out in Oyster Point? Sorry.

Townshend: So the company, he started the company there. It's out of one of JLabs, accelerator. So, building it up there. His sister's helping out, they're doing a lot of the-- doing design-- oh, I should've worn my logo shirt.

Spicer: You've got a logo shirt? That's great. Yeah. Well, is there anything you would like to say in finishing that I didn't ask about?

Townshend: I think we covered a lot. It's taken a while here, huh?

Spicer: Yeah. What a great life.

Townshend: I mean, it's been interesting to discuss. These are a lot of things I hadn't thought about in many years, like you brought back into my thinking, or-- from the oil deliveries, <laughs> up to the present.

Spicer: Yeah, I was saying, you know, look at the generational differences from just your generation and your son's, and, you know, they're just incredibly high achievers. So it's nice to see the value of education. It just shows you that it changes lives, right?

Townshend: I would have to say that moving away from here and going to Paris, and going to Montreal and things, really creates really-- especially for the kids, an environment that's really…

Spicer: By the way, can you believe the lunches that kids get in France? <laughs>

Townshend: Oh. That was exactly-- Camille--

Spicer: Isn't that unreal?

Townshend: The first day home from elementary school, she's saying "Ah, this is so good." So lunch served by the school, the public elementary school, not a private school or anything, so it was a salad to start, and then steak with asparagus, and then a cheese course, and then dessert. <laughs>

Spicer: It's amazing, yeah. My niece went there for five years, and then you compare it to what kids here get, right? Like fish sticks and French fries, or something, right?

Townshend: Yeah.

Spicer: So that was very heartening, when I saw France treating their kids well. They've got their priorities right, yeah. And I guess your kids are bilingual too, right?

Townshend: Yes, absolutely, especially Camille, she's like-- she criticizes my-- well, criticizes. Corrects my French very often, French pronunciation, since mine is still very English influenced, so...

Spicer: Well, thank you so much, Brent. This has been lovely, and I really appreciate you coming in today. We've learned a lot of new things.

Townshend: Thank you.

Spicer: This will be very useful to people interested in the history of technology to read through what you've said today. So thank you.

Townshend: Great, well, thank you. Thanks, this has been a great opportunity to be here, and thanks for all the work here at the museum, too. This is an amazing place.

Spicer: No, thank you.

END OF THE INTERVIEW

